Mobil Oil Corporation

REC'D JUL 27 1966 RESEARCH AND DEVELOPMENT DEPARTMENT

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July 21, 1966

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K. L. Berry - Pan American Petroleum Corp.
W. H. Decker - Sinclair Research, Inc.
H. P. Dengler - Esso Research & Engineering Co.
R. T. Ellington, Jr. - Sinclair Gas and Oil Company
K. M. Elliott - Mobil Oil Corporation
W. L. Jensen - Continental Oil Company
R. P. Lehman - Phillips Petroleum Company
R. Mungen - Pan American Petroleum Corp.
N. P. Peet - Humble Oil & Refining Co.
D. C. Smith - Phillips Petroleum Company
J. H. Smith - Continental Oil Company

Gentlemen:

Attached is a copy of the minutes of the thirteenth regular Shale Oil Technical Advisory Committee meeting held in Denver, Colorado, on June 23, 1966.

S. L. Meisel
S. L. Meisel

ob

Attachment

cc: R. H. Cramer

Minutes of the Thirteenth Regular Meeting
of the
OIL SHALE TECHNICAL ADVISORY COMMITTEE
held at
Anvil Points Research Center
Rifle, Colorado
on
June 23, 1966

Those present for the Committee were:

| | |
|---|---|
| W. L. Jensen | Continental Oil Company |
| R. T. Ellington | Sinclair Oil and Gas Company |
| D. C. Smith, Chairman | Phillips Petroleum Company |
| R. P. Lehman | Phillips Petroleum Company |
| N. P. Peet | Humble Oil and Refining Company |
| H. P. Dengler | Esso Research & Engineering Company |
| R. Mungen | Pan American Petroleum Corporation |
| K. L. Berry | Pan American Petroleum Corporation |
| K. M. Elliott | Mobil Oil Corporation |

Messrs. J. H. Smith, W. H. Decker and S. L. Meisel were absent. Dr. H. P. Dengler of Esso Research and Engineering Company was welcomed as a new member of the committee replacing B. L. Schulman who will continue to follow the project work and attend observers' meetings.

## Old Business

Minutes of the 12th regular Technical Advisory Committee meeting were approved as distributed.

Mr. Cramer reported on the information he was able to collect on spent shale disposal. The results are summarized in the appendix. No program on spent shale disposal is planned.

N. P. Peet referred to the problem of spent shale disposal, including air and water pollution aspects, and raised the question of what it would cost to have crushing tests and compaction tests performed on spent shale. In the discussion some reservation was expressed with regard to spent shale work, and particularly with regard to the objective of solving the spent shale disposal problem. No objections were expressed to a small effort restricted to determining the properties of spent shale, including crushing and compaction. It was agreed that Bob Cramer would determine what could be done by the staff with modest effort and using equipment that might be available at Anvil Points, with conclusions to be reported at the next meeting.

## New Business

The next observers' meeting was scheduled for August 24-25 at the Anvil Points Research Center. The next TAC meeting was scheduled for September 8 in Denver, probably in Phillips' offices on the 13th floor of the Security Life Building.

The technical presentation of progress since the previous meeting was made by Bob Cramer and members of his staff, as summarized in the appendix. Particular attention is directed to the list of eight major conclusions drawn on the basis of work during this period.

Much of the technical presentation heard by the committee brought forth no committee discussion of consequence and is adequately covered in the appendix. Additional information and discussion developed around a number of points, as summarized in the following paragraphs.

In summarizing work on process understanding and economics Paul Snyder emphasized that the effect of dust was always a factor, with the extent of dusting a determining factor in yield loss. It was indicated that the addition of dust to Fischer Assay experiments had confirmed the loss in yield, but it was developed in discussion that extrapolation of Fischer Assay results to dynamic retort conditions is somewhat questionable. It was reported that the dust effect is operable at all times and may account for the limit of 92 percent FA retort yield as compared to a possible 105 percent FA yield. Uncondensed shale oil naphtha, which is in the off gas because of its low partial pressure, also may account for part of the yield loss.

In response to a question during the report on shale size and rate studies it was stated that standard practice now involves running four 8-hour material balances per condition being investigated.

In discussion of maximum particle size for retorting, now believed to be in the range of 2½ to 3", it was stated that some yield loss even at optimum retorting time-temperature conditions is expected for 3" shale and that there is little cost advantage on going to maximum shale sizes above 3".

Reporting on horizontal air distributor studies, John Hasz concluded that the same problems were encountered as with previous work using horizontal distributors (bridging and clinkering) and that operability which had been achieved with the 8-bayonet design had not been realized with horizontal distributors, particularly at higher gas rates. This may be due either to (1) greater cross-section restriction which enhances the dusting effect, or (2) a more uniform gas and air flow pattern which prevents downward dust escape. In discussion the view was expressed that horizontal air distributors appeared to offer no advantage with respect to operability or yield, but that they might still be desirable from the standpoint of maintenance or cost in commercial operations if comparable operability and yield could be obtained.

Tom Lyons in reporting on mechanical model studies, which now include small scale models of Retorts Nos. 2 and 3 and the 60 and 100 ton storage bins, concluded that the 4-bayonet air distributor design for Retort No. 2 gives superior mass flow properties to the 8-bayonet design when using 1½ - 3" shale. This was portrayed convincingly by movie films, and, combined with retort experience, leads to the conclusion that improved shale flow properties outweigh the poorer air distribution in the case of the 4-bayonet design. In committee discussions it was indicated that liberal documentation of this important model work is desirable. Cramer stated that loan or copy of all films are available upon request, and that a film-documented report on flow model studies would be prepared and distributed later.

In regard to program planning, John Lawson reported that the study being conducted currently is on 35 gal/T shale in Retort No. 2 in an effort to confirm results obtained previously on Retort No. 1. This work should be completed by the plant shutdown. During the shutdown, July 1-July 17, it is anticipated that a 15-bayonet air distributor will be installed in Retort No. 2, in an attempt to improve operability with small shale. Some slack time for additional studies in Retorts Nos. 1 or 2 is expected to be available during the September-October period, and specific recommendations will be included in the next Planning Group report in time for discussion at the next observers' and TAC meetings. It was reported that the crushing plant will be inoperable during the first two weeks of this period, imposing some limitations on the retorting program.

Priority-wise, support studies for Retort No. 3 will receive first attention during the next two months, with work on processing fines and shale richness studies receiving about equal but secondary emphasis. In response to Cramer's question if the committee had greater interest in richness studies than in fines processing, various opinions were expressed with the consensus being that both will have to be thoroughly evaluated. Cramer stated that the work scheduled on rich shale included two recycle rates and two size ranges, which in effect is one small step toward establishing optimum conditions for rich shale processing.

In the discussion it was suggested that work on wide range 1/4 - 3" shale should receive full consideration because if operability could be established at satisfactory yield much of the extensive work planned on separate ranges might be abandoned.

Gordon Haworth reported that all equipment for mining work during Stage II had now been ordered except the downhole drill, which will not be needed until bench mining starts next February. Difficulties were encountered during the opening of the new mine portal. These problems have now been overcome with the advance away from the cliff face and with the change to Swedish bits and steel for drilling. In response to a question, it was indicated that none of the University group contacted were interested in performing fundamental measurement on oil shale properties, so that these studies will be contracted out to Terrametrics Inc. of Denver.

Bergen indicated that Retort No. 3 is still scheduled for completion during the week of October 3, with 50 percent of the engineering now completed, 10 percent of construction completed, and 25 percent of the material ordered. In discussion it was reported that Torkelson had been paid something in the range of $700-800 to prepare a critical path (200 event) program which uses the University of Utah computer to give a comprehensive print-out of all starting and completion dates, etc., at a cost of $40 per print-out. Bergen stated that this is proving invaluable in following progress on Retort No. 3 and insuring against delays.

The maximum design capacity for mass rate of Retort No. 3 (which was discussed at the previous meeting and left to Bergen's discretion) was kept at the 700 lbs/hr $ft^2$ capability, but two stages of compression have been eliminated and the size reduced for gas piping. It was emphasized that these can be added later, if needed for the higher mass flow rates, without appreciable penalty in project time or cost. Maximum bed height above air distributors will be 15 feet, as compared to the 17-foot maximum height used to date in test work on Retort No. 2. Bergen stated his belief that the top star feeder would have to be removed and the retort operated at balanced pressure in a commercial design, indicating that possible work along this line could be considered later.

Executive Session

There was a brief discussion of current activity and publicity with respect to nuclear applications to oil shale, with the consensus being that much of the publicity evolving from such activities is based on information which is both unreliable and unrealistic, and which should have no bearing on the planning and conduct of project work.

At the next observers' meeting, continuation of the formal concluding critique by a representative from each company will not be planned or scheduled, but all comments will be welcomed.

In a final round of comments from each of the companies general satisfaction was expressed with regard to progress since the previous meeting, and Mr. Cramer and his staff were thanked for their efforts and for their good presentation at the meeting.

Bob Cramer announced that the planned tour of the mine and retort facilities would start at 8 o'clock on the following morning, June 24.

D C Smith / SLM

D. C. Smith, Chairman

S L Meisel

S. L. Meisel, Secretary

APPENDIX

THIRTEENTH REGULAR TECHNICAL ADVISORY COMMITTEE MEETING, JUNE 23, 1966
RIFLE, COLORADO

I. Old Business

B. (Other) Spent Shale Disposal Information:

In accordance with the request by the Technical Advisory Committee at the May 2, 1966 meeting to develop information on outside work concerning spent shale disposal the Program Manager reported that he had contacted the U. S. Bureau of Mines at Laramie, Wyoming. Harold Sohns of Laramie indicated that the Bureau was not conducting any research along this line at present, but that they had included some work in their three-year proposal, scheduled for about 1968.

In the past, work had been carried out on growth of vegatation on potted spent shale from Rulison, Union and the Gas Combustion Retort, in conjunction with the University of Wyoming. It was found that dry land grases (Kachia, Crested Wheat Grass and Winter Wheat Grass) grew. The major problem encountered was that coarse granular spent shales would not retain sufficient water to sustain growth. However, if the spent shales were crushed to minus - 40 mesh, there was good water retention and growth occurred. The conclusion was that if the spent shale was crushed and a nutrient was added satisfactory growth occurred.

Leaching of salts from the spent shales was not a problem unless naccolite or trona occurred. This would be a very minor problem.

The major problem encountered in the study of the behavior of piled spent shale was concerned with finely divided solids in water run-off. This could require settling ponds

In an experiment performed on Union spent shale, shale oil was sprayed on the pile. During the first three years, the shale oil acted as an herbicide. After this period, the shale oil acted as a mild fertilizer, because of slow release of nitrogen. At present vegetation is growing on this pile.

The Program Manager reported that no program on spent shale disposal is planned.

II. New Business

B. Technical Presentation

1. General Remarks - R. H. Cramer

The Program Manager discussed estimated expenditures through June 30, 1966, shown on Handout RHC-1. This indicates that the program expenses are running about $50,000 under budget. The large accrued expenses

($547,474) reflect the orders for large scale mining equipment, construction contractors expenses, etc.

Program manpower totals 138 as of June 30 - 23 from the Participating Parties and 115 from the Research Foundation. Two from the Participating Parties are still carried as Technical Observers. New staff comprises:

| Retort Engineers | Reported |
|---|---|
| R. L. McGalliard (Pan American) | May 4, 1966 |
| B. L. Reymond (Continental) | June 20, 1966 |
| W. M. Broman (Sinclair) | Est. July 18, 1966 |
| Secretary Stenographer (Mobil) | June 27, 1966 |

The plant vacation shutdown will be from July 1 to July 17, 1966 inclusive. During this period, personnel on site will conduct turnaround maintenance work. In addition, the contractor will conduct a major overhaul of the crushing plant.

The Program Manager reviewed the Program objectives, which are:

Broad: To define and understand the Gas Combustion Retorting process in sufficient depth so that economical operation can be achieved in commercial retorts.

Specific: (Stage II)

1. Understand the Gas Combustion Process in sufficient depth so that results achieved on Retort No. 2 can be scaled up to Retort No. 3.
2. Develop sufficient understanding so that Retort No. 3 results can be scaled to commercial operation.

3. Develop sufficient understanding of mining so that results can be scaled to commercial operation.

The Program Manager then reviewed the major conclusions arrived at since the May 2, 1966 meeting. These are presented on Handout 2 - RHC.

2. Retort Program

a. Discussion of Theoretical Aspects

1. Review Mechanisms Controlling Operability and Yield

P. W. Snyder touched on and unified the following past and current results related to process understanding.

(a) Mechanisms Controlling Operability (Handout 1 - PWS)

(1) Heat Input

At least 400,000 Btu/Ton (4,000 SCF/T) for stable combustion.

(2) Clinkering

(a) Not over 7,000 SCF/T of air or clinkers

(b) Poor air distribution particularly with low recycle (startups).

(c) Particular problem with small size shale since intrinsic burning rate is four to five times that for cracking catalyst.

(3) Shale Flow

(a) Adequate shale flow dimensions must be provided in the retort around internals - the minimum spacing increases with shale size.

(b) Recent mechanical model study in the small plexiglass model has hammered home the importance of this factor.

(4) Dust Circulation

(a) Description - Dust is formed in retorting and combustion zones - fine particles are elutriated up the bed until they reach the oil condensing zone (900 to 1,000° F). They are agglomerated by the oil wet shale and carried back down. If this becomes excessive the interstices can become completely blocked by a tarry-oil dust mixture and shale flow stopped.

(b) Evidence

(1) Presence

a. Mechanical Model studies.

b. Quench tests on Retort No. 1.

c. Grab samples from Retort No. 2.

(2) <u>Circulation and Oil Accumulation</u>

a. Mechanical models.

b. Special tagged-dust run on Retort No. 1.

c. High pressure gradient in region of initial oil condensation (900 to 1,000° F).

d. Gas velocity limitation irrespective of raw shale size.

e. Analyses of grab and quench samples of oil-dust mixture.

(3) <u>Effects</u>

a. Small restriction of cross-sectional area in retorting or combustion zone causes dust accumulation at 500 mass rate with eventual shale flow stoppage.

1. Initial horizontal air distributors.

2. Recent streamlined horizontal distributors.
3. Tapered retort.
4. Bayonet air distributors with enlarged caps.

b. Excessive gas velocity via increased mass rate or increased gas ratio also can cause dust build-up to the point of shale flow stoppage.

c. Uniform horizontal temperature in the combustion zone may also contribute to dust accumulation above the air distributors. Uniform temperatures mean uniform gas velocities which eliminate localized low gas velocity areas for dust to drop through the combustion zone.

Our recent experience

with the horizontal air distributor which produced a uniform temperature is some evidence supporting this hypotheses although not conclusive. But the converse is true that what we would consider fairly severe non-uniform temperatures do not hurt operation.

(5) Oil-Refluxing

a. Description - There is the dust-oil reflux previously described, but oil refluxing referred to here is the "bogging" problem sometimes encountered. This mechanism involves oil impingement and condensation (when cooling rates become low) on the shale near the top of the retort. This can become excessive and cause a retort shutdown.

b. Causes

1. Excessive gas velocity or gas ratio.

b. <u>Mechanisms Controlling Yield (Handout 2 - PWS)</u>

(1) <u>Dust Circulation</u>

(a) <u>Description Relative to Yield Loss</u>

Internally circulating dust adsorbs oil which polymerizes or cracks on revaporization.

(b) <u>Evidence</u>

(1) <u>Can Cause Yield Loss</u>

(a) Fischer Assay Retorting in the presence of retorted shale fines reduces yield. This loss is a function of the dust/oil ratio as shown by varying richness in this study:

| Assay | Yield Loss |
|---|---|
| 20 | 6 |
| 28 | 4 |
| 37 | 1 |

(b) Vaporization of oil from retorted shale fines resulted in a 15% oil loss.

(2) Its presence in our retort was covered under operability.

(c) <u>The Adverse Effects of Dust on Yields Are Minimized by:</u>

(1) Limiting gas velocity below the point of poor operability.

(3) Impaction Studies Indicate Oil Refluxing Above the Retorting Zone May Be Minimized By:

(a) Maintaining good nucleating conditions (a large per cent of the mist particles over 4 microns will be refluxed - impaction varies exponentially with $D_p^3$) therefore rapid cooling of the gas.

(b) Processing large shale - impaction varies exponentially with the inverse of APD.

(c) Maintaining as low a gas velocity as is reasonable from time-temperature considerations. Impactions varies exponentially with the gas velocity. With gas velocities above 4 feet per second the top of the bed will always flood.

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(3) Time-Temperature

(a) Description - Retorting shale at temperatures much above 900° F cracks some of the oil to coke and gas. A rapid heat up in our countercurrent process results in retorting at temperatures above 900° F.

(b) Evidence

(1) High Retorting Temperatures Do Destroy Yield

(a) Bureau of Mines data.

(b) Our experience with low gas rates - faced with compromise as low gas rates helps nucleation.

(c) Our experience with large shale and wide range shale.

(2) High Retorting Temperatures Are Minimized By:

(a) Maintaining maximum gas-to-shale ratio consistent with good operability and low oil refluxing.

(b) Process small shale which more closely approaches the gas temperature and permits a more rapid cooling for the same retorting residence time.

(4) Shale Flow

(a) Description Relative to Yield - The retort may be very operable and still have a poor shale flow with respect to yield. There may be particle size segregation or a stable bridge-and-break flow. Both of these results can have an adverse effect on the time-temperature history of the large particles.

(b) Evidence

(1) Changing the locations of the feed chute on Retort No. 2 to minimize particle size segregation in the retort resulted in an increased yield.

(2) Our recent studies retorting large size shale showed a yield improvement when changing the air distributor to one which was designed for minimum shale flow problem at the expense of gas distribution.

(3) Shale flow studies through small plexiglass models of Retort No. 2 have clearly shown the bridge-and-break flow results in a large reduction in the density of the bed and development of large voids.

(c) Poor Shale Flow Can Be Minimized By:

(1) Use of the small plexiglass models to develop internals which have the minimum effect on shale flow.

(2) Sacrifice good gas distribution for adequate spacing of internals.

(3) Not trying to run a shale size which is too large for the maximum geometry available - i.e. Retort No. 2 is limited to about 2 1/2 inch maximum

size as a narrow size fraction.

(4) Designing to prevent size segregation at the top of the retort.

(5) Naphtha Vapor in Offgas

(a) Description - The low partial pressure of heavy hydrocarbons in the offgas retains naphtha as a vapor. When this material is recycled it can crack or burn to gas and coke.

(b) Evidence

(1) Vapor-liquid equilibrium calculations made last year showed that if there is any naphtha it will be retained as a vapor at normal offgas temperatures of 130 to 150° F.

(2) Analytical has recovered naphtha from the recycle gas via cold traps. This has amounted to 2 to 3 pounds per 1,000 SCF or 5 to 10% of Fischer Assay loss with the vent gas.

(3) The naphtha is 50% olefinic with diolefins such as 1,3 butadiene being measured.

(c) Loss Because of the Retention of Heavy Hydrocarbon as a Vapor Can be Minimized By:

(1) Minimizing the amount of cracking in the process.

(2) Maintaining offgas temperatures below 140° F. In one recent test

a 2% yield loss resulted when bed height was lowered to the extent of increasing offgas temperatures from 130 to 160° F.

2. Updating Process Performance Correlations

a. Distribution of Carbon Among Products Versus Yield (Handout 3 - PWS)

Although we still have about 4% unaccounted for organic carbon (which is most likely undetected naphtha in the vent gas). Yield losses increase the carbon in both the gas and in the spent shale.

b. Bed Height Requirement

(1) Height above the air distributor should be controlled to maintain an offgas temperature of less than 140° F. This means bed heights of about:

| | |
|---|---|
| 1/4 to 1 inch | ~ 5 feet |
| 3/4 to 1 1/2 inch | ~ 9 feet |
| 1 - 3 inch | ~12 feet |
| 1 1/2 to 2 1/2 inch | ~15 feet |

(2) Height below the air distributor also increases with shale size. One to three inch shale requires about 7 feet versus 6 feet for 3/4 to 1 1/2 inches. Increasing bed height 1 1/2 feet and installing

improved bayonets reduced the unaccounted for heat from 80 MBtu/Ton to → 40 MBtu/Ton.

b. <u>Preliminary Estimates of Economic Optimum Shale Rate and Maximum Size.</u>

1. <u>Conclusions From Initial Estimates of Economic Optima For Mass Rate and Maximum Shale Size</u>

a. Mass rates can be varied ± 75lbs/(hr)($ft^2$) from the optimum without varying overall cost more than 1¢/bbl.

b. The optimum mass rate for size fractions in the range of 1 1/2 to 3 inches in the region of 350 to 450 lbs/(hr)($ft^2$).

c. The optimum shale mass rate for size fractions below 1 1/2 inches is in the region of 500 to 600 lbs/(hr)($ft^2$).

d. The optimum maximum shale size is between 2 1/2 and 3 inches depending on what is done with fines.

e. Crushing cost versus maximum size, as well as fines make, are major factors in establishing the optimum particle size.

2. <u>Shale Size Definition:</u> (Handout 4 - PWS)

a. Yields correlate with weight mean. (Automatic or grab samples adequate).

b. Bed height requirements; retorting time, and other heat transfer related factors correlate with APD. The Ty-Lab results in a misleading APD as does including the pan fraction.

c. "C" belt sample is representative of what is in retorts.

3. <u>Optimum Mass Rate</u> (Handout 6 - PWS)

a. Bases for calculations

(1) Yield

(2) Economic

(3) Retorting single size shale - when combined with overall operations there is some interaction in the final optimization. But this appears to predict it within 50 lbs/(hr)(ft$^2$) and ± 0.5¢/B.

b. Conclusions

4. <u>Optimum Maximum Size</u> (Handout 7 PWS)

a. Bases for calculations

(1) Yield

(2) Economic

(3) Fines make

b. Conclusions

5. <u>Status of Crushing Studies</u>

a. Secondary crusher contract has been executed and will be installed during shutdown.

b. Size distribution and cost study has been reviewed by Mobil attorneys and is now being reviewed by Allis-Chalmers.

c. Nordberg has not submitted their proposal yet.

6. Incentive For Processing Fines (Handout 8 - PWS)

a. Bases

b. Conclusions:

(1) Being able to process 1/4 inch to 8 mesh at 200 mass rate with 85% yield is a big step in reducing the cost, 4¢/bbl out of a potential 10¢/bbl.

(2) Increasing mass rate on the fines fraction from 200 to 500 lbs/(hr)($ft^2$); processing the remaining 25% of the fines; and increasing yield to 95% on fines retorting will each reduce costs another 1 1/2 to 2¢/bbl.

(3) Processing all fines could reduce costs another 3 1/2 to 6¢/bbl.

The alternate of licensing a process to retort these fines may be an even more attractive route; however, it is beyond the scope of the program at Anvil Points to establish the economics of this route.

c. Shale Size and Rate Study in Rëtort No. 2 - R. L. Clampitt

1. Purpose of Study (Provide data which would permit the economic analysis group to define

general region of economic optimums for mass rate, size range, and maximum shale size.)

2. Results of mass rate and size range on oil yield while retorting with the 8-bayonet distributor.

   a. Oil yield versus mass rate for various size ranges of shale with 8-bayonet distributor at constant gas rates - Handout 1 - RLC.

      (1) New shale size characterization method (comparison of old and new methods on Handout 1). In planning this study an arbitrary basis was chosen for characterizing the size range shale. Purpose was to establish a reference basis of size distribution for all pertinent past shale size mass rate investigations as well as further investigations.

      (2) Operability for 1/4 to 1 inch, 1/2 to 3/4, 1 to 3 inch, 1/4 to e inch shale sizes.

      (3) Conclusions drawn while operating with 8-bayonet distributor (Yields at 500 mass rate are good but may be able to improve operability

with 1/4 to 1 inch shale. Improved air distributor design - 15-bayonets. Possibly dilution gas. Then firm up yields with the improved distributor design.)

(Yields and operability with 3/4 to 1 1/2 inch extremely close to optimum.)

(Operations with 1 to 3 inch shale unsatisfactory because of poor shale flow, oil in spent shale and high offgas temperatures, high air rates required. Poor shale flow observed with distributor was predicted by Mechanical Model Group in scale model work. These results precipitated a new air distributor design.)

(Operability was good with 1/4 to 3 inch however yields were low - increasing size range of shale results in lower yields.)

3. Operability and yield results while retorting 3/4 to 3 inch shale with a 4-bayonet distributor designed to provide good shale flow and adequate air distribution.

   a. Mechanical changes to Retort No. 2 prior to these operations.

(1) 4-bayonet distributor 12" X 16" centers.

(2) We increased the bed height below the air distributor by 1.5'. This increase was based on calculation of additional height required for large shale sizes.

(3) Installed equipment to permit obtainment of 17' bed height above distributor.

(4) We increased rectangular size of feed chute to eliminate shale bridging.

b. Effects of changes listed above on operability and yields while retorting the 3/4 to 3 inch shale (Handout 2 - RLC.

(1) Conclusions why we got improved yield and operability.

-Improved shale flow with 4-bayonet distributor. Improved the overall retorting residence time. Produced a more dense bed; thus increasing surface heat exchange area. This in turn reduced the effective bed height requirements required to give the same offgas temperatures.

R. L. Clampitt compared the 500 mass rate operation with offgas temperatures 170° F using 8-bayonet - 13.5' bed height with the 4-bayonet distributors, offgas temperatures 135° F - 13.5' bed height. I also would like to point out that the improved shale flow and the denser bed with the 4-bayonet distributor was analogous to results obtained when we initially installed stainless steel liner back in summer of 1965. Offgas temperatures came down then. Based on calculations it had been predicted earlier that high offgas temperatures would lower yields because of naphtha losses.

-Lower offgas temperatures improved yields by decreasing the amount of naphtha in the vapor state which is recycled back to the retort. Our policy is to maintain offgas temperatures at 125 to 135° F if mechanically possible.

Recent experience where reduction of bed height lowered yields by 2 to 3% was reviewed. Offgas temperatures were increased from 25 to 30° F

-The additional bed height of 1.5' below the air distributor had a positive effect on yields by increasing the overall heat recovery from the spent shale - this allowed us to reduce the air rate requirements. Previously it had been shown that reductions in air rates will improve yields. Additional bed height helped to reduce the oil in the spent shale.

- We were able to improve operability following a startup by reducing the air and recycle 6% from the 4,600 SCF/T and 16,500 SCF/T level. Had what appeared to be a total gas rate limitation which was observed in the two week demonstration run.
- In scale up to Retort No. 3, we will be able to increase the clearances between the retort walls and the improved distributor design while retorting 1 to 3 inch shale. This should result in further improvements in shale flow and operability.

d. Fines Processing - R. L. McGalliard

Because of the apparent economic incentive for shale fines processing, advantage was taken of recent Retort No. 2 turnarounds to conduct preliminary fines operability studies in Retort No. 1. Past experience with 1/4 to 1 inch shale had indicated that combustion distribution and clinkering would be problems with this even finer material. Better air distribution, air dilution, and/or partial external combustion were considered as potential tools for attacking these problems.

Initial operations with +8 mesh to 1/4 inch shale gave an oil yield of about 81%. Although operability was poor, indications were that +8 mesh to 1/4 inch shale could be processed by the gas combustion retort. Difficulty in establishing stable even combustion and formation of clinkers did prove to be major problems.

During the second operating period, comparative data on a wide range material, +10 mesh to 1 inch was generated. Operability and yield was poorer than for the +8 mesh to 1/4 inch shale study. Considering the high yield and mass rates characteristic of +1/4 to 1 inch shale retorting, there appeared to be no incentive to investigate the +10 mesh to 1 inch shale further.

Additional +8 mesh to 1/4 inch shale studies were conducted during the third operating period. In addition to the primary objective of evaluating air dilution as a means of improving operability, a short evaluation of partial external combustion was planned. This short partial external combustion test gave yield about the same as that of the previous +8 mesh to 1/4 inch operations. Shortly after switching to undiluted air operations, the retort was shut down by bridging. A massive clinker was found blocking the center of the retort. The retort was restarted after the removal of the center air distributor and was again shut down by bridging. A clinker covering half the cross section of the retort was again found in the retort. An analysis of the data showed that gas channeling up the vertical thermowell was the cause of the clinker. Failure of support equipment prevented fu ther operations at this time.

Periods of excellent shale flow, even with a major portion of the retort cross section blocked by clinker, and reasonably good yields (about 80%), with poor operability, make it appear that fines can be processed satisfactorily in the gas combustion retort. Further studies on the +8 mesh to 1/4 inch shale fraction appear justified. Retorts No. 1 or No. 2 may be utilized for these studies if relative priorities allow.

e. Horizontal Air Distributor Study - J. W. Hasz

1. Object of Study:

   To determine if good air distribution with resultant more uniform temperatures and gas velocities was desirable or undesirable.

2. Differences Between These Horizontals and Previous Horizontals

   (a) Two distributors parallel to long axis of retort instead of three internal distributors parallel to short axis of retort.

   (b) Stainless steel liner. Liner extended to air injection level.

   (c) Both roll feeders operable.

   (d) Shale feed chute modified to reduce particle size segregation.

   (e) Provided about 90% open area at air injection level versus 78% for the five-pipe horizontals.

   (f) Distributor cross section shown in Handout 1 - JWH.

   (g) Remark by operators - "Most professi-oal looking air distributors they had seen".

3. Shale Sizes Investigated

   (a) 3/4 to 1 1/2 (1/2 to 1 1/2) demonstration run condition, 500 mass rate, 4,300 SCF/T air, 15,000 SCF/% recycle.

   (b) 1 to 3 (3/4 to 3) demonstration run

condition, 500 mass rate, 5,000 SCF/T air, 13,000 SCF/T recycle.

(c) 1/4 to 1 (1/4 to 1) demonstration run condition, 500 mass rate, 4,300 SCF/T air, 15,000 SCF/T recycle.

4. <u>Results</u>

(a) 3/4 to 1 1/2 inch shale

(1) Operated about 20 hours total after reaching conditions.

(2) Operation appeared smooth until two hours before shutdown.

(3) Shale bridged above air distributor.

(4) See attached Handout 2 - JWH for plot of temperatures, pressure drop, pressure gradient, and liquid product rate as a function of time.
(Note steady increase in temperatures, $\Delta P$.)

(5) Yield from B886PT = 81.8 Vol % FA.
Typical yield for previous horizontals = 82%.

(b) 1 to 3 inch shale

(1) Started up on 3/4 to 1 1/2 inch shale, switched to 1 to 3 inch shale without difficulty.

(2) Operated with 1 to 3 inch shale at lower recycle higher air.

(3) Bridge-and-break type operation.

(4) Raised recycle rate to 15,000 SCF/T - bridge did not break.

(5) Air distributor spacing not adequate for 1 to 3 inch shale.

(6) Yield B-887 = 75.3 vol % FA.

(c) 1/4 to 1 inch shale

(1) Had poor initial startup - clinkered - knocked clinker loose but shut down to verify.

(2) Second startup good.

(3) Operated six hours after reaching demonstration run operating conditions.

(4) Started bridging two hours after reaching conditions.

(5) Bridged and clinkered above air distributor.

(6) See Handout 4 - JWH for plot of temperatures, pressures, etc.

5. <u>Conclusions:</u>

a. Horizontal air distributors not operable at same gas rates as bayonets.

b. Even horizontal temperatures not good in Retort No. 2.

(1) May result from additional restriction caused by the hardware required to give an even profile.

(2) May be result of the uniform temperatures and velocities causing more stable bridges.

(3) Probably both.

c. Failure mechanism may have been different for the 1/4 to 1 inch shale than for the 3/4 to 1 1/2 inch shale.

d. The fact that the liner was extended to air injection level may have been a contributing factor in failure.

e. Additional work is needed to quantize the design of air distributors.

3. Mechanical Models - T. C. Lyons

The Mechanical Model group continues to supplement the retorting effort by providing: (1) Understanding
(2) Design Guidance

(a) Mist Studies

(1) Phil Gifford has been studying the behavior of mist for some time and his work is nearing completion.

(2) Although his results have not:

(a) Changed the retort operation to any great extent.

(b) Reduced the yield loss we have experienced.

They certainly have:

(a) Led to a better understanding of certain phenomena which had been observed by the retort people - flooding and the rapid pressure buildup associated with it, refluxing, liquid entrainment out of the bed, and has shed light on mist size as a function of gas cooling rate.

(b) Tied together - in the form of an empirical correlation - the many factors that influence the impaction of mist in a bed of shale.

(3) In addition, these studies have assisted in hardware design. They have:

(a) Demonstrated that elaborate hardware is not required in the top of the unit to disengage mist from the shale bed.

(b) Demonstrated the value of skimmer-type devices in the low pressure oil recovery train.

(b) Shale Flow Studies

(1) In the shale flow area, the most important news is the Evolution of Small-Scale Models as a research tool.

(a) Originally built for demonstration purposes.

(b) Noted:

(1) Similarities to large flow models.

(2) Shortcomings in our thinking for design of Retort No. 3. (Spacing of recycle distributors)

(c) Needed confidence in small models before decisions could be made based on the observations.

(2) Direct Comparison of Small vs. Large Flow Models

(a) Made a direct comparison of a large flow model (10feet x 20 feet x 2 feet) with a miniature 1/12 scale model (10 inches x 20 inches x 2 inches)

(1) In spite of some inconsistencies, the small scale model predicted the results of hardware changes

with surprising accuracy.

This included:

(a) Basic systems without internal hardware.

(b) Recycle distributor shape.

(c) Recycle distributor spacing within the retort.

(1) Concluded that scale models could give valuable guidance and that we could proceed with studies in a scale model of Retort No. 3.

(3) Flow Studies in 1/12 Scale Model of Retort No. 3.

(a) The shape and spacing of recycle gas distributors now planned for Retort No. 3 were based on our observations of the flow through the small model of that unit.

(1) Spacing - Found that distributor elements should be equally spaced in the retort vessel to provide adequate shale flow at the walls with the larger shale sizes. (Favors shale flow rather than gas distribution.)

(2) Shape - Found that the smoothest shale flow was obtained with elements which had a sharp leading edge and a triangular top section. (Have used this information to contour all the horizontal manifolds in a retort in the air distributor section as well as the recycle section.) HANDOUT 1 shows the general shapes that were evaluated - short triangles with vertical skirts (lower left) gave the best flow patterns in all cases. There, this shape was recommended for the recycle distributor in Retort No. 3.

(b) Checked the 6-pipe shale feed system and found no flow inconsistencies.

(4) Prepared Film Clip to Illustrate How We've Used Scale Models to Solve A Typical Design Problem.

PROBLEM: To develop a riser-type air distributor for Retort No. 2 which will flow the larger shale sizes and still give adequate air distribution.

The Film Strip Illustrated the Following.

(a) The 1/6 scale model of Retort No. 2.

(b) The 3/4 - 1 1/2 inch shale flows through the 8 riser distributor system adequately - demonstration run was O. K. - but, there is evidence of larger voids forming in the distributor section.

(c) The flow of 1 1/2 - 3 inch shale is very poor through the 8 riser system - large voids - bridge and break gives accordian type flow.

(Retort people agree that this was what was happening in the retort with this shale size.)

(d) Proceeded to streamline the intervals

(1) Reduced number of risers from 8 to 4.

(2) Improved contour of horizontal manifold to facilitate flow - now sharp and thin.

(3) Repositioned the hori-

zontal manifolds to provide adequate wall clearance.

(4) This design resulted in flow through the model with 1 1/2-3 inch which was comparable to that of 3/4 - 1 1/2 inch shale with 8 risers.

(5) This vastly improved shale flow was also noted in the retort operation.

We plan to continue using scale models as a quick and inexpensive means of solving a problem. Wherever possible we will cross check large vs. small to minimize the chances of being misled.

We now have scale models of:

Retort 2

Retort 3

60 ton storage bins with drawoff intervals

100 ton storage bin with covical intervals

Large shale flow model

(4) Research Program Planning, J. E. Lawson

(I) Status of Program

Program planning in recent past has centered around definition of the various problems which must be solved for successful prosecution of the Retort 3 program. Also, recent economic analysis work has given perspective on the development work which has greatest potential in purely economic terms. A summary of the status of each of these items is presented in Handout 1 (JEL).

Data recently obtained include those of the effect of and requirements for bed heights below and above the air distributor for large size shale. These data, coupled with information developed earlier, provide a basis for confident estimation of bed heights required once shale size and mass rate are specified. Work in both small and large models have provided design bases relative to the shale feed and drawoff systems to be used for Retort 3 and for spacing of air and recycle gas distributor manifolds.

Problems near solution include (1) maximum economical particle size, (2) number of particle size ranges to be examined in the program, and (3) optimum mass rates for each particle size. All shale size - mass rate data planned for the program has been collected and analysis of these data will provide answers to the above problems.

Recent experience with the four bayonet distributor has indicated that it is an adequate air distributor for large size shale. Complete analysis of this data, it is believed, will allow selection of a design suitable for large shale in Retort 3.

A significant problem remaining in establishing design criteria for Retort 3 is that of distributor configuration required for small shale (i.e., 1/4 - 1 inch or 1/4 - 3/4 inch). As described in earlier presentations, the concern here is clinkering. Runs with a 15 bayonet air distributor, and perhaps dilution gas, are planned in an effort to improve this situation.

Economic analysis work, reported earlier, has shown the economic importance of successful processing of fines. Preliminary efforts in the retorting program have produced some encouraging results, reported earlier. Further efforts are planned. It is also known that under specific conditions, wherein rich shale can be mined cheaply, processing of rich shale (i.e., greater than 30 gpt) can be very attractive. Runs to confirm Retort 1 data on 35 gpt shale are planned.

Assuming there is time available, certain other exploratory work might be desirable. A listing of these possibilities is shown at the bottom of Handout 1. Some of these items, however attractive, would require unanimous consent by the TAC for prosecution since they represent radical departures from the Research Agreement. It is planned to establish economic potential and success probabilities for each of these studies and thereby establish an order of priority for utilization of program time available after basic requirements are met. Recommendations in this regard will be made prior to the next TAC meeting.

(II) Program Plan

(A) Retort 3 Program

No further definition of the Retort 3 program has been attempted. The program shown is still merely illustrative since shale size ranges to be used are not yet defined. Such definition is awaiting analysis of the results of the current program on Retort 2.

(B) Retorts 1 and 2 Program - High Priority

The current program on Retorts 1 and 2 has commanded most of the recent efforts in planning. These efforts have culminated in a comprehensive plan to satisfy the requirements for successful prosecution of the Stage II major objective. The plan for this part of the program is presented in the bar graph of Handout 2 (JEL).

(1) Process Variable Studies

(a) Shale size and rate studies

Efforts in the above category are now complete except for final analysis and conclusions from the data.

(b) Optimization

One period of operation has been completed. These studies examined bed height requirements and an air distributor for large shale, apparently with success. One more period is planned in the current program, i.e., examination of an improved air distributor for small shale. This study may also include the effect of dilution gas on clinkering, if the 15 bayonet distributor is not completely satisfactory.

(c) Raw Shale Screening

This program is an effort to improve our ability to produce shale for retort studies of specified particle size range. It will be carried out in conjunction with preparation of shale for retort studies and will not require any appreciable program time.

(d) Base Runs for Retort 3

In order to establish reliable base points for demonstration in Retort 3, it is planned to run single conditions on each shale size for approximately six days. Once adequate hardware is available and shale sizes and economic mass rates are established, these base point runs will be made. As shown in the plan, these runs are expected to occur in August.

(2) Fines Retorting

Two exploratory periods of operation have already been accomplished, with results reported earlier. One more period of operation is currently planned. This operation is planned to confirm encouraging results on 8 mesh - 1/4 inch shale, and possibly to examine the effect of dilution gas and external heating to reduce what is apparently the major problem of the operation, clinkering.

(3) Shale Richness Study

Two periods of operation on rich shale are currently planned. The first will be an attempt to confirm Retort 1 results on 3/4 - 1 1/2 inch 35 gallon per ton shale in Retort 2. Assuming this is successful, a second attempt will examine 1/4 - 3/4 inch, 35 gpt. shale. The latter operation should provide the severest test since it combines excessive richness with small shale, which has the greatest tendency toward flooding and clinkering. Further planning in the shale richness category will be deferred until the results of these tests are available.

(4) Startup Studies

Currently, the confidence in startup

capability is high. Therefore, it is considered that no special startup studies are required. This effort will consist of documentation of normal startups and consequent evolutionary improvements such that no net program time will be required.

(5) Horizontal Distributors

This study is complete and was reported earlier. No further work in development of horizontal air distributors is planned at this time.

(6) Slack Time

Some 45 days of slack time prior to startup of Retort 3 will be available after plans outlined above are complete. This time will be used, under first priority, to finish up work in the categories outlined above. Any remaining time will be utilized to undertake other exploratory work under the system of priorities established for such work.

(C) Retorts 1 and 2 - Low Priority

The plan shown in this section of the bar graph is illustrative only for a very good reason; i.e., time available is a function of Retort 3 service factor, which is still undetermined. Currently, the intention is to use such time as is available for exploratory work under the previously mentioned priority system for the work in this category.

5. Analytical Laboratory Analyses - D. Liederman

a. Recycle Gas

(1) Despite plant upsets and mechanical problems, the water and $C_3^+$ organic content in the Total Gas Line "A" is higher than calculated from vent purge measurements. $C_3^+$ hydrocarbons may normally be as high as 3 lbs/MSCF of gas - 8% of Fischer Assay oil loss with vent gas with additional loss via the recycle gas and cracking in the retort.

(2) With properly heat-traced lines, the gas after the vent purge condenser is equivalent (in water and $C_3^+$ organic) to the gas at the laboratory (Handout 1 - DL).

(3) Mass spectrographic and chromatographic analyses of -110° F cold trap hydrocarbons indicate fraction is $C_2$ - $C_{11}$ with averages of $C_6$ or $C_7$ (Handout 5 - DL).

(4) There are quantities of heavy (API = 20.9) oil which run along the bottom of the recycle line.

b. Fischer Assay Versus Particle Size and Spent Shale Composition (Handout 2 - DL)

(1) Slight lowering of Fischer Assay with decreasing particle size.

(2) No variation of carbon, hydrogen or benzene extractables as decomposed kerogen (oil) moves up Fischer Assay retort from the bottom layers through other spent shale layers.

c. <u>Fischer Assay Versus Particle Size</u> (Handout 2A - DL)

(1) Slight decrease of Fischer Assay with decreasing particle size. Magnitude of this effect is not known.

(2) Shale losses during grinding operations are disturbing and will be investigated.

d. <u>Water Contents - Centrifugation Versus Distillation</u> (Handout 3 - DL)

For Samples cited, both methods are entirely equivalent.

e. <u>Cooperative Program (Laramie and Anvil Points)</u> (Handout 4- DL)

(1) Data indicate slight bias in

water content ("t" test = 3.7)

Specific gravity ("t" test = 7.3)

(2) Anvil Points data is more precise than Laramie's. We should perhaps not use Laramie as our standard reference when it comes to analytical work. From our cooperative programs, it appears that the Anvil Points data are more precise than data from Laramie.

(6) Mining Program - G. Haworth

(1) General Mining Plan and Schedule (Handout 1-GRH)

(a) Present status of schedule

(b) Discussion of completion dates for various phases of the development work.

(c) Ventilation methods.

(2) Selection and Purchase of Equipment

(a) Down hole drill yet to be ordered.

(b) Heading drill jumbo purchased from Gardner Denver, selection based on versatility, good back-up service and previous experience with rotary drilling.

(c) Aerial platform purchased from Truco Denver, selection based upon design advantages (Handout 2 and 2A GRH)

(d) Loader is to be rented from Koehning selection based upon high capacity per dollar invested. Fast loading cycle and track type undercarriage as opposed to wheeled units.

(e) Forty ton truck is to be rented from Mack Trucks, selection based upon price and design which is suitable for operation on mine road.

(3) Opening up of new mine portal (Handout 3 GRH)

(a) Problems encountered in establishing a sound back.

(b) Problems encountered drilling in weathered shale.

(4) Description of the type of blasting rounds used in driving the ventilation crosscut (Handout 4, 4A, 5, GRH)

(a) Bum cut

(b) Pyramid cut

(c) V-cut

(5) Description of work started on driving haulage ramp

(6) Summary of roof bolt test work (Handout 6 7 GRH)

(7) Summary of bench scale test program to be contracted to Terrametrics.

(a) Cost

(b) Type of equipment (Handout 8 GRH)

(c) Type of tests to be undertaken (Handout 9 GRH)

(8) Description of over-coring work to be carried out in ventilation - crosscut for determination of rock stresses inherent in the rock (Handout 10 GRH)

(9) Screen analysis of run-of-mine shale

(7) Stage II Rehabilitation - W. S. Bergen

Rehabilitation and revisions to Retort No. 3 and supporting facilities are progressing in accord with projected schedules.

To date - Engineering is approximately 50% complete, construction about 10%, and about 1/4th of materials are on order.

We are scheduled to finish Retort No. 3 the end of the first week in October - barring any strikes. As yet we have not encountered any material delivery problems that we have not been able to overcome.

To assist in any scheduling the work, a Critical Path Schedule was prepared by the Torkelson Company. This was put on a 7044 IBM Computor at the University of Utah. It will be up dated once a month to reflect present progress and material deliveries.

Information from this print out shows the critical path, early and late start dates, for critical path items, all systems which must be engineered, fabricated, or ordered during any given month, and completion dates. It would appear to be a fairly valuable guide in our case and is being used.

Plans for the work in the crusher plant and storage bins have been formulated. As you know, most of the revisions in this area will be made during the plant vacation shut down.

·Primary and secondary screener revisions, bucket elevator repairs, secondary and tertiary crusher installation and repairs, conveyor revisions, 100 ton bin internals, Their feeder and conveyor installations, will all be made during this period.

Another crusher plant shut down is scheduled during September to install a new pan feeder ahead of the primary crusher, repair the primary crusher, and install a new motor control center in the crushing plant.

With regard to construction, demolition is complete and the shell of the retort is being repaired. Bricking will start next week. Forms for the recycle blower and precipitator have been prepared and concrete poured. Work has started removing equipment from under the 500 ton bin and storage tank cleaning is underway.

Handout No. 1 is my estimate of expenditures and % completions to date. As you can see, we have expended approximately $217,000 of the contractors estimated $686,000 job cost.

Using this breakdown, I see no areas which might develop into serious overruns.

This type of cost and job progress comparison is being used as a cost control mechanism.

My personal control sheet is divided into smaller catagories for control and informational purposes.

Since our last meeting, Dick Reitz and I have reviewed and calculated crusher plant shale production capabilities for narrower shale ranges. This data was reported in the June Progress report. We see no problems in meeting current Retort No. 3 demonstration run needs. The most difficult fraction to produce would be a 1 1/2 inch to 2 1/2 cut. Sufficient quantities for a 500 mass run could be produced in approximately 16 hours. Our projected crusher plant schedule is 2 shifts - 7 days per week. The 3rd shift is for maintenance.

In reviewing this work, the biggest burden will be placed on the mining group. They will deliver shale 3 shifts. As our crushing efficiency drops to 40%, their shale delivery schedules will be put to a severe test. Handout No. 2 is the latest flow diagram for your records. This will not be commented on unless there are some specific question.

I think it would be well to mention some of the supplies of the major equipment for Retort No. 3. One major criteria for selecting equipment is that it be commercially available for larger sizes and throughputs where feasible. The shale weight and rate control system is from Merrick. The line burner is being manufactured by Surface Combustion. Star feeders being supplied by Fuller Company. The multi-clones from Aerotec - 6 inch clones. The precipitators from Koppers. Blowers from Spencer. Instrumentation while not determined as yet - by a not unknown company such as Honeywell, Foxboro, Taylor, or CEC.

Temperature Recorders by Honeywell, other critica recorders by L & N.

Brick work being furnished is by A. P. Green. We have selected their clipper D P brick for facing the retort. It has a high spalling resistance, is CO degredation resistant, is of low porosity, and has good abrasion resistance. It is also used in highly reducing atmospheres such as ashing furnaces. These factors had to be balanced to find an overall brick suitable for our needs.

Handout No. 3 is the current air distributor layout. It shows riser spacings for three ranges of shale that may be used in Retort No. 3. This arrangement meets all criteria developed to date. There should be little or no shale flow problems and fair air distribution. The header spacings are the same for various shale sizes so further construction changes, when changing shale sizes, will not be required. For the small shale, fractions 1/4 - 3/4 or 1/4 - 1, there is approximately .7 square feet of bed/riser, for intermediate size shale of 3/4 - 1 1/2, there is approximately 1.1 square feet of bed/riser and for large shale 1.3, 1 1/2 - 2 1/2, there is approximately 2.5 square feed of bed/riser. These match Retort No. 2 tested or projected riser study spacings.

Rehabilitation of the mine office change room and garage and Retort office facilities is progressing well. Contracts have been let for all construction. Most material is on order and the engineering is complete. The Retort office will be revemped during the vacation shut down. This total job cost is within our budget estimate.

Manpower hiring has been revised to meet current manpower needs. Handout 4 - WSB details our hiring . To date, we have accelerated hiring of several personnel. Present total personnel at Anvil Points is 135 permanent employees and 2 summer employees. Our scoping report prosposed for manpower strength at this time was 121. The overall total manpower need will remain as indicated in our scoping report.

## STAGE II ESTIMATED EXPENDITURES TO JUNE 30, 1966

| | |
|---|---|
| Actual Cash Disbursements to 6/20/66 | $263,710 |
| Accrued Costs | 547,474 |
| Estimated Expenditures to 6/30/66 | $811,184 |
| Budget to 6/30/66 | 861,895 |
| Variance - Favorable | $ 50,710 |

## ESTIMATED MANPOWER 6/30/66

| | |
|---|---|
| Participating Parties[(1)] | 23 |
| Research Foundation (Authorized) | 115 |
| Total | 138 |

(1) Includes Two Technical Observers

RHCramer
6/20/66

MAJOR CONCLUSIONS SINCE MAY TECHNICAL
ADVISORY COMMITTEE MEETING

1. Economic optimum shale mass rate is between 350 and 500 lbs/(hr)($ft^2$); decreasing with increasing mean shale size.

2. Economic optimum maximum shale size is a fairly flat region between 2 1/2 and 3 inches.

3. Air distributor layout and design is a critical factor when retorting large size shale with respect to shale flow, and hence to operability and yield.

4. Large size shale requires additional shale cooling height below the air distributor for efficient recovery and distribution of heat.

5. Gas velocity and mass rate, independent of raw shale size, appear to control the maximum operable gas rate. Dust elutriation and accumulation with oil appears to be the operative factor.

6. There is some possibility of being able to retort 8 mesh - 1/4 inch fines in the Gas-Combustion Retort at 200 mass rate with 85% yield.

7. Retorting of fines in mixture with 1/4 - 1 inch shale does not appear attractive from either operability or yield considerations.

8. Horizontal air distributors are not attractive. The added area restriction they introduce reduces yield as well as operability.

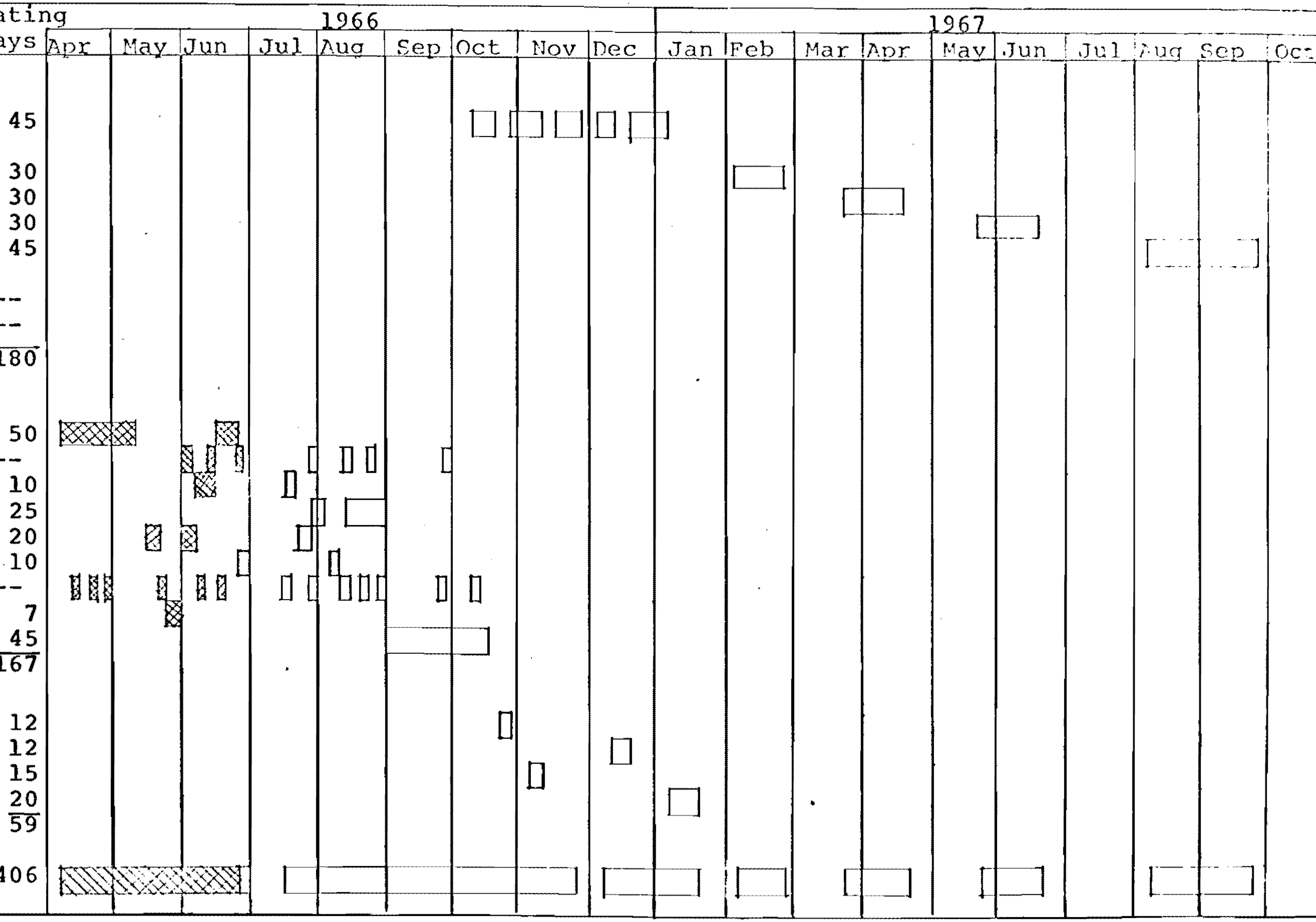
Note: At the request of H. P. Dengler of Esso Research and Engineering, the following statement is included:

"These conclusions 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."

RHCramer
6/20/66

STAGE II RETORTING PROGRAM

- Planned - Completed




variables, design changes, fines retorting, or shale richness study depending on
on Retort No. 3.

Revised 6/23/66

| PROGRAM | Op |
|---|---|
| A. RETORT NO. 3 | |
| 1. Shakedown Operation | |
| 2. Demonstrations of Optima: | |
| a. 1/4" X 1" (3 shale rates) | |
| b. 1/4" X 3" (3 shale rates) | |
| c. 1" X 3" (3 shale rates) | |
| 3. Final Demonstration Run | |
| 4. Hardware Studies as Time Permits | |
| a. Distributors | |
| b. Feed and Drawoff Systems | |
| B. RETORTS NO. 1 & 2 - HIGH PRIORITY | |
| 1. Process Variable Study: | |
| a. Shale Size-Mass Rate | |
| b. Raw Shale Screening & Handlin | |
| c. Optimization | |
| d. Base Runs For Retort No. 3 | |
| 2. Fines Retorting | |
| 3 Shale Richness Study - Retort No. | |
| 4. Startup Studies | |
| 5. Horizontal Distributors | |
| 6. Slack Time[(1)] | |
| C. RETORTS NO. 1 & 2 - LOW PRIORITY | |
| 1. Evaluate External Heating | |
| 2. Evaluate Nucleation Techniques | |
| 3. Soaking Zone Experiment | |
| 4. Additional Oil Refluxing Studies | |
| D. OPERATING TIME - ALL RETORTS | |

(1) Slack time allocated to firm up proces
what data is still needed to demonstra

PRIORITY OF STAGE II RETORTING STUDIES

| Objectives | Reason for Study | Type of Change |
|---|---|---|
| Draw preliminary conclusion on:<br>1. Maximum economical particle size<br>2. Optimum particle size range<br>3. Optimum shale rate for each particle size | Maximum particle size, optimum particle size range, and optimum shale rate for each are important economic parameters which must be developed in program. | Process variable and equipment |
| Develop procedures and equipment modifications required to produce narrow size ranges. | Debug potential screening and large shale handling problems. | Equipment |
| Provide final answers on maximum particle size, optimum size range and optimum shale rate and optimize each particle size with respect to air and recycle gas rates, bed heights, and air distributor hardware. | Final answers must be obtained to permit optimization of economics of a commercial venture. | Process variable and equipment |
| Demonstrate optimum conditions predicted by optimization study. | Establish base conditions to compare Retort No. 3 performance against. | Process and equipment |
| Investigate economic methods of processing raw shale fines. | Success would mean significant decrease in costs predicted for shale oil production. | Process variable and equipment |
| Evaluate the value of more uniform air distribution and establish whether a horizontal air distributor design is feasible. | More uniform distribution may increase operability and improve yield on some shale sizes. | Equipment |
| Establish a more successful startup procedure. | Smoothest startup must be achieved because of penalty for poor startup of a large retort. | Process variable |
| Confirm initial results obtained on Retort No. 1 and make a mini- e[illegible]ort to search for operating conditions which will permit retorting a 40 gal/ton shale [illegible] | Increased shale richness significantly reduces overall costs if uni[illegible] mining and crushing costs do not increase significantly with richness [illegible] | Process variable |

ORDER OF

| Order of Priority | Study |
|---|---|
| 1 | Process Variable |
| | A. Shale Size and Rate Study (Completed) |
| | B. Crushing and Screening Plant Evaluation |
| | C. Optimization Studies |
| | D. Base Conditions for Retort No. 3 |
| 2 | Fines Processing |
| 3 | Horizontal Air Distributor (Completed) |
| 4 | Startup Studies (Documentation effort only) |
| 5 | Shale Richness Studies |

| | | |
|---|---|---|
| Establish suitability of hardware selected, including problem solving as necessary; refine test procedures; and establish precision of test results. | This work must be done before demonstration can proceed. | None required except to solve problems |
| Demonstrate scale up of process to large unit by showing results equivalent to Retort No. 2 at selected process conditions. | Establish confidence in ability to scale process as required for commercial application. | Process variable and equipment |
| Demonstrate long-term stability of process and provide assessment of hardware reliability and/or problems. | Establish confidence in long-term stability of process and provide answers needed in mechanical design of commercial unit. | -- |
| Make evaluation of alternate hardware systems and/or process conditions. | Establish commercial feasibility of alternate hardware and process conditions to provide greater latitude in retort design. | Process variable or equipment |
| Provide evaluation of improvement in process by use of indirect heating. | Increase understanding of process by removing combustion from bed. | Equipment |
| Provide evaluation of improvement in process by use of nucleation techniques. | Increase yield by decreasing mist impaction. | Equipment |
| Determine improvement to process afforded by increase of shale residence time at retorting temperatures. | Increase yield by providing longer retorting residence time. | Equipment |
| Increase understanding of process by additional evaluations of the effect of oil refluxing on yields and operability. | Initial oil refluxing data were not very precise, therefore the effect of oil refluxing on yield and carbon distribution could be established as well as extending the range of oil reflux ratio to higher levels. | Equipment |

| | |
|---|---|
| 6 | Shakedown - Retort No. 3 |
| 7 | Demonstration of Optima |
| 8 | Final Demonstration Run |
| 9 | Additional Studies |
| 10 | External Heating |
| 11 | Nucleation Studies |
| 12 | Soaking Zone Studies |
| 13 | Oil Refluxing Studies |

# STATUS OF RETORTING PROGRAM

## PROBLEMS SOLVED

1. Effect of and requirements for bed height above air distributor.
2. Effect of and requirements for bed height below air distributor.
3. Shale inlet and drawoff systems.
4. Gas distributor shape and spacing.

## PROBLEMS NEAR SOLUTION

1. Maximum economical particle size.
2. Shale size ranges.
3. Optimum mass rates for each size range.
4. Adequate air distributor for large shale.

## PROBLEMS REMAINING

1. Air distribution on small shale.

## DEVELOPMENT WORK WITH HIGH ECONOMIC POTENTIAL

1. Fines processing.
2. Shale richness studies.

## OTHER EXPLORATORY WORK OR STUDIES OF LOW ECONOMIC POTENTIAL

1. Gas Rate Optimization
2. External Heating
3. Soaking Zone
4. Nucleation
5. Dilution Gas
6. Oil Refluxing
7. Dust Injection
8. Dust Removal
9. Air in Recycle Gas
10. Instrumentation Studies
11. Additional Gas Distribution Studies
12. Multi Level Hot Gas
13. Pressure Retorting
14. Others

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6/20/66

# MECHANISMS WHICH MOST LIKELY CONTROL OPERABILITY

1. HEAT INPUT - Must be sufficient to maintain a stable combustion zone.

2. CLINKERING - Excessive localized oxygen concentration can result in clinkering with subsequent shale stoppage. This is a particular problem retorting small size shale where combustion rates can be four to five times that on cracking catalyst. Therefore air distribution is more critical for small size shale.

3. SHALE FLOW - Must be smooth enough to prevent bridging and excessive channelling; shale flow may stop or fire may go out.

4. DUST CIRCULATION - Process conditions and/or internal design must extract all the dust produced with the spent shale or it will choke off the shale flow.

5. OIL REFLUXING - Process conditions must not exceed the flooding limitation or process will begin to channel with eventual loss of the combustion zone or shale stoppage.

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MECHANISMS WHICH MOST LIKELY CONTROL YIELD

1. DUST CIRCULATION - Internally circulating dust adsorbs oil which polymerizes or cracks on revaporization. Effect minimized by limiting restrictions in combustion zone and limiting gas velocity. Uniform temperature profile may also aggravate dust accumulation.

2. OIL REFLUXING - Impingement and condensation of oil on shale which polymerizes and cracks on revaporization. Effect minimized by limiting gas velocity.

3. TIME-TEMPERATURE - Retorting at temperatures much above 900° F causes cracking to coke and gas. Effect minimized by maintaining high gas rates and processing small shale.

4. SHALE FLOW - Poor shale flow produces voids which results in poor time-temperature history for some of the shale particles with cracking or burning of oil in the combustion zone. Proper spacing of internals minimizes poor shale flow.

5. NAPHTHA VAPOR IN OFFGAS - Low partial pressure of heavy hydrocarbons in offgas retains them as a vapor. Therefore methods to reduce cracking as well as maintaining offgas temperatures below 140° F minimize this loss.

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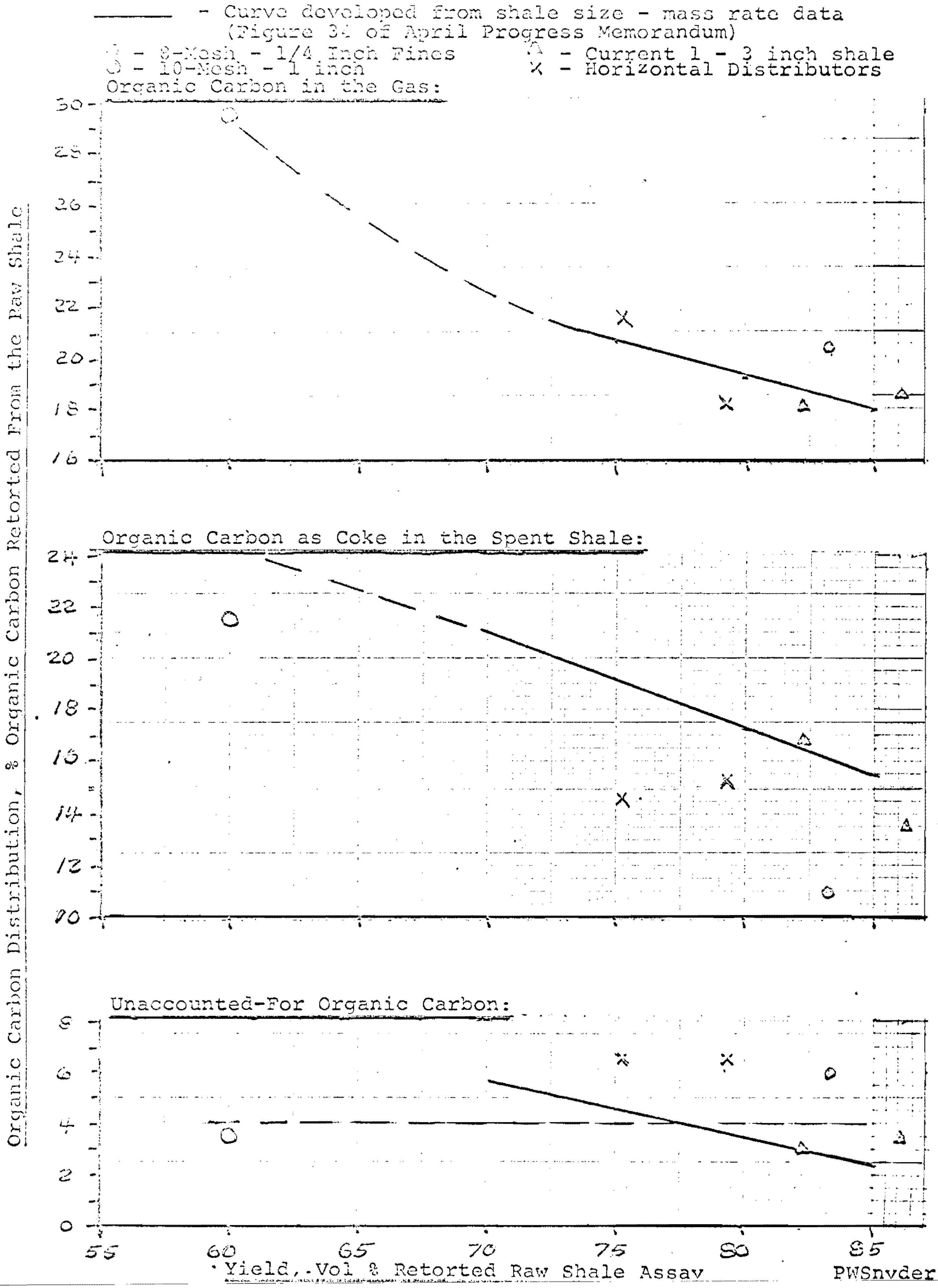
## ADDITIONAL DATA ON ORGANIC CARBON DISTRIBUTION AMONG PRODUCTS



## SHALE SIZE DEFINITION

| Nominal Size, Inches | 1 1/2 - 3 | 1 - 3 | |
|---|---|---|---|
| Source of Sample | Automatic Sampler | Automatic Sampler | Grab From "C" Belt |
| Number of Samples | 4 | 4 | 8 |
| Ty-Lab Size, Inches | | | |
| 98% Passing Through | 2.6 | 2.9 | 3.1 |
| 50% Passing Through | 1.65 | 1.55 | 1.65 |
| 5% Passing Through | 0.7 | 0.6 | 0.9 |
| Average Size, Inches | | | |
| Weight Mean | 1.65 | 1.60 | 1.70 |
| APD | | | |
| Including Pan | 0.7 | 0.5 | 0.9 |
| Excluding Pan | 1.4 | 1.3 | 1.5 |

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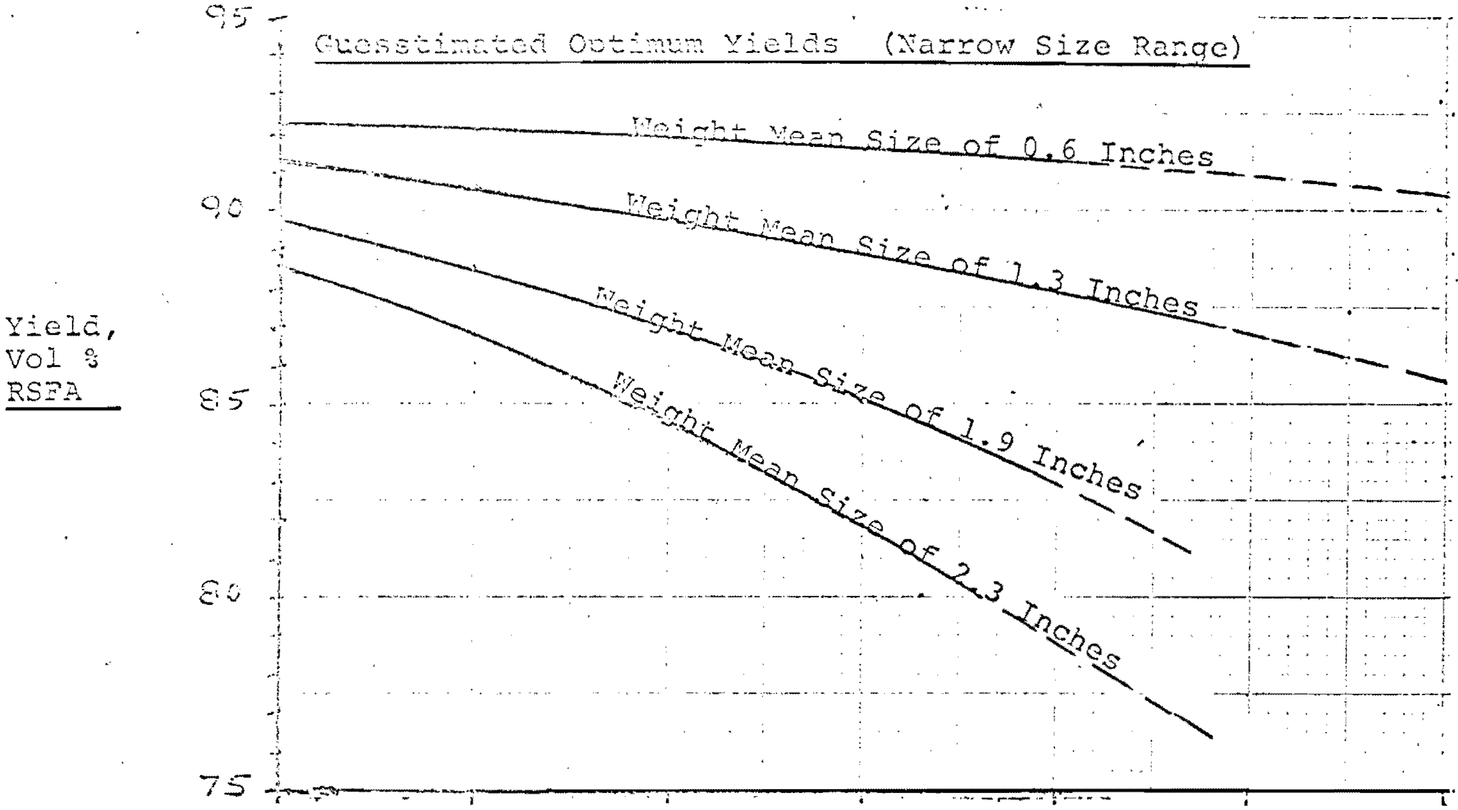
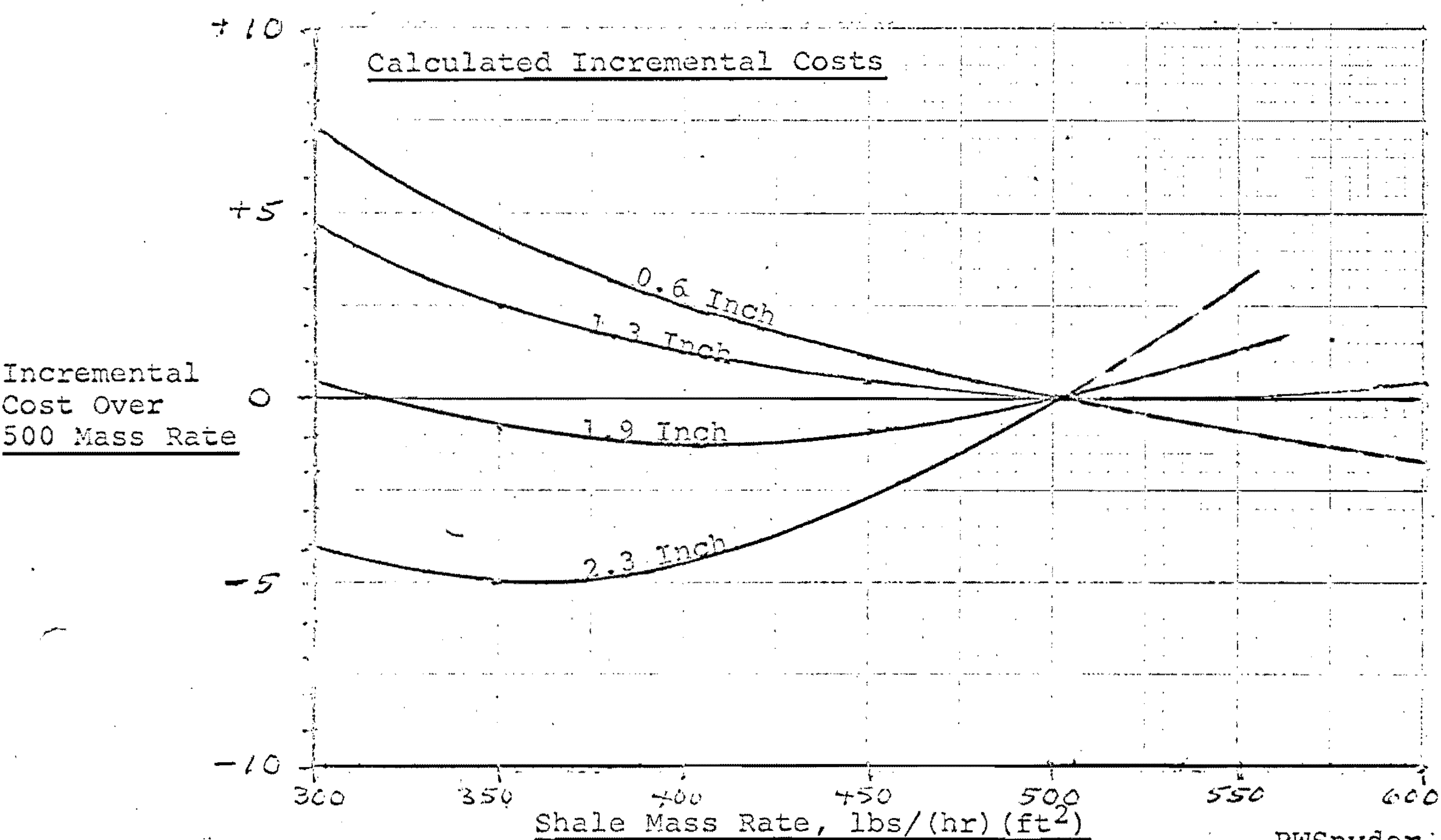
PRELIMINARY ATTEMPT AT ESTIMATING OPTIMUM MASS RATE

1. Yields are preliminary estimates.
2. Mining costs are 40¢/ton at 84,000 T/D and vary with the 0.8 power of production rate.
3. Crushing costs are 14¢/ton and vary with the 0.6 power of throughput.
4. Retorting costs are as published in the August 1965 Progress Memo.

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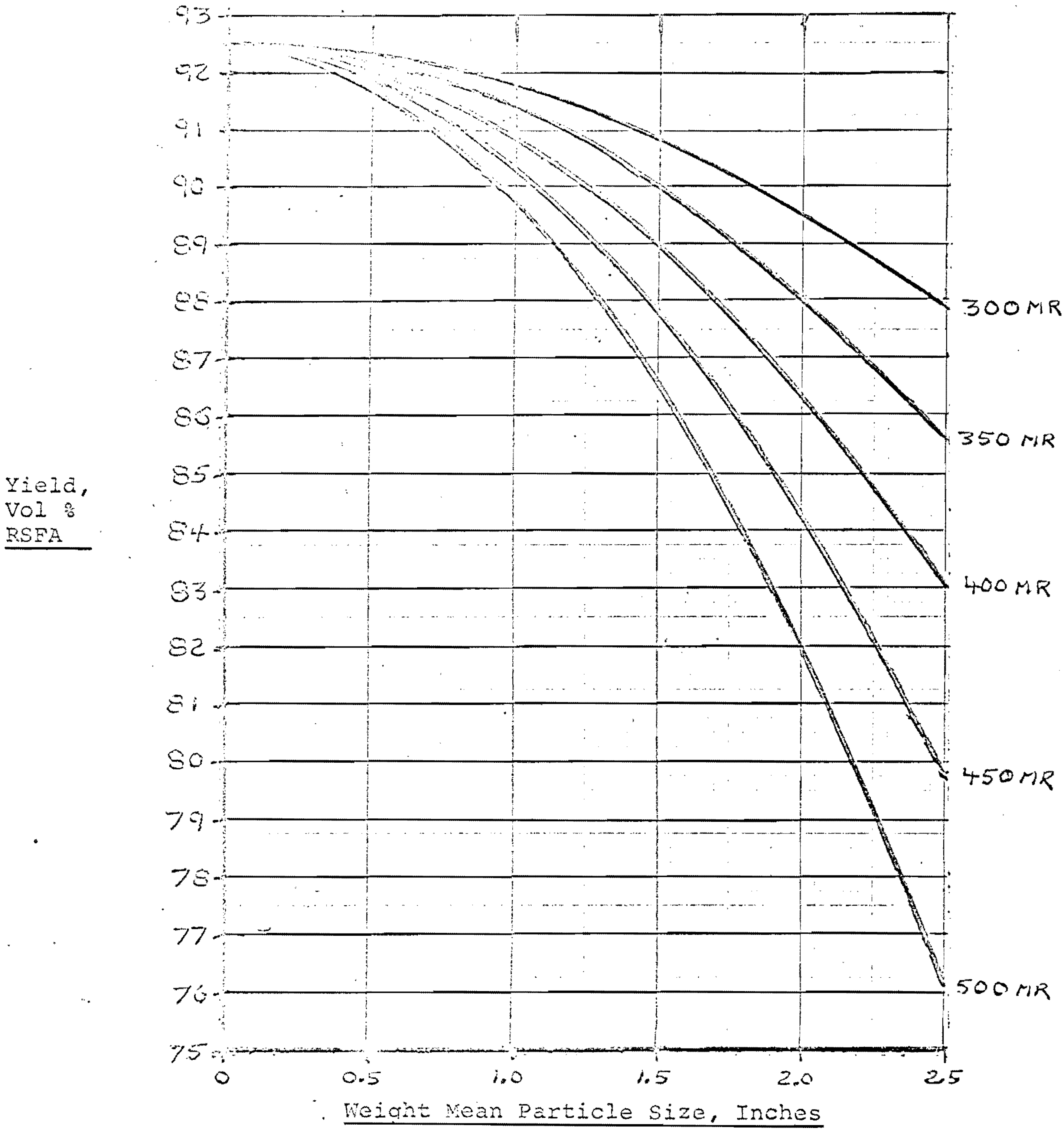
## PRELIMINARY GUESSTIMATE OF YIELD VERSUS SHALE SIZE

(Narrow Size Range Assumed)

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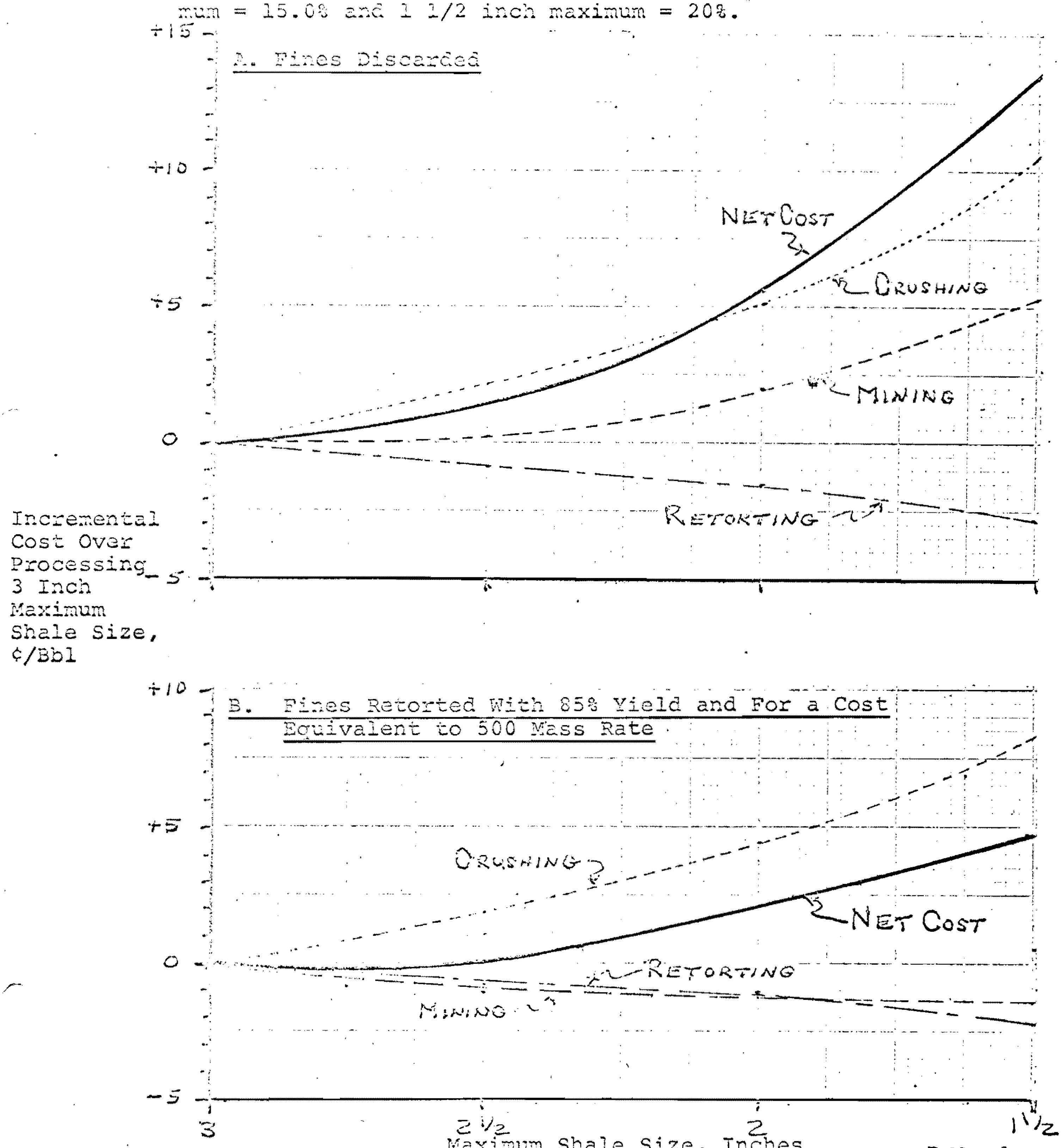
# PRELIMINARY OPTIMIZATION OF MAXIMUM SHALE SIZE

Bases:
1. Yields as shown on Handout 6.
2. Anvil Points retorting cost as presented in the August 1965 Progress Memorandum
3. Mining costs of 40¢/ton at the 84,000 ton/day level and varied with the 0.8 power of production rate.
4. Crushing costs of 14¢/ton for 3 inch⁻, 16.8¢/ton for 2 inch⁻ and 19¢/ton for 1 1/2 inch⁻. Crushing costs are assumed to vary with the 0.6 power of throughout.
5. Nordberg estimate of fines: 3 inch maximum = 10.5%, 2 inch maximum = 15.0% and 1 1/2 inch maximum = 20%.

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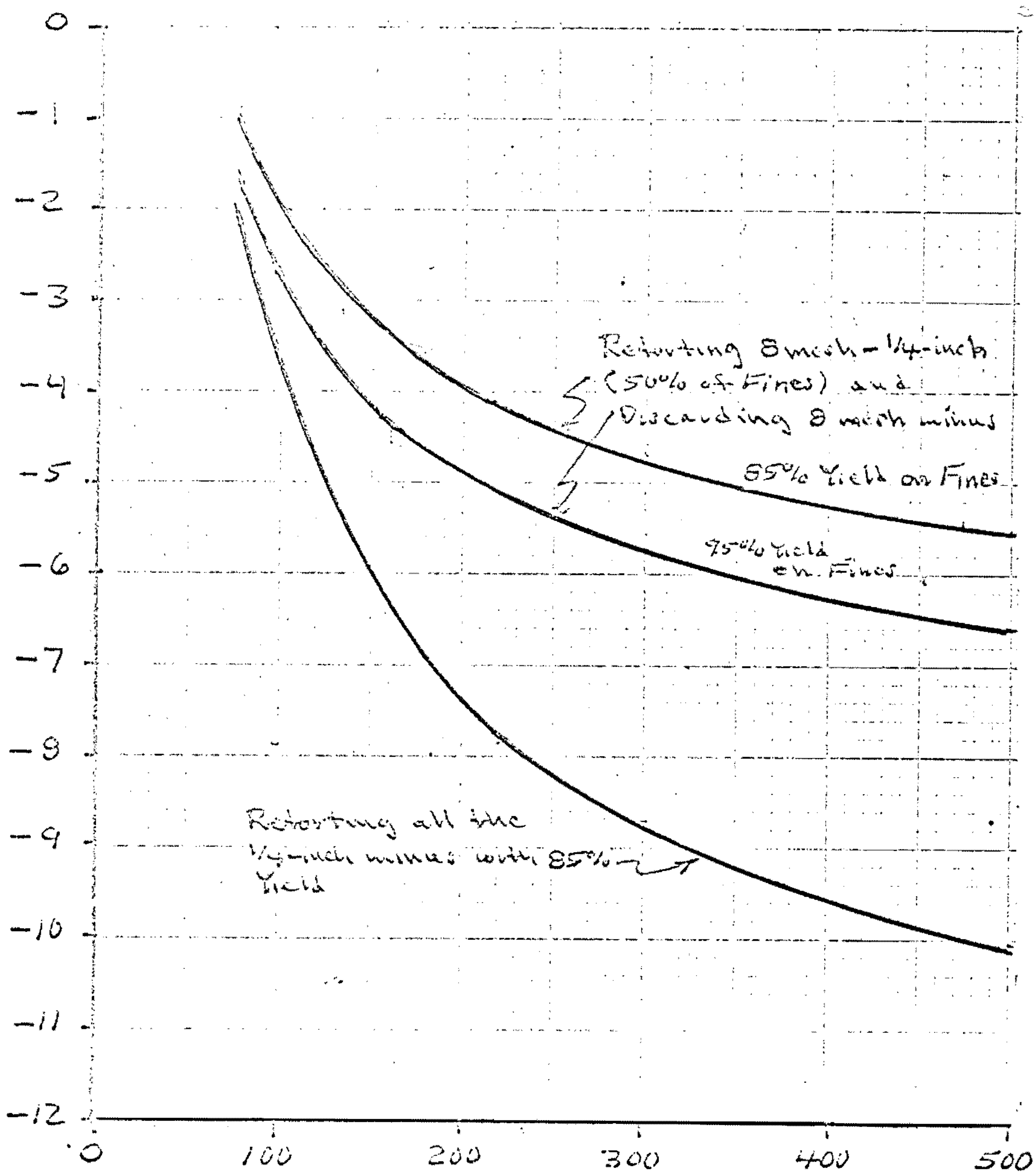
## APPROXIMATE EFFECT OF FINES RETORTING ON COSTS TO PROVIDE 50,000 B/D OF SHALE OIL

Bases:

1. Costs as described on Handout 7.
2. Retorting a 2 1/2 inch maximum size 30 gallon per ton shale (12.3% fines).
3. Yield as shown on Handout 6 for 1/4 inch plus fractions.

Incremental Cost Over Discarding Fines, ¢/Bbl




Cost Equivalent Mass Rate On Fines, lbs/(hr)(ft$^2$)

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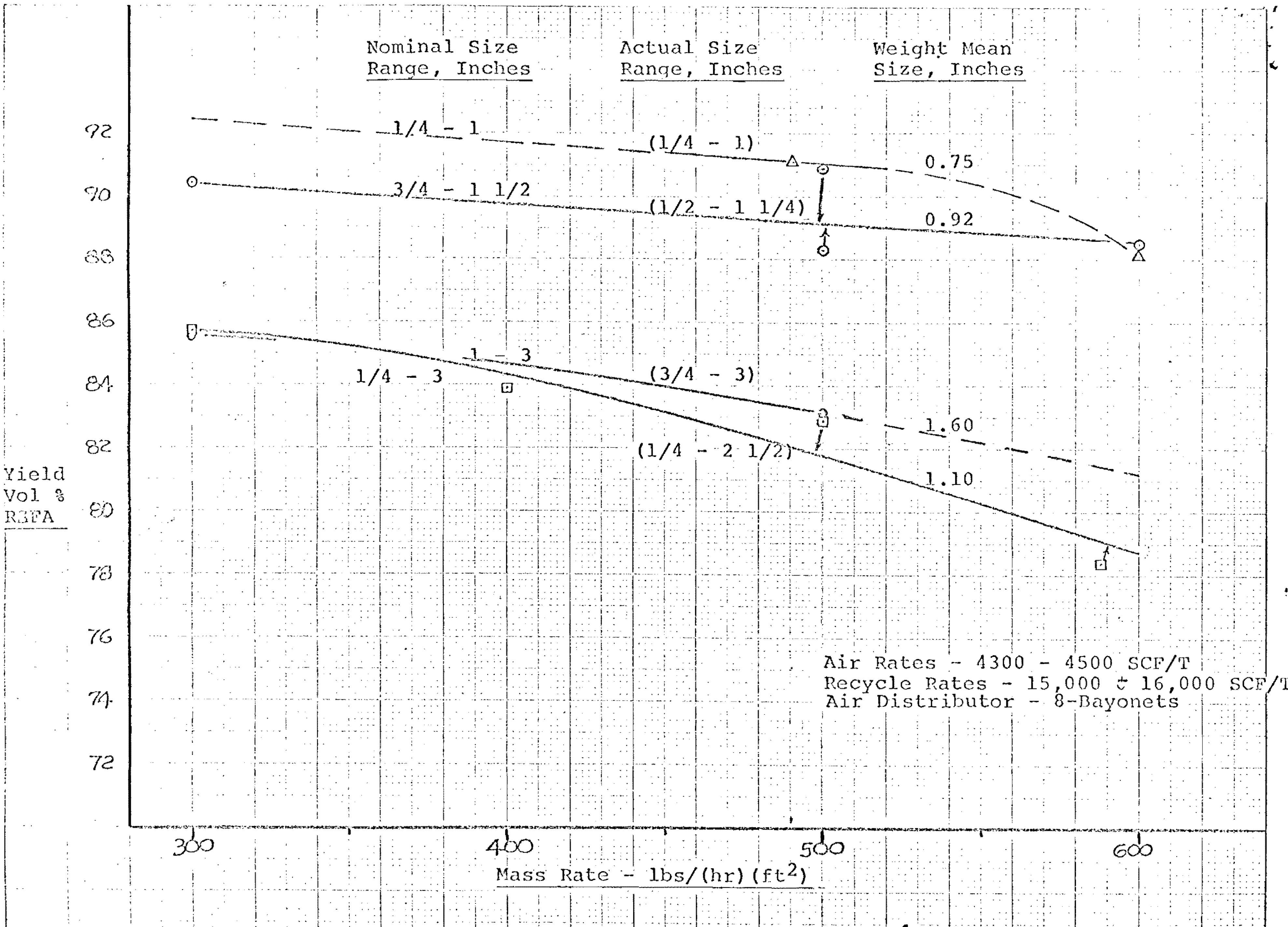
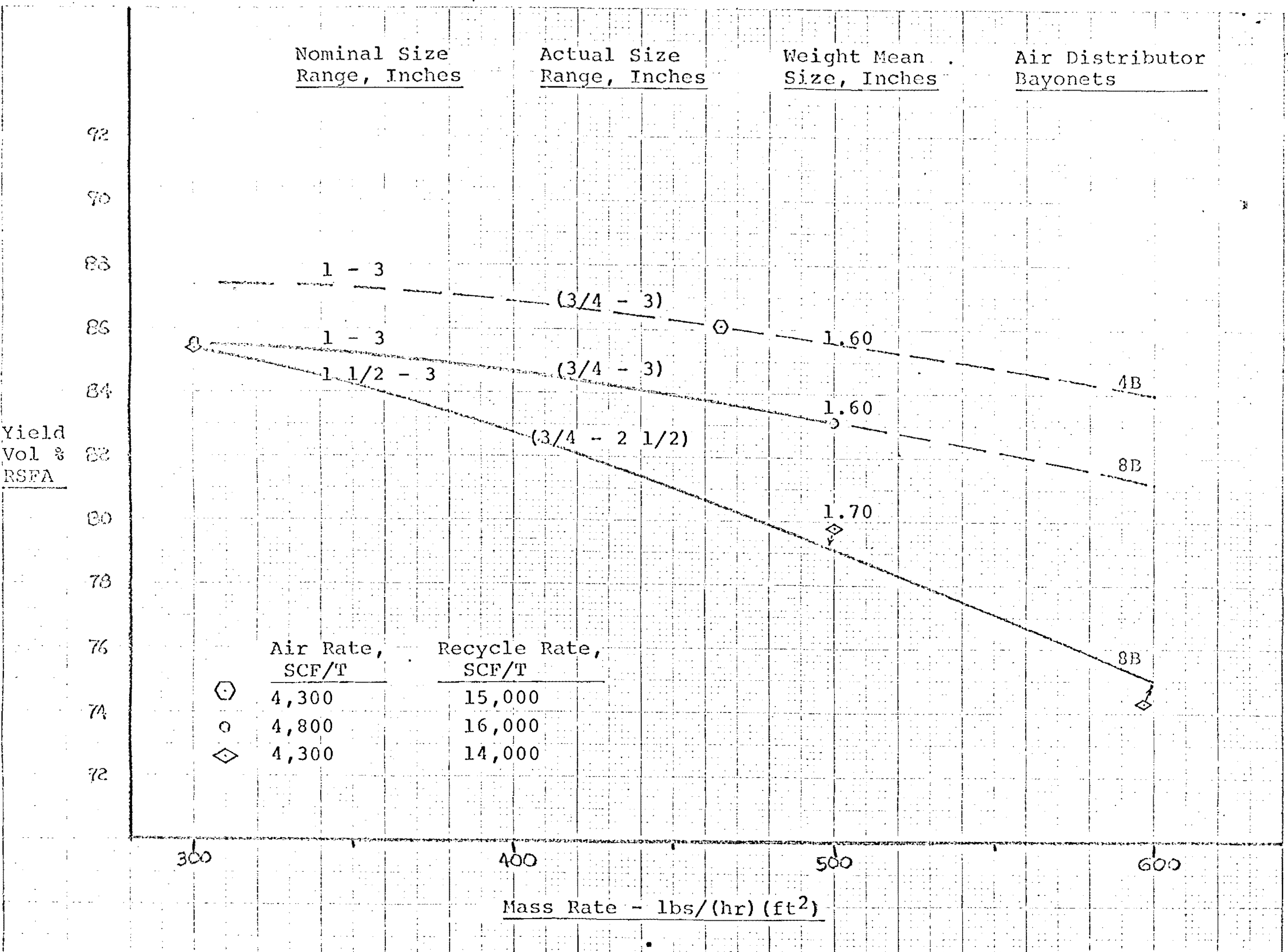
# EFFECT OF SHALE RATE ON YIELD




RLC [illegible]mpitt
6/2[illegible], 66

## EFFECT OF SHALE RATE ON YIELD




R. lampitt
6/.0/66

# FINES OPERABILITY STUDY IN RETORT NO. 1

A. Introduction

B. Initial Operations

C. Wide Shale Range Operations

D. Additional Operations With +8Mesh -1/4 Inch Shale

E. Future Work

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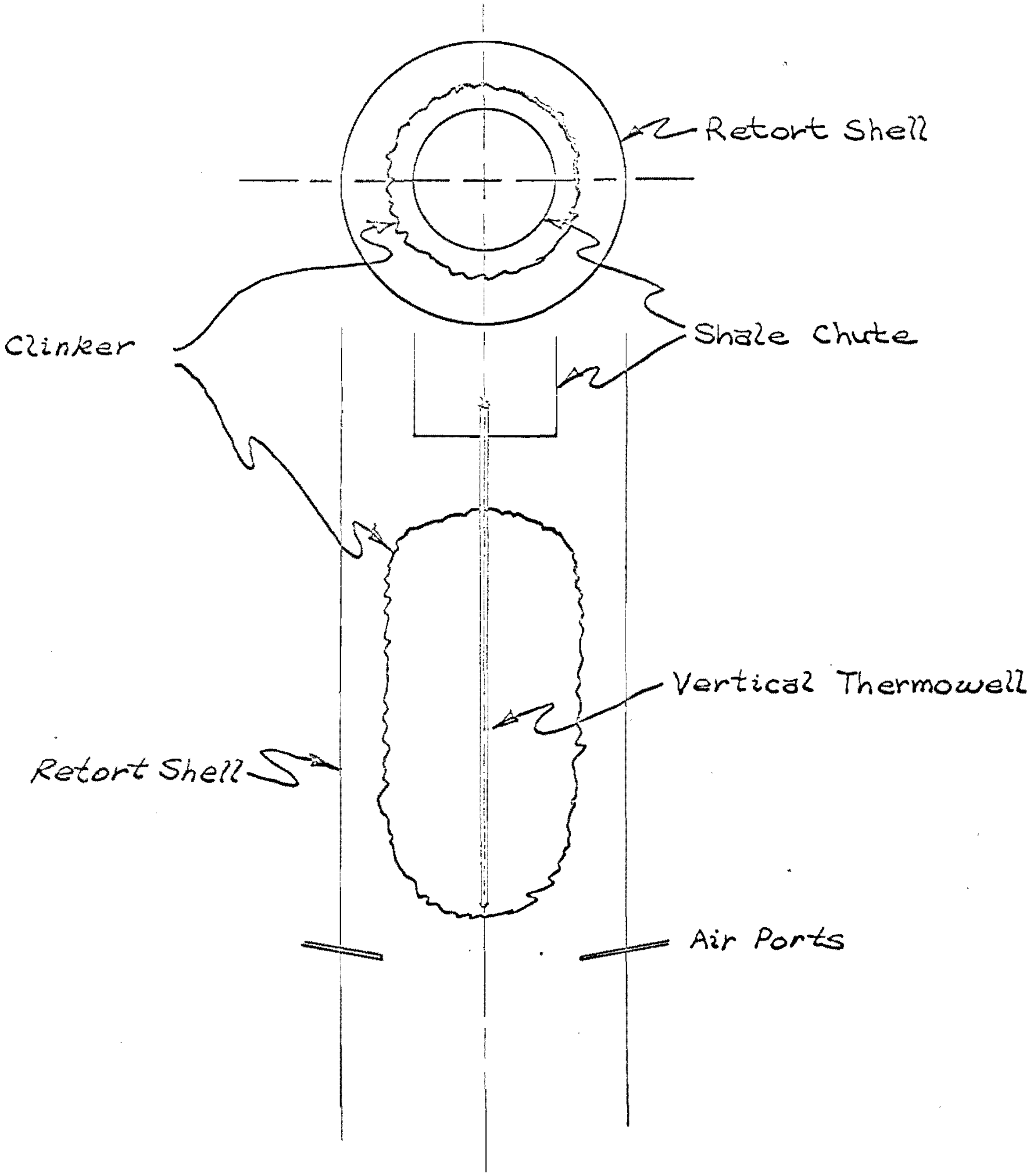
## SUMMARY OF FINES OPERABILITY DATA

| | Runs 884 - 885 | Run 894 | Special Run 895 |
|---|---|---|---|
| **Operating Conditions** | | | |
| Shale Size | +8 Mesh -1/4 Inch | +10 Mesh -1 Inch | +8 Mesh -1/4 Inch |
| Mass Rate, lbs/(hr)(ft$^2$) | 194 | 291 | 197 |
| Air Rate, SCF/T | 6,100 | 7,890 | 12,900 |
| Recycle Rate, SCF/T | 15,200 | 11,900 | 10,500 |
| Fischer Assay, Gal/Ton | 27.6 | 26.5 | 26.4 |
| Bed Height, Feet | 3 | 5 | 3 |
| **Operating Data** | | | |
| $\Delta$ P, Overall, Inches/Feet | 1.38 | 0.78 | -- |
| $\Delta$ P, Above Air Distr., In/Ft | 2.05 | 1.18 | -- |
| Offgas Temperature, ° F | 220 | 213 | 262 |
| **Yields** | | | |
| Oil, % Fischer Assay | 81.3 | 62.8 | 83.3 |
| Vent Gas, SCF/T | 7,820 | 9,200 | -- |
| $CO_2$ Decomposition, % | 43.2 | 10.9 | 40 |
| **Material Balances** | | | |
| Ash, % | 98 | 107 | -- |
| Overall, % | 99 | 102 | -- |
| Organic Carbon, % | 94 | 99 | -- |
| Water, % | 72 | 126 | -- |
| Gas Loss, SCF/T | -2,145 | 2,340 | -- |

HANDOUT 2 - RLM

RLMcGalliard
6/20/66




CLINKER FORMED ABOUT VERTICAL THERMOWELL DURING +8MESH -1/4" OPERATIONS IN RETORT NO.1.

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Summary Of Results For +8mesh - 1/4" Shale

# YIELDS: ~ 80% FA

# OPERABILITY: POOR

# CONCLUSION:

PROMISING BECAUSE OF PERIODS OF EXCELLENT SHALE FLOW AND REASONABLY GOOD YIELDS

PROBABLE CAUSE OF POOR OPERABILITY — MECHANICAL LIMITATIONS OF RETORT No. 1

# FUTURE STUDIES:

REHABILITATE & MODIFY RETORT No. 1

OR MODIFY RETORT No. 2

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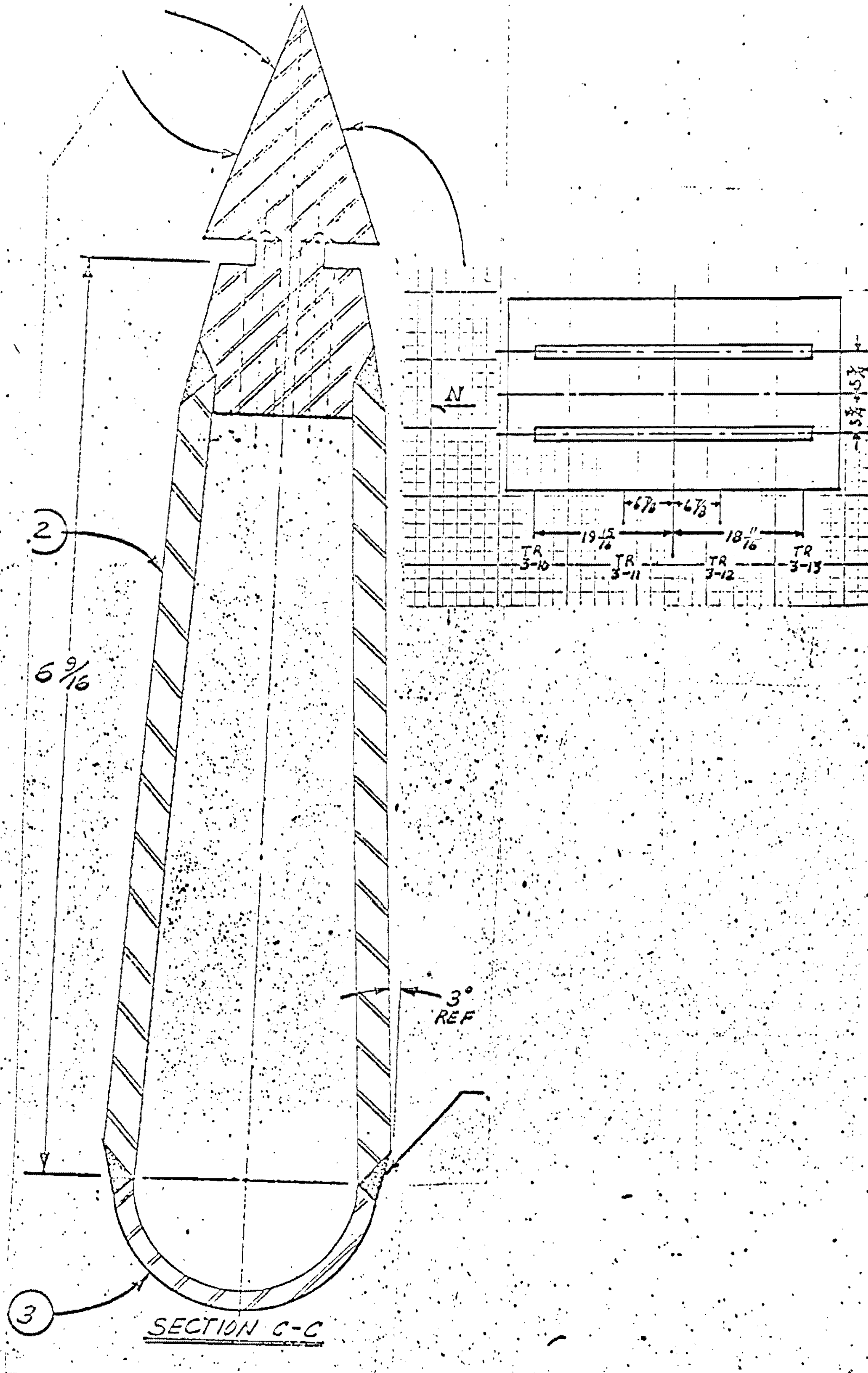
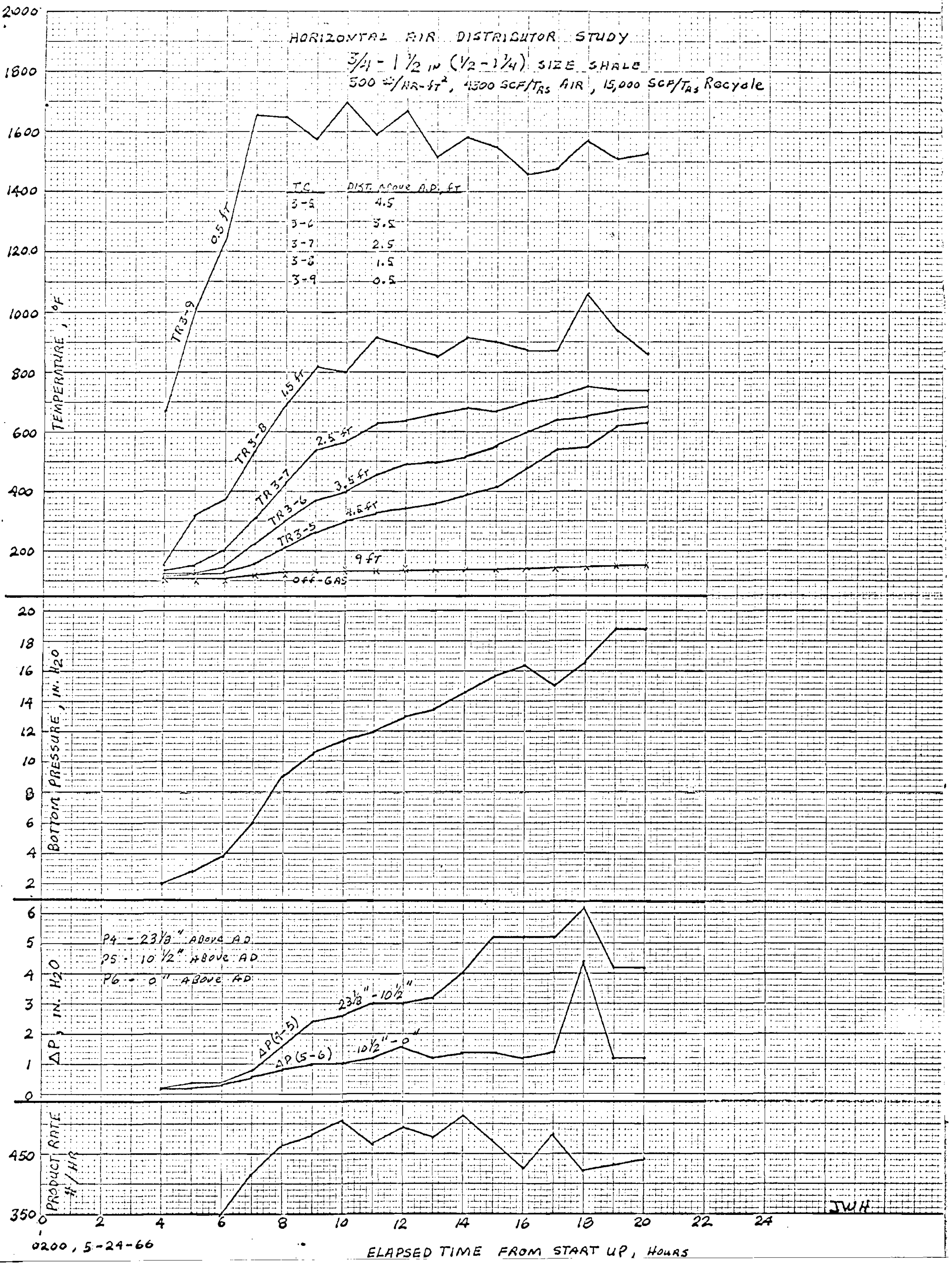
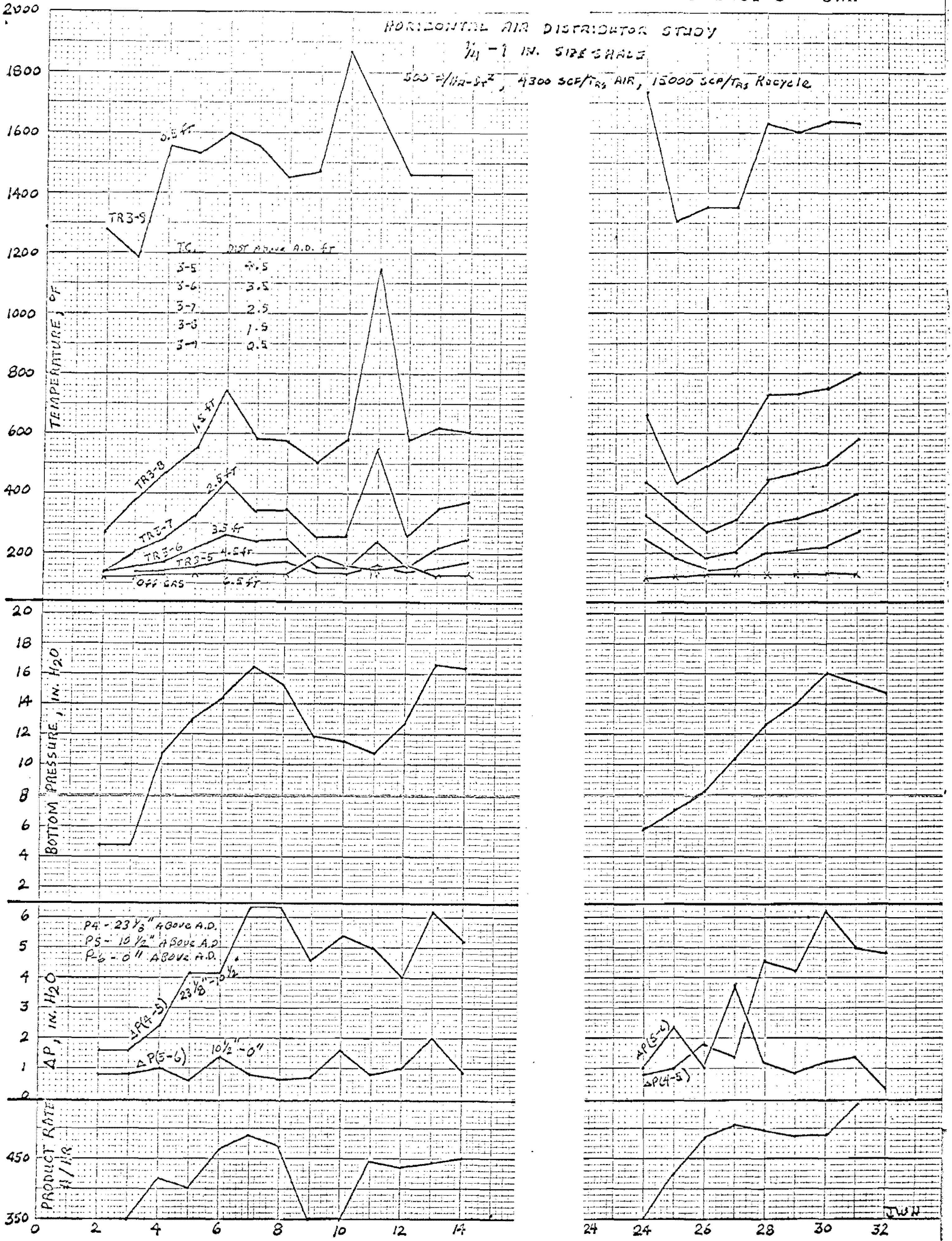
# HORIZONTAL AIR DISTRIBUTOR CROSS SECTION

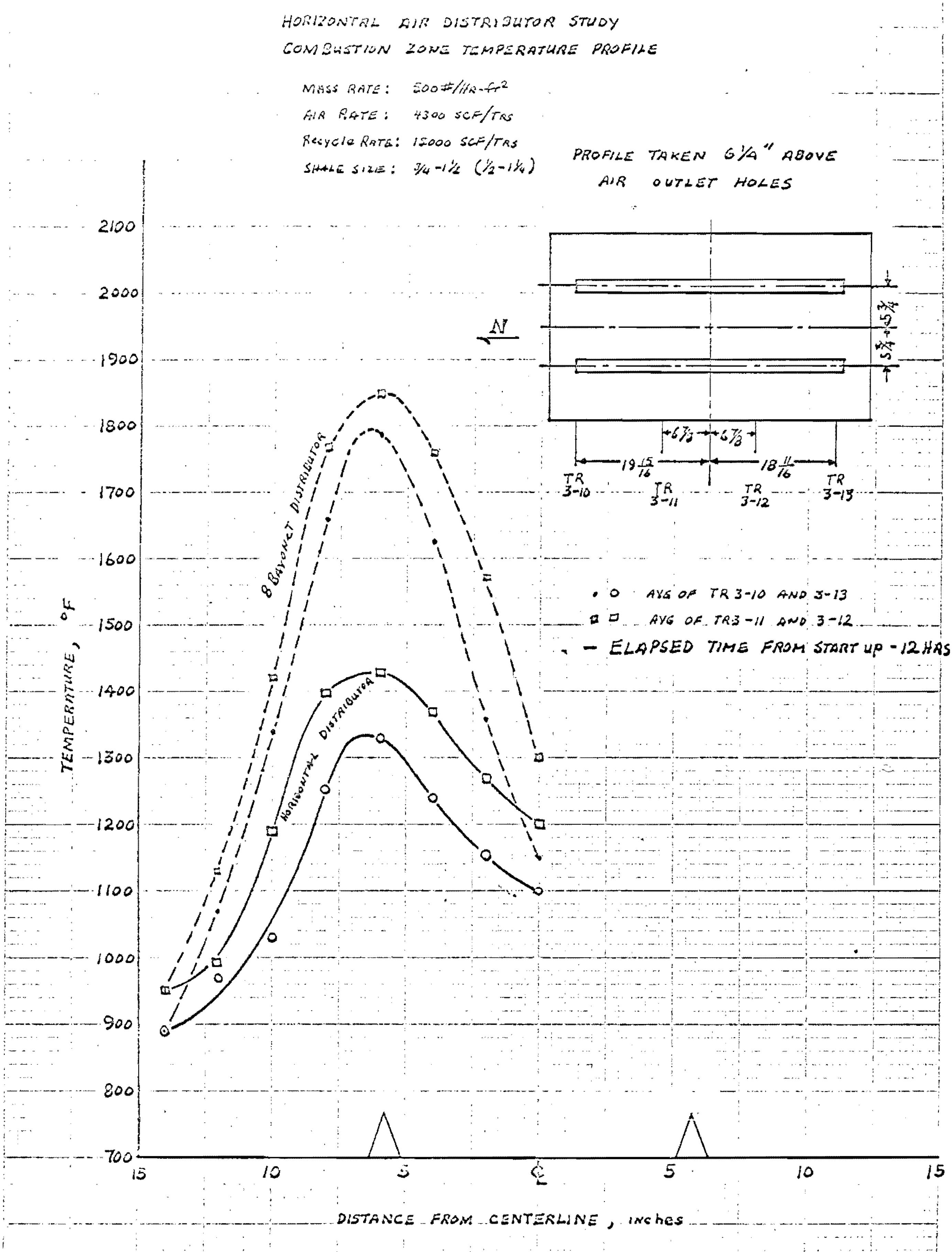





HORIZONTAL AIR DISTRIBUTOR STUDY
3/4 - 1 1/2 IN (1/2 - 1 1/4) SIZE SHALE
500 #/HR-FT², 4300 SCF/TRS AIR, 15,000 SCF/TRS Recycle
T.C. DIST. ABOVE A.D. FT
3-5 4.5
3-6 3.5
3-7 2.5
3-8 1.5
3-9 0.5
TR3-9 0.5 ft
TR3-8 1.5 ft
TR3-7 2.5 ft
TR3-6 3.5 ft
TR3-5 4.5 ft
9 ft
OFF-GAS
TEMPERATURE, °F
BOTTOM PRESSURE, IN. H2O
P4 - 23 1/8" ABOVE AD
P5 - 10 1/2" ABOVE AD
P6 - 0" ABOVE AD
ΔP(4-5) 23 1/8" - 10 1/2"
ΔP(5-6) 10 1/2" - 0"
ΔP, IN. H2O
PRODUCT RATE #/HR
JWH
0200, 5-24-66
ELAPSED TIME FROM START UP, HOURS


HORIZONTAL AIR DISTRIBUTOR STUDY
¼ - 1 IN. SIZE SHALE
500 #/HR-FT², 4300 SCF/TON AIR, 15000 SCF/TON Recycle
TEMPERATURE, °F
TR3-9
0.5 ft
TR3-8
1.5 ft
TR3-7
2.5 ft
TR3-6
3.5 ft
TR3-5
4.5 ft
OFF GAS
6.5 ft
T.C.
DIST ABOVE A.D. FT
3-5 4.5
3-6 3.5
3-7 2.5
3-8 1.5
3-9 0.5
BOTTOM PRESSURE, IN. H2O
ΔP, IN. H2O
P4 - 23 ⅞" ABOVE A.D.
P5 - 10 ½" ABOVE A.D.
P6 - 0" ABOVE A.D.
ΔP(4-5)
23 ⅞" - 10 ½"
ΔP(5-6)
10 ½" - 0"
PRODUCT RATE #/HR
JWH
ELAPSED TIME FROM START UP, HOURS

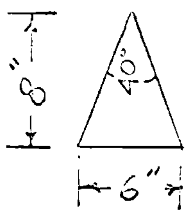
2300, 5-26-66


HORIZONTAL AIR DISTRIBUTOR STUDY
COMBUSTION ZONE TEMPERATURE PROFILE
MASS RATE: 500#/HR-FT²
AIR RATE: 4300 SCF/TRS
RECYCLE RATE: 15000 SCF/TRS
SHALE SIZE: 3/4-1 1/2 (1/2-1 1/4)
PROFILE TAKEN 6 1/4" ABOVE AIR OUTLET HOLES
N
5 3/4
5 3/4
6 7/8
6 7/8
19 15/16
18 11/16
TR 3-10
TR 3-11
TR 3-12
TR 3-13
8 BAYONET DISTRIBUTOR
HORIZONTAL DISTRIBUTOR
• ○ AVG OF TR 3-10 AND 3-13
□ AVG OF TR 3-11 AND 3-12
- ELAPSED TIME FROM START UP - 12 HRS
TEMPERATURE, °F
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
15
10
5
℄
5
10
15
DISTANCE FROM CENTERLINE, inches

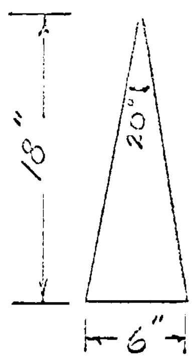
JWH

# RECYCLE DISTRIBUTOR SHAPES

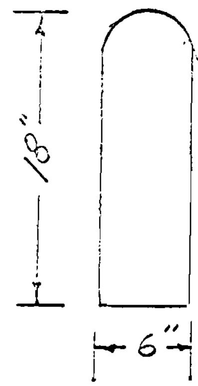
SHORT TRIANGLE



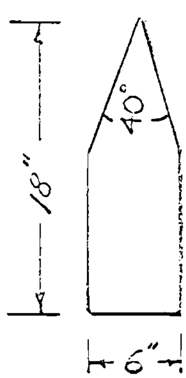

LONG TRIANGLE



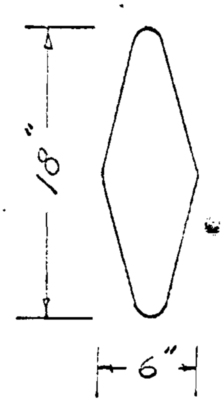

ROUND WITH VERTICAL SKIRTS




SHORT TRIANGLE WITH VERTICAL SKIRTS

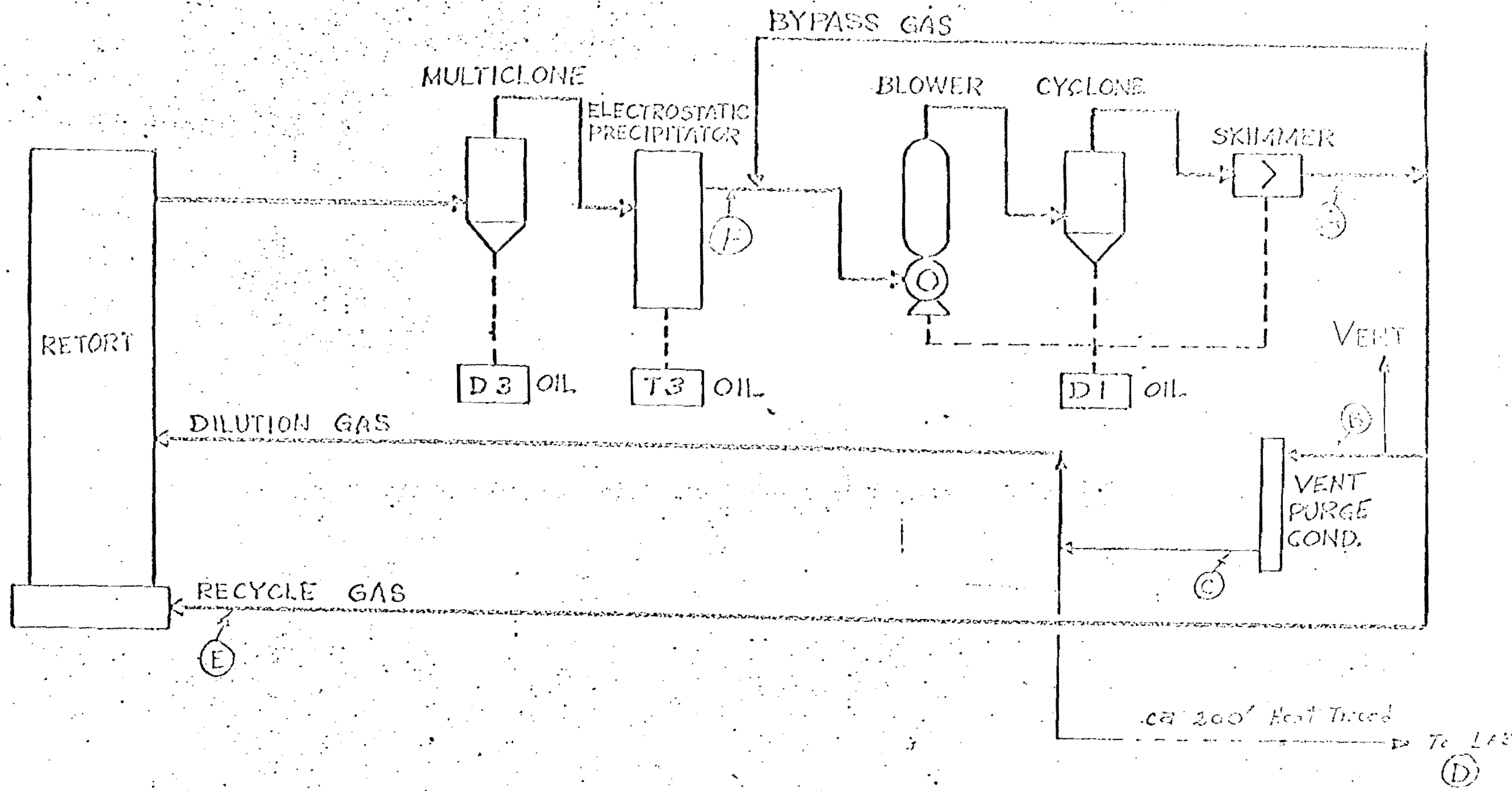



DIAMOND




NOTE: SHORT TRIANGLE IS NOT COMMERCIALLY FEASIBLE. IT WAS INCLUDED IN THIS STUDY TO COMPARE ELEMENT HEIGHT.

T C LYONS 5-66




NOTE: DISTANCE FROM A TO E IS ABOUT 30 FT

| NO. | DATE | PRINT ISSUED TO | ANVIL POINTS OIL SHALE RESEARCH CENTER RIFLE, COLO. PROJECT MANAGER-SOCONY MOBIL OIL CO., INC. | SCALE ~ | RETORT NO. 2 RECOVERY SYSTEM |
|---|---|---|---|---|---|
| | | | JOB NO. / CHARGE | DRAWN BY Joe Hamilton | |
| | | | | STARTED | |
| | | | | COMPLETED | |
| | | | APPROVED / PROCESS / DESIGN / SAFETY | DIMENS. CHECK | LOCATION / DRAWING NO. RE |

397 (8-58)

DIFFERENT PARTICLE SIZES, AND COMPOSITION OF SPENT SHALE

| Spent* Shale Layer | Min. $CO_2$ | | Ash | | Carbon | | Hydrogen | | Benz. Extr. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 19.4 | 19.2 | 77.5 | 77.8 | 8.00 | 8.07 | 0.26 | 0.25 | 0.07 | 0.05 | |
| 2 | 19.4 | 19.9 | 77.5 | 77.5 | 8.04 | 7.99 | 0.24 | 0.25 | 0.08 | 0.05 | |
| 3 | 19.6 | 20.0 | 77.6 | 77.7 | 8.10 | 7.98 | 0.24 | 0.24 | 0.09 | 0.07 | |
| 4 | 19.7 | 19.5 | 77.7 | 77.7 | 8.00 | 8.01 | 0.24 | 0.24 | 0.09 | 0.04 | |
| 5 | 19.4 | 19.9 | 77.7 | 77.6 | 8.22** | 8.13 | 0.26 | 0.25 | 0.18** | 0.07 | |
| 1 | 18.0** | 19.3 | 77.5 | 77.6 | 8.05 | 8.08 | 0.21 | 0.26 | 0.05 | -- | |
| 2 | 19.5 | 19.6 | 77.6 | 77.5 | 8.05 | 8.04 | 0.22 | 0.22 | 0.06 | 0.05 | |
| 3 | 19.2 | 19.2 | 77.6 | 77.6 | 7.98 | 8.08 | 0.26 | 0.24 | 0.05 | 0.05 | |
| 4 | 19.4 | 19.2 | 77.7 | 77.6 | 8.03 | 8.95** | 0.26 | 0.30 | 0.03 | 0.06 | |
| 5 | 19.3 | 19.4 | 77.7 | 77.7 | 8.07 | 8.19 | 0.26 | 0.23 | 0.03 | 0.05 | |
| 1 | 19.2 | 19.3 | 77.9 | 77.5 | 8.40** | 8.16 | 0.25 | 0.21 | -- | -- | |
| 2 | 19.4 | 19.3 | 77.7 | 77.8 | 7.65** | 8.12 | 0.26 | 0.26 | 0.13 | 0.08 | |
| 3 | 19.3 | 19.4 | 77.7 | 77.6 | 8.14 | 8.08 | 0.25 | 0.26 | 0.06 | 0.07 | |
| 4 | 19.3 | 19.2 | 77.8 | 77.8 | 8.10 | 8.12 | 0.27 | 0.28 | 0.06 | 0.06 | |
| 5 | 19.4 | 19.4 | 77.7 | 77.8 | 8.20 | 8.12 | 0.26 | 0.28 | 0.06 | 0.07 | |
| 1 | 19.1 | 19.1 | 78.2 | 78.0 | 8.06 | 7.96 | 0.24 | 0.18 | 0.07 | 0.10 | |
| 2 | 19.2 | 19.2 | 78.1 | 78.2 | 7.89 | 7.91 | 0.25 | 0.18 | 0.06 | 0.07 | |
| 3 | 19.2 | 19.3 | 78.3 | 78.2 | 7.94 | 7.99 | 0.25 | 0.25 | 0.06 | 0.06 | |
| 4 | 19.2 | 19.0 | 78.3 | 78.2 | 7.92 | 7.98 | 0.25 | 0.24 | 0.05 | 0.04 | |
| 5 | 19.1 | 19.2 | 78.1 | 78.3 | 7.99 | 8.00 | 0.25 | 0.23 | 0.06 | 0.05 | |
| | 17.3 | | 68.0 | | 16.6 | | 1.74 | | 1.56 | | 0.15% Wt Moisture |

uality Control)

DLiederman
5/26/66

RESULTS ON FISCHER ASSAY OF

| Through Mesh Size | FA Oil Gal/Ton | Oil Gravity 60/60 F | Water Wt % | Gas+Loss Wt % |
|---|---|---|---|---|
| 8 | 26.6 | 0.917 | 1.2 | 2.2 |
| | 26.8 | 0.916 | 1.3 | 2.1 |
| 20 | 26.3 | 0.912 | 1.3 | 2.0 |
| | 26.1 | 0.914 | 1.3 | 1.9 |
| 35 | 26.4 | 0.916 | 1.4 | 1.9 |
| | 26.5 | 0.913 | 1.4 | 1.9 |
| 65 | 26.2 | 0.913 | 1.3 | 2.2 |
| | 26.0 | 0.914 | 1.4 | 2.3 |
| 8 | Raw Shale | | | |

*Layer 1 is the top fifth, 2 the next lower, etc.
**Questionable data.

Note: The shale used was QC-FA-2 (Fischer Assay

# RESULTS ON FISCHER ASSAY OF DIFFERENT PARTICLE SIZES

| Through Mesh Size | Fischer Assay Oil, Gal/Ton | | | | % Loss of -8 Mesh QC-FA-4 With Pulverizing to Mesh Size Noted |
|---|---|---|---|---|---|
| | QC-FA-2 | | QC-FA-4 | | |
| 8 | 27.4<br>27.7 | (27.55) | 27.9<br>28.2 | (28.05) | -- |
| 20 | 26.4<br>26.8 | (26.60) | --<br>-- | | -- |
| 65 | 27.0<br>27.6 | (27.30) | 27.5<br>27.6 | (27.55) | 6.8 |
| 100 | 26.7<br>26.5 | (26.60) | 27.3<br>27.6 | (27.45) | 9.6 |

( ) Average

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6/20/66

WATER BY READING CENTRIFUGE VOLUMES VERSUS BY DISTILLATION

| Sample | Water, ml: Original Reading | Water, ml: By Distillation |
|---|---|---|
| 1 | 1.30 | 1.30 |
| 2 | 1.30 | 1.25 |
| 3 | 1.28 | 1.22 |
| 4 | 1.25 | 1.33 |
| 5 | 1.30 | 1.33 |
| 6 | 1.28 | 1.30 |
| 7 | 1.25 | 1.23 |
| 8 | 1.20 | 1.20 |
| 9 | 1.22 | 1.20 |
| 10 | 1.20 | 1.17 |
| 11 | 1.30 | 1.31 |
| 12 | 1.22 | 1.25 |
| | Av. 1.258 | Av. 1.258 |

DLiederman
5/27/66

# RESULTS OF COOPERATIVE PROGRAM BETWEEN LARAMIE AND ANVIL POINTS ON FISCHER ASSAY (5/66)

| | | FA Oil gal/ton | SG g/ml | $H_2O$ Wt % | Oil Wt % | $H_2O$ + Oil Wt % | Spent Shale Wt % | Gas + Loss Wt % |
|---|---|---|---|---|---|---|---|---|
| Anvil Points | 1 | 26.7 | 0.925 | 1.2 | 10.3 | 11.5 | 86.4 | 2.1 |
| | 2 | 26.6 | 0.920 | 1.3 | 10.2 | 11.5 | 86.3 | 2.2 |
| | 3 | 26.4 | 0.922 | 1.2 | 10.2 | 11.4 | 86.4 | 2.2 |
| | 4 | 26.8 | 0.925 | 1.3 | 10.4 | 11.7 | 86.4 | 1.9 |
| | 5 | 26.7 | 0.920 | 1.3 | 10.3 | 11.6 | 86.5 | 1.9 |
| | 6 | 26.9 | 0.923 | 1.3 | 10.3 | 11.6 | 86.3 | 2.1 |
| | Averages | 26.78 | 0.922 | 1.25 | 10.28 | 11.55 | 86.38 | 2.07 |
| | SD | 0.17 | 0.0023 | 0.055 | 0.074 | 0.105 | 0.075 | 0.137 |
| Laramie | 7 | 26.7 | 0.916 | 1.2 | 10.2 | 11.4 | 86.2 | 2.4 |
| | 8 | 26.9 | 0.915 | 1.0 | 10.3 | 11.3 | 86.7 | 2.0 |
| | 9 | 26.7 | 0.915 | 1.1 | 10.2 | 11.4 | 86.6 | 2.1 |
| | 10 | 26.5 | 0.915 | 1.0 | 10.1 | 11.1 | 86.4 | 2.5 |
| | 11 | 27.5 | 0.913 | 1.2 | 10.5 | 11.7 | 86.0 | 2.3 |
| | 12 | 27.5 | 0.913 | 1.0 | 10.5 | 11.5 | 86.1 | 2.4 |
| | Averages | 26.97 | 0.914 | 1.08 | 10.30 | 11.40 | 86.33 | 2.28 |
| | SD | 0.43 | 0.0013 | 0.099 | 0.167 | 0.200 | 0.280 | 0.194 |
| Difference in Averages - Laramie Minus Anvil Points | | 0.29 | -0.008 | -0.17 | 0.02 | -0.15 | -0.05 | 0.21 |
| Calculated "t" Value | | 1.53 | 7.3 | 3.7 | 0.26 | 1.62 | 0.42 | 2.16 |
| 5% Critical "t" Value (10DF) | = | 2.23 | | | | | | |
| 1% Critical "t" Value (10DF) | = | 3.17 | | | | | | |

DLiederman
6/3/66

# RECYCLE GAS ANALYSIS

Comparison of Organic Materials From 0° and -78° C Baths
(Analyses By Mobil's Paulsboro Labs)

## °Carbon Type Distribution

| | Weight % | |
|---|---|---|
| | 0° C | -78° C |
| Paraffins | 38.2 | 37.3 |
| Olefins | 48.5 | 47.8 |
| Aromatics | 13.3 | 14.8 |
| Totals | 100.0 | 99.9 |

## °Aromatics Carbon Distribution

| | Weight % | |
|---|---|---|
| | 0° C | -78° C |
| $C_6$ | 1.1 | 6.0 |
| $C_7$ | 1.7 | 3.0 |
| $C_8$ | 2.9 | 1.0 |
| $C_9$ | 2.4 | 0.4 |
| $C_{10}$ | 1.1 | 0.2 |
| $C_{11}$ | 0.6 | -- |
| $C_{12}$ | 0.3 | -- |
| $C_{13}$ | 0.1 | -- |
| Naphthalenes | 0.8 | 4.2 |
| Indanes, Tetralins | 2.5 | -- |

## °Carbon Number Distribution

| | Paraffins Weight % | | Total Hydrocarbons |
|---|---|---|---|
| | 0° C | -78° C | -78° C |
| $C_2$ | | 0.03 | 0.03 |
| $C_3$ | | 0.1 | 0.3 |
| $C_4$ | | 1.3 | 5.8 |

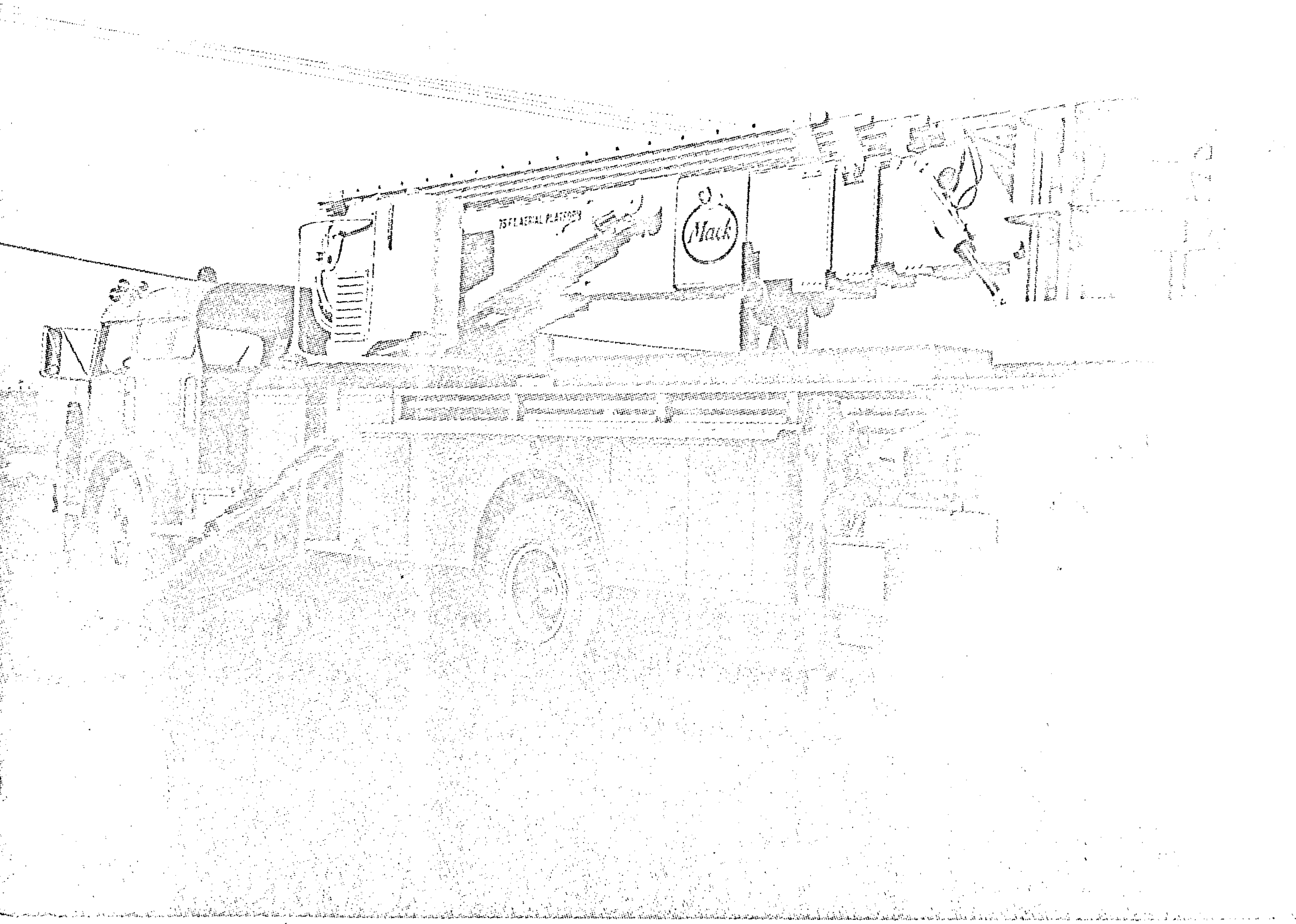
| | | | |
|---|---|---|---|
| $C_5$ | 1.2 | 6.9 | 14.1 |
| $C_6$ | 1.6 | 15.1 | 31.3 |
| $C_7$ | 1.9 | 6.5 | 19.2 |
| $C_8$ | 3.8 | 4.5 | 9.9 |
| $C_9$ | 10.4 | 1.9 | 2.3 |
| $C_{10}$ | 5.1 | 0.8 | 0.9 |
| $C_{11}$ | 2.8 | 0.3 | 0.3 |
| $C_{12}$ | 1.2 | | |
| $C_{13}$ | 0.6 | | |

RBernheimer
6/23/66

TRUCO-DENVER

DIVISION OF
EATON METAL PRODUCTS CO.

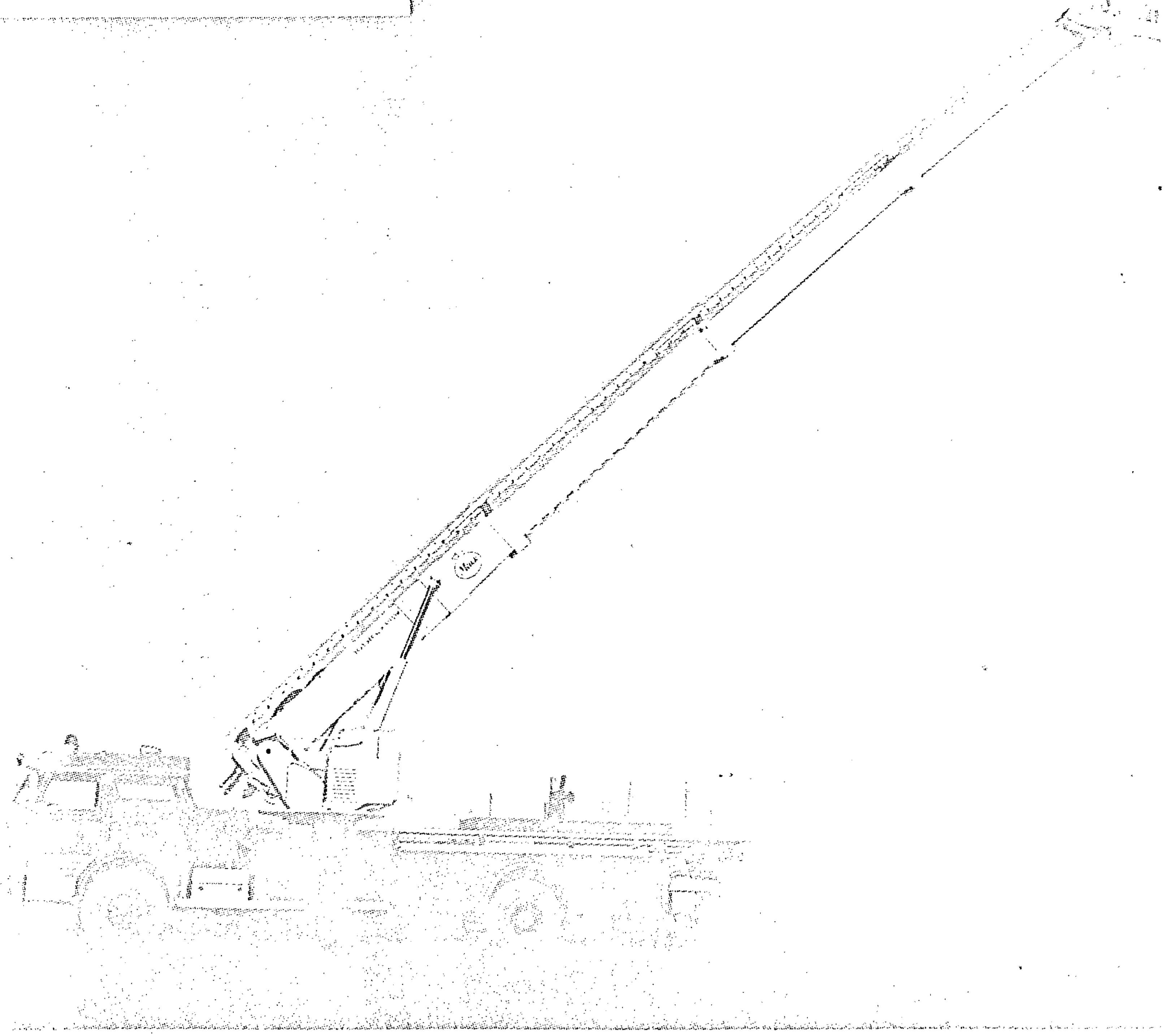
490 [illegible] Street
825-7204 • Area Code 303
DENVER, COLORADO




HANDOUT 2 - GPH

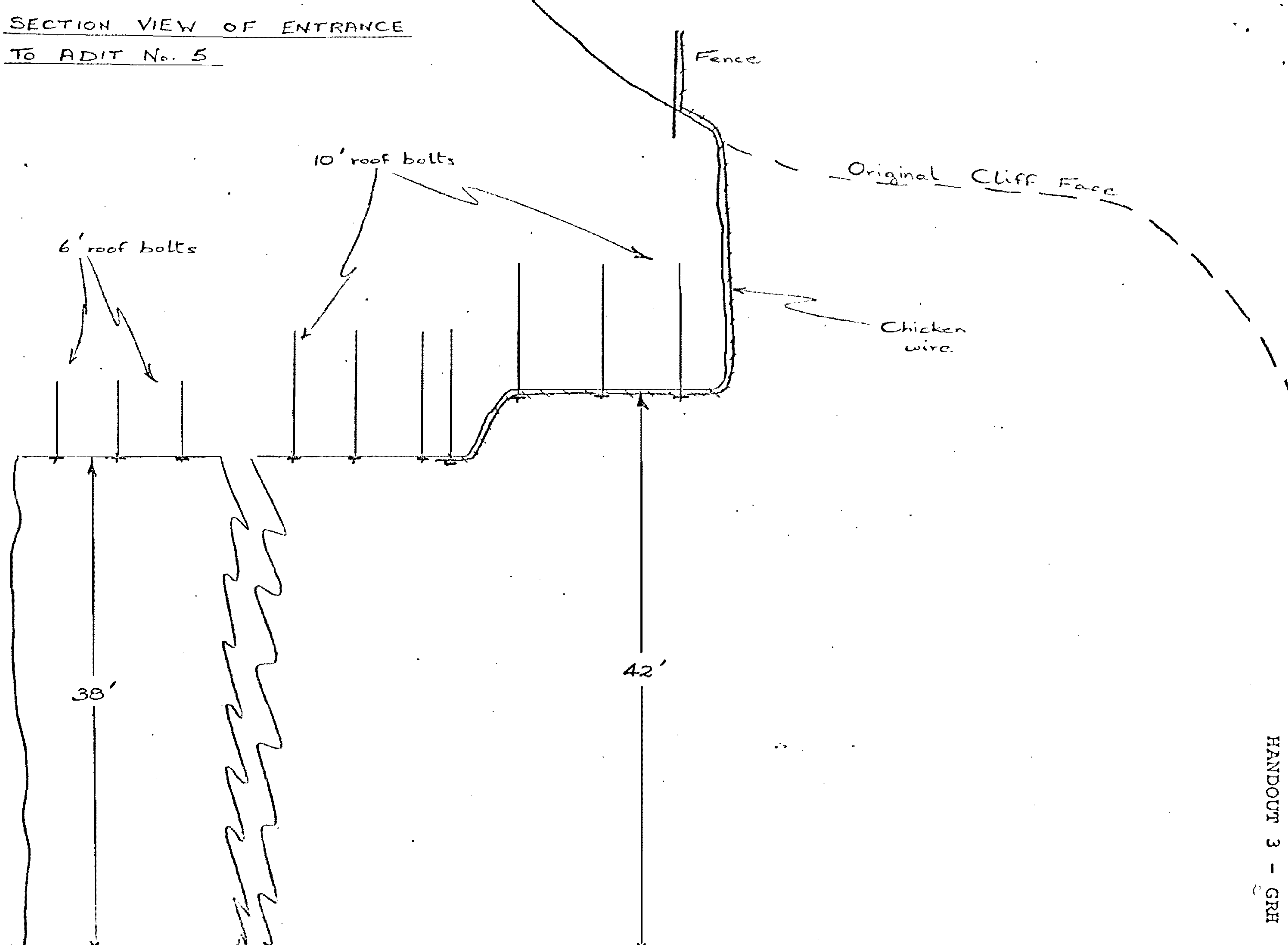
T..JCO-DENVER
DIVISION OF
EATON METAL PRODUCTS CO.

4800 York Street
825-7204 • Area Code 303
DENVER, COLORADO



HANDOUT 2A - GRH

SECTION VIEW OF ENTRANCE
TO ADIT No. 5

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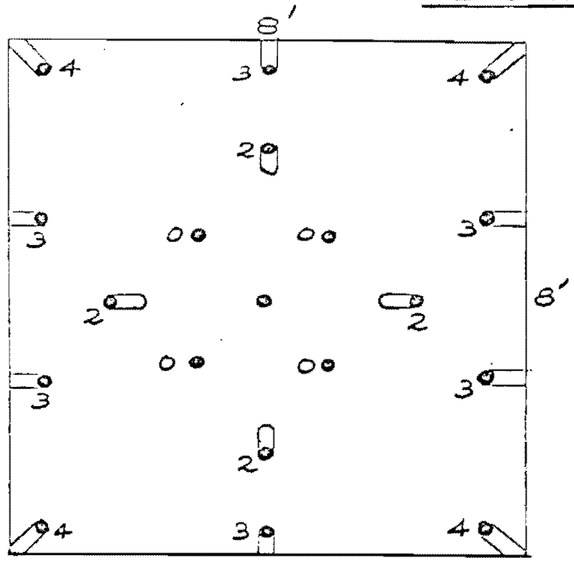
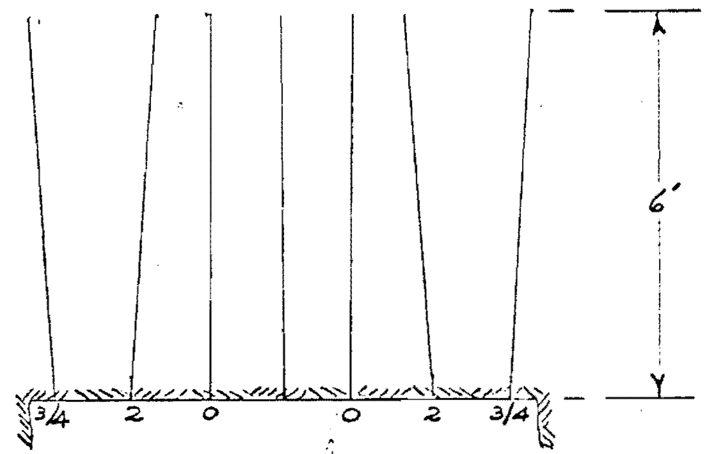
HANDOUT 3 - GRH

# DRILL ROUNDS USED IN VENTILATION CROSSCUT

## BURN CUT

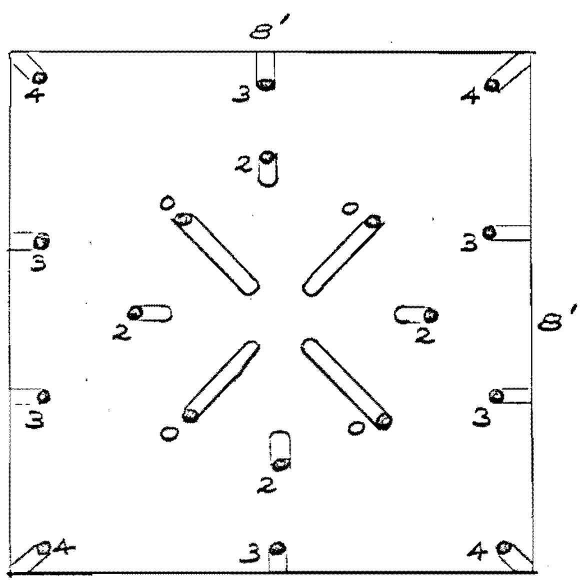



Face View

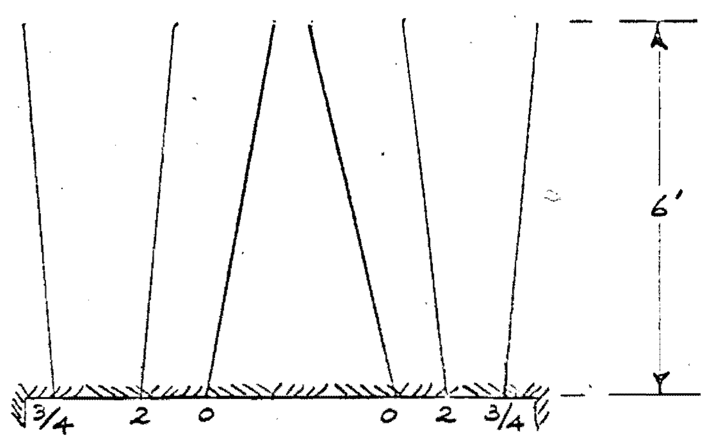



Plan View

## PYRAMID CUT




Face View




Plan View

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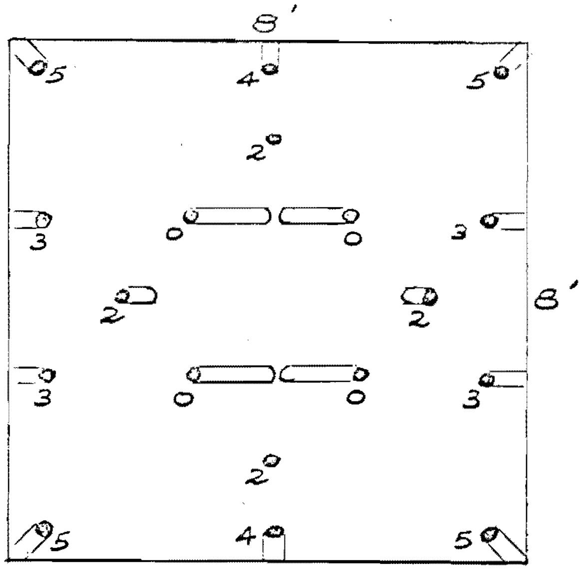
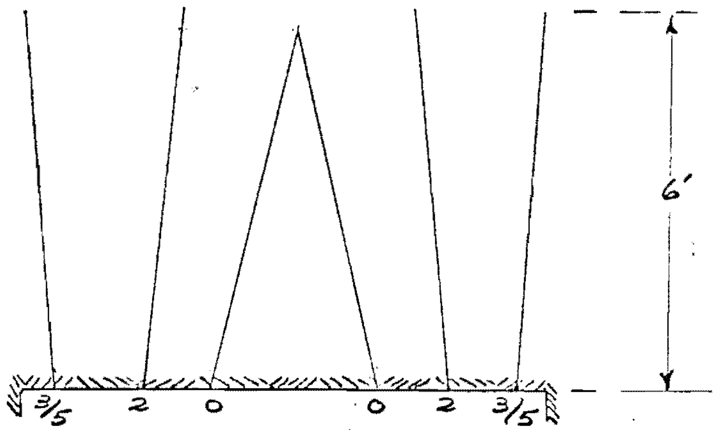
## 4 HOLE V - CUT

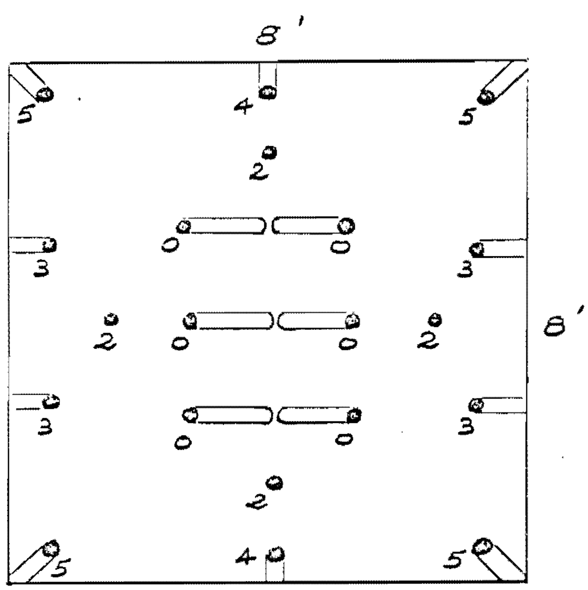



Face View

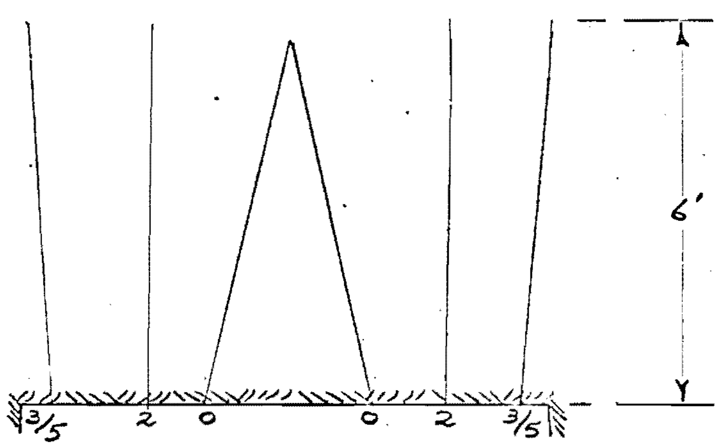



Plan View

## 6 HOLE V-CUT




Face View




Plan View

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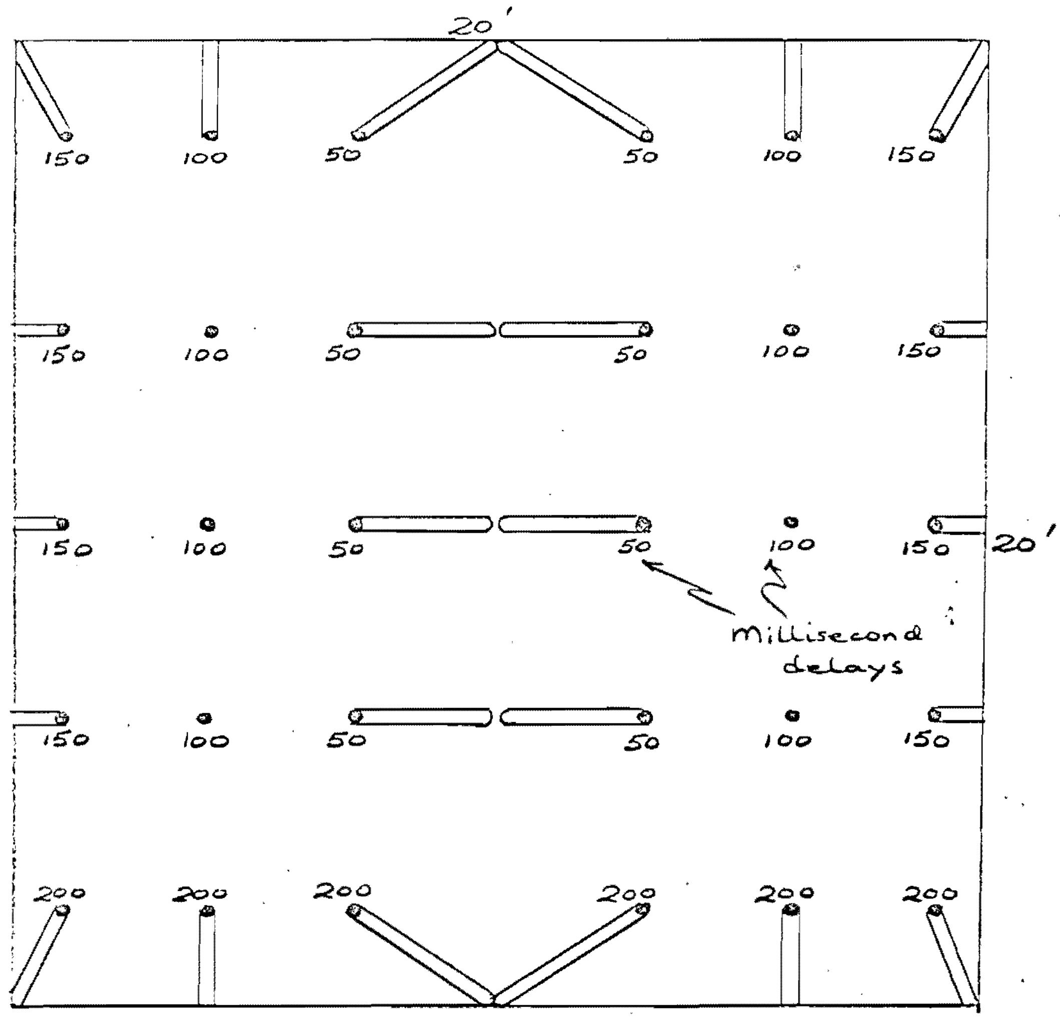
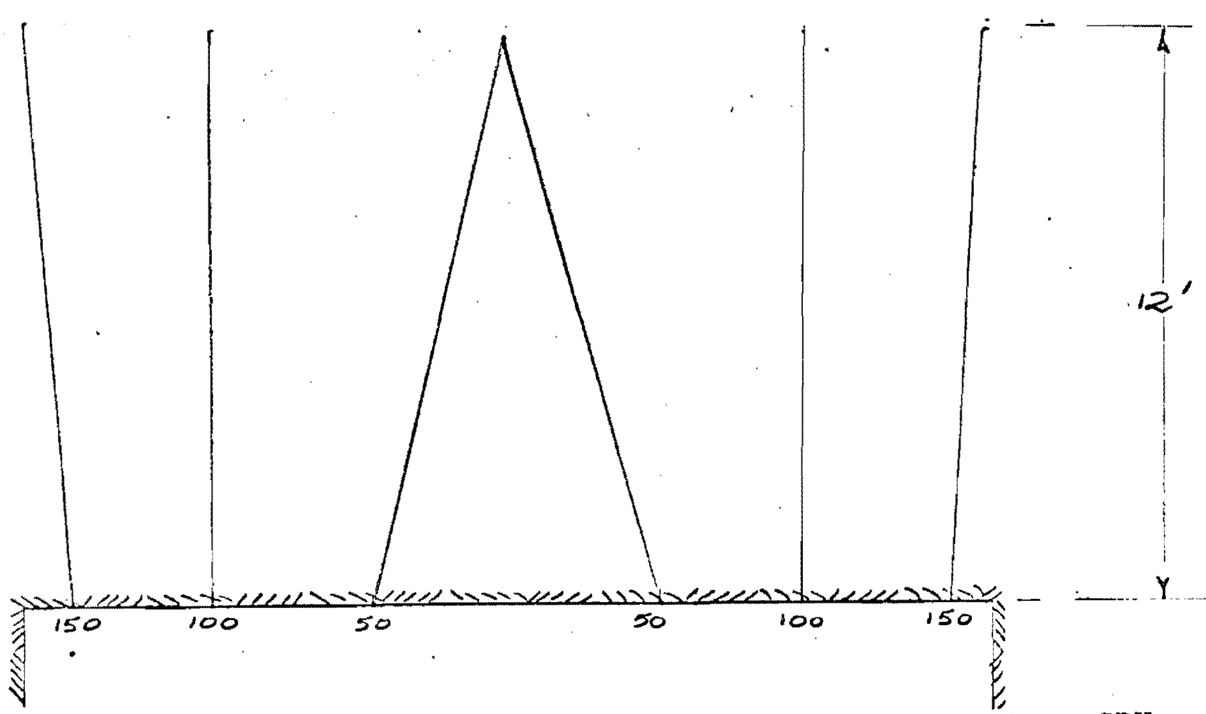
# V-Cut Round Being Tried in Haulage Ramp




Face View




Plan View

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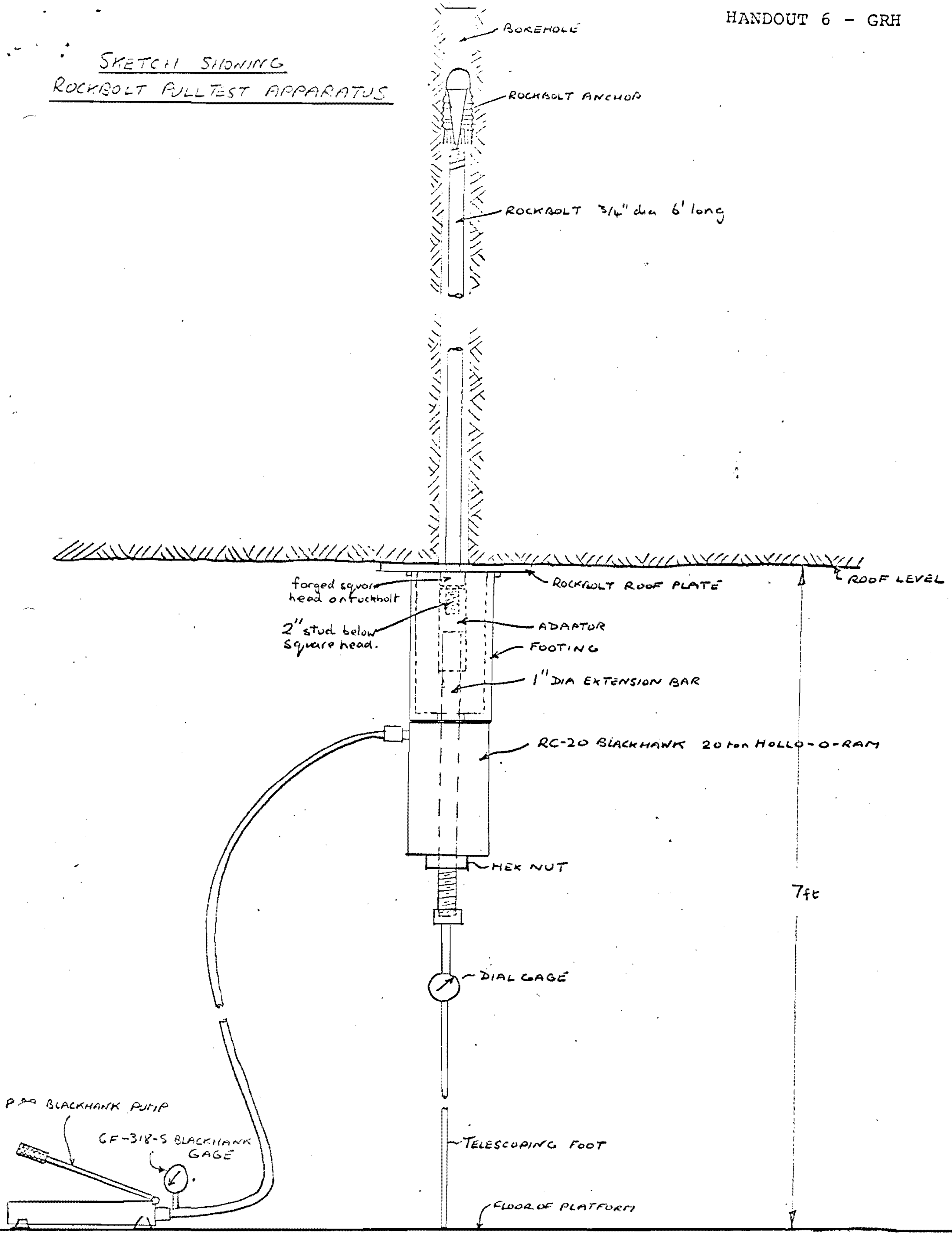
SKETCH SHOWING ROCKBOLT PULLTEST APPARATUS

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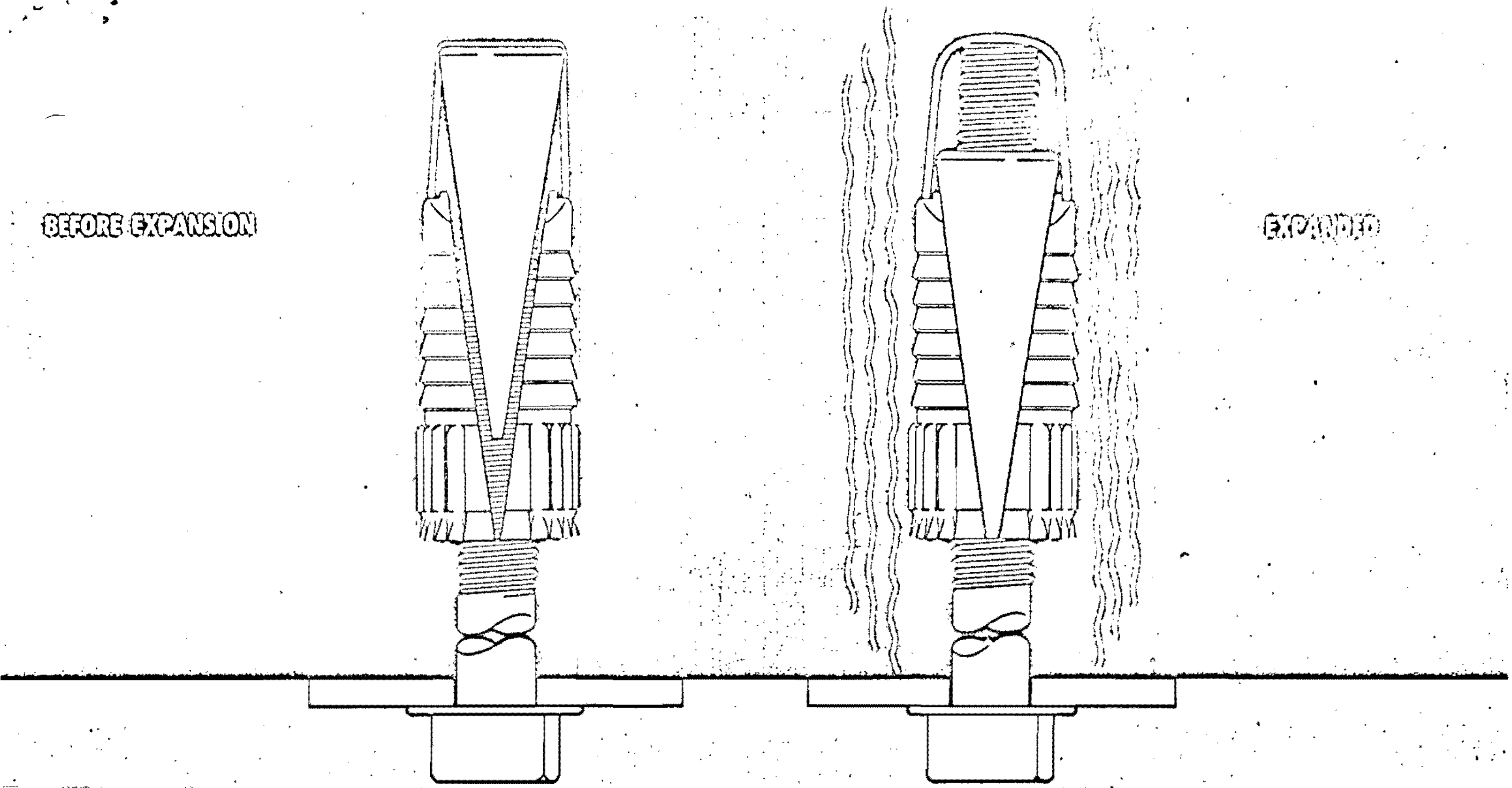
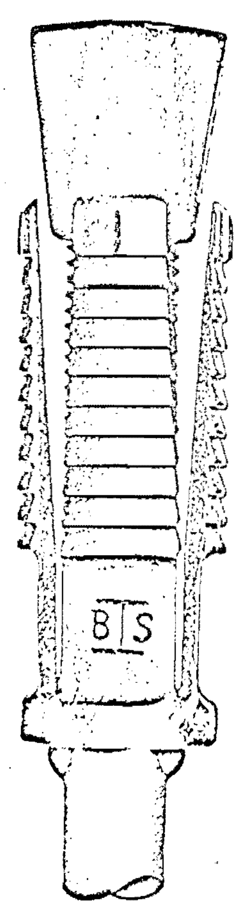
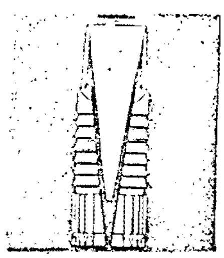
D I SHELL

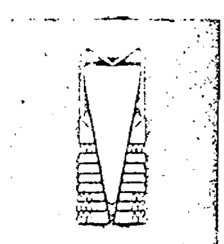


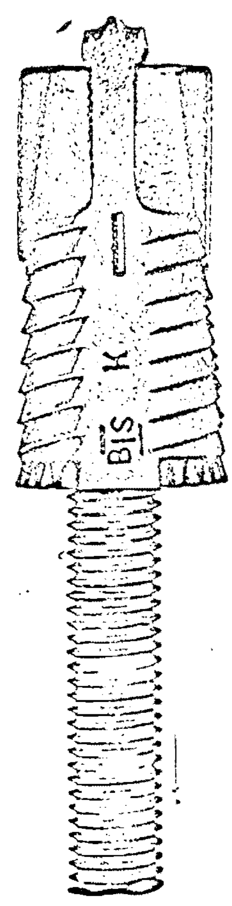
'C' SHELL



D-1 SHELL



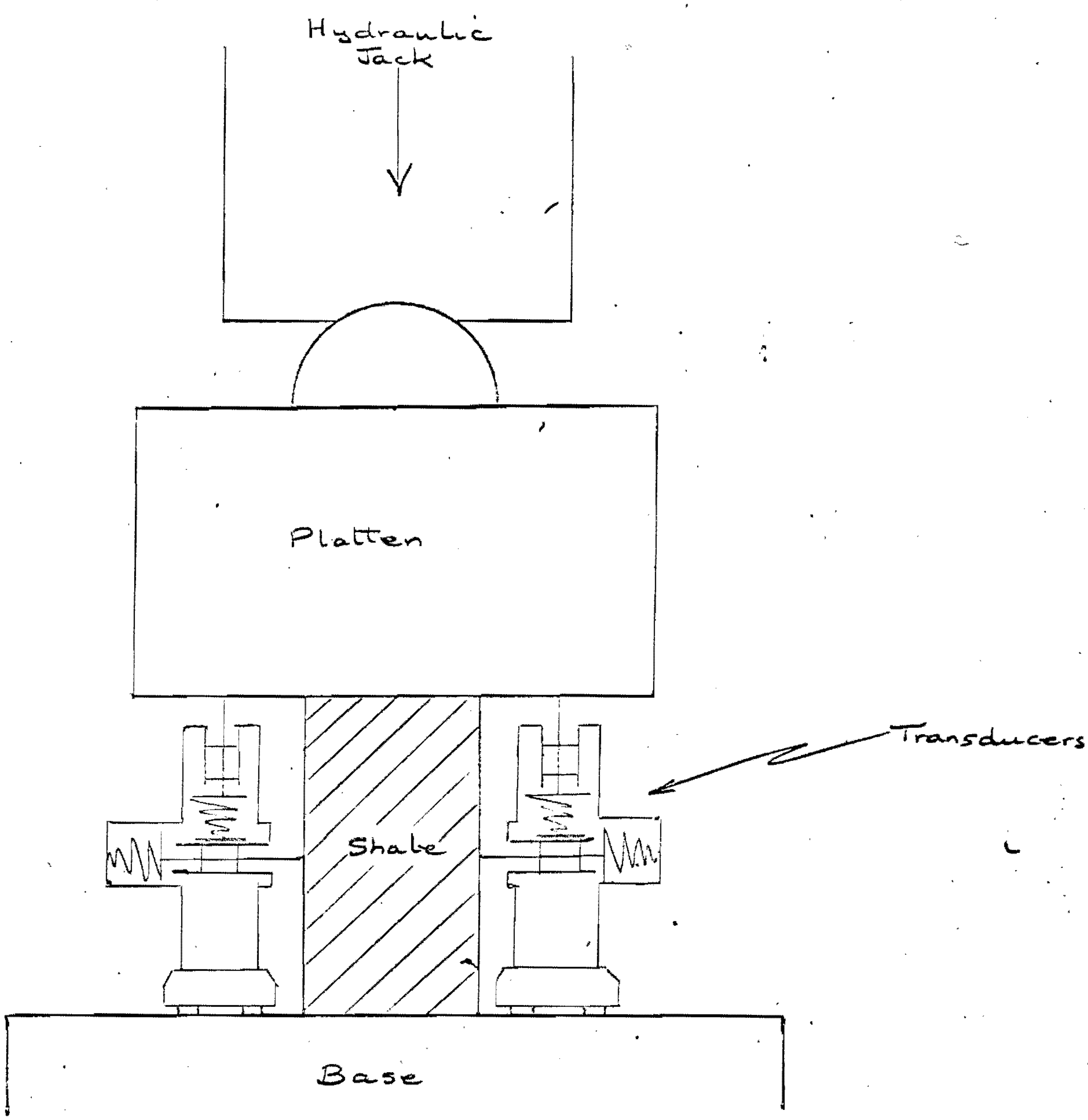
D-3 SHELL



K SHELL

THE FOUR TYPES OF EXPANSION SHELLS USED IN THE PULL TESTS

TYPICAL ROCK LOADING EQUIPMENT WITH INSTRUMENTATION FOR MEASURING STRAINS

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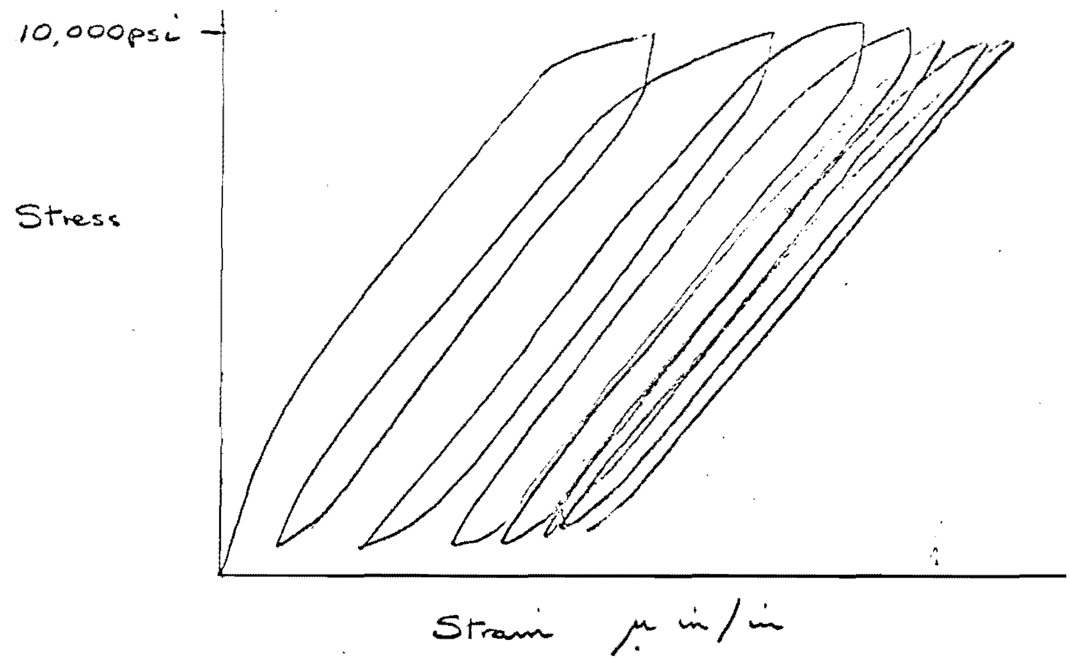
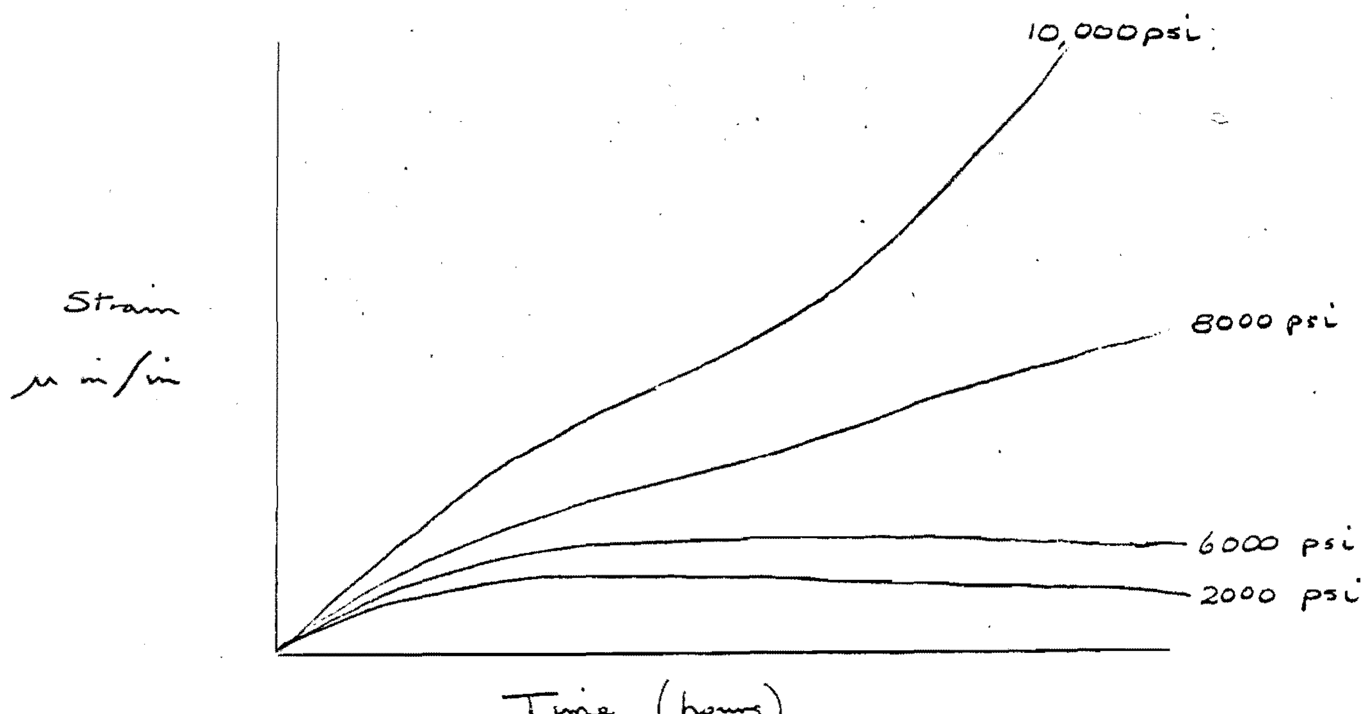
HANDOUT 9 - GRH

# TYPICAL STRESS / STRAIN CURVES




Elastic Properties




Plastic Properties

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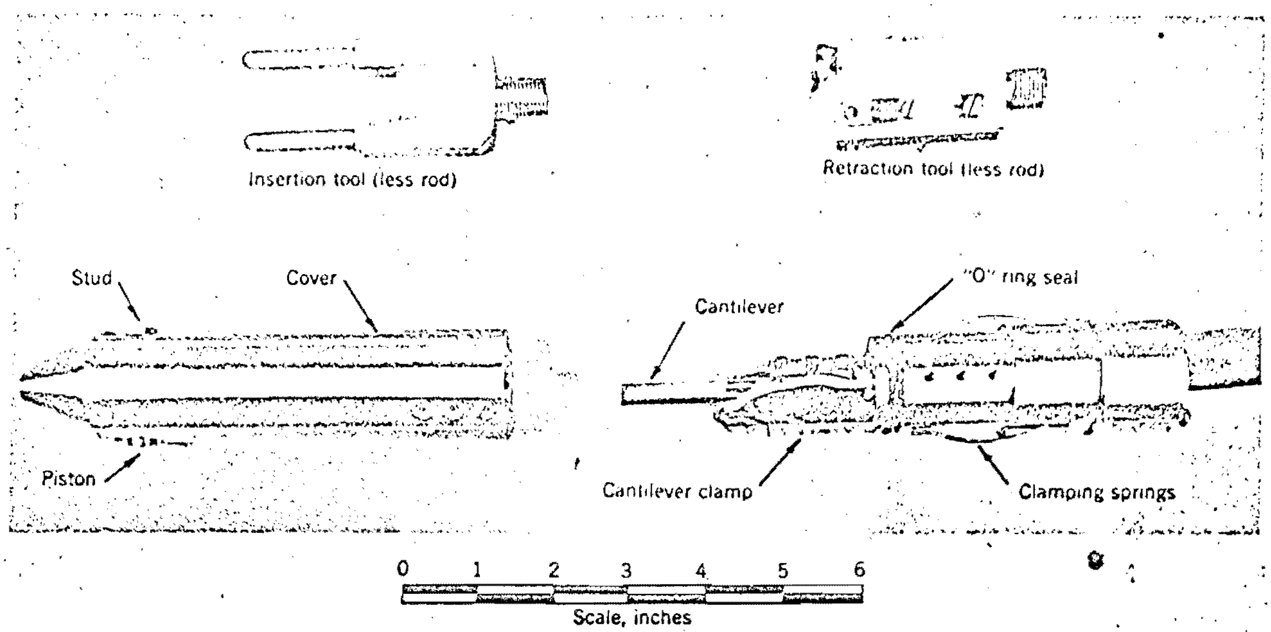


FIGURE 1. - Exploded Photograph of Borehole Gage.

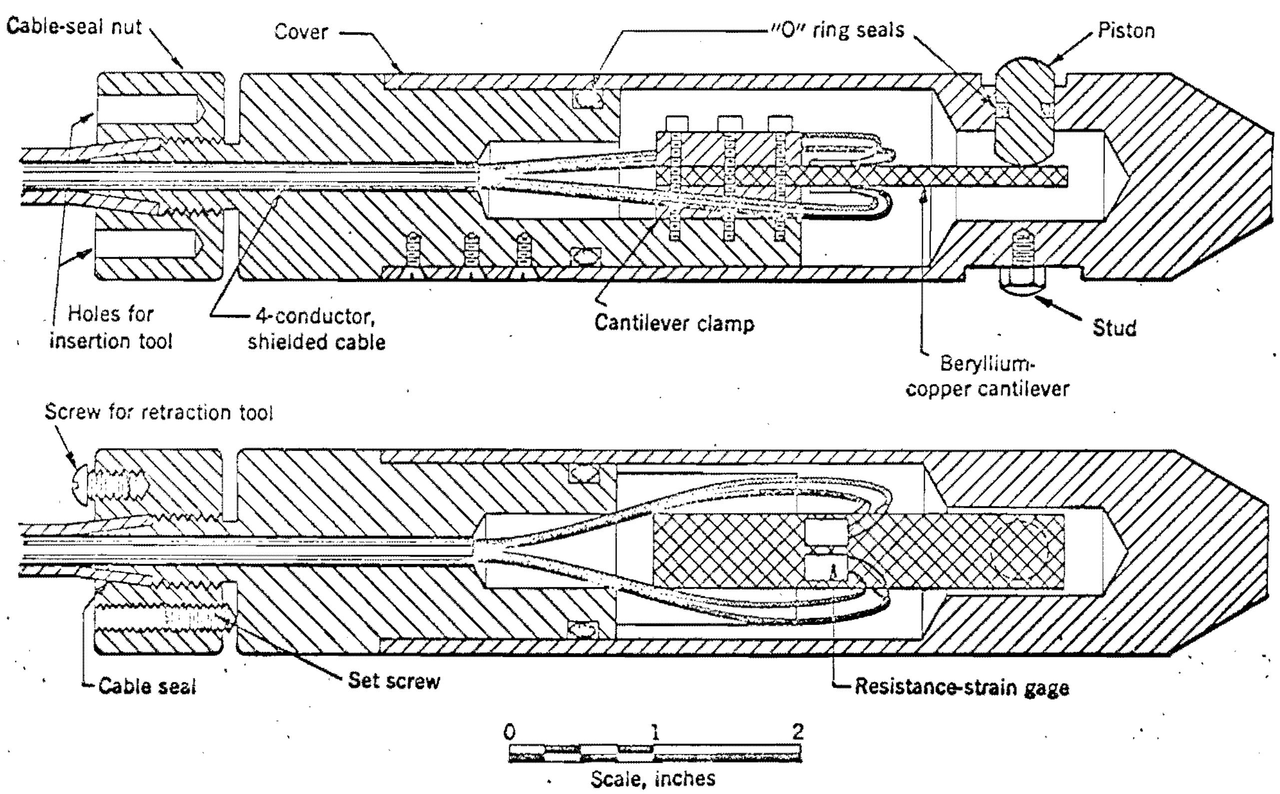


FIGURE 2. - Sections of Borehole Gage.

RETORT NO. 3 - ESTIMATED EXPENDITURES TO JUNE 22, 1966

| | Engineering | | | Construction | | | Procurement | | |
|---|---|---|---|---|---|---|---|---|---|
| | Est. Cost | Est. Exp. to Date | Comp. | Est. Cost | Est. Exp. to Date | Est. % Comp. | Est. Cost | Est. Commit to Date | Est. % Comp. |
| 1. Crusher, Storage | 7,460 | 5,000 | 75 | 40,979 | 3,000 | 10 | 44,562 | 25,000 | 60 |
| 2. Shale Control, Instrumentation | 7,999 | 7,000 | 75 | 33,650 | 2,000 | 5 | 74,200 | 22,000 | 30 |
| 3. Piping, Retort | 15,532 | 8,000 | 50 | 70,961 | 10,000 | 15 | 162,728 | 80,000 | 50 |
| 4. Spent Shale, Product | 12,388 | 3,000 | 25 | 30,666 | 1,000 | 5 | 48,808 | 5,000 | 10 |
| 5. Demolition, Utilities, Equipment Rental | 4,052 | 3,100 | 75 | 29,430 | 5,000 | 15 | 10,800 | 6,500 | 70 |
| 6. Supervision General Exp. | 26,610 | 10,000 | | 15,932 | 6,000 | | 5,100 | 1,500 | |
| Sub Total | 74,041 | 36,100 | | 221,618 | 27,000 | | 346,197 | 140,000 | |
| Fee | 5,180 | 2,520 | | 15,530 | 1,890 | | 24,200 | 9,800 | |
| Totals | 79,221 | 38,620 | | 237,148 | 28,890 | | 370,397 | 149,800 | |

Total Estimated Expenditures - to Date $217,000

Estimated Total Expenditure - Completed Job $686,700

WSBergen
6/21/66