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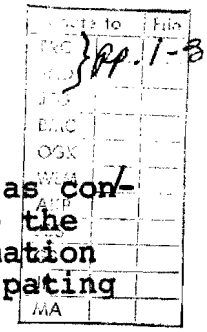

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MOBIL RESEARCH AND DEVELOPMENT CORPORATION

RESEARCH DEPARTMENT

TECHNICAL MEMORANDUM NO. 67-27

PRIMARY CRUSHER TEST WITH A TOOTH TYPE, SINGLE ROLL CRUSHER

ANVIL POINTS OIL SHALE RESEARCH CENTER

Rifle, Colorado

October 5, 1967

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Approval:

R H Cramer

R. H. Cramer
Program Manager

C. to JCK-LWRB

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

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

[1] Mobil Research and Development Corporation, Project Manager

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

PRIMARY CRUSHER TEST WITH A TOOTH TYPE, SINGLE ROLL CRUSHER

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PRIMARY CRUSHER TEST WITH A TOOTH TYPE, SINGLE ROLL CRUSHER

I. INTRODUCTION

The program for Stage II called for a crushing research study to develop basic data and demonstrate various types of crushers. To this end, Allis-Chalmers recommended a commercial crushing sequence of a single roll, tooth type primary crusher followed by a double roll, tooth type secondary crusher. Basic data and demonstration of the secondary crusher was to be obtained from a test machine loaned to Anvil Points by Allis-Chalmers. However, it was necessary to arrange an offsite test of a primary crusher to meet the goals of the crushing research program.

Consequently, Allis-Chalmers arranged for a test in which 200 tons of 6"+(1) oil shale was crushed in a 36 inch diameter by 60 inch single roll, tooth type crusher. The test was performed January 21, 1967 at a plant owned by Camp Concrete Rock Company and located outside of Brooksville, Florida. The following people conducted or observed the test:

R. D. Manninen - Allis-Chalmers
R. J. Pollak - Allis-Chalmers
H. W. Winter - Allis-Chalmers
R. D. Pryor - Phillips Petroleum Company
R. A. Reitz - Anvil Points Staff

Also on hand were Camp Concrete personnel who supervised and operated the installation.

The primary crushing test is also described in a report issued by Allis-Chalmers and entitled "Crushing Research Program on Oil Shale for Anvil Points Oil Shale Research Center." This Technical Memorandum has been issued to report the views of the Anvil Points Staff Observer for the test on the applicability of the single roll crusher to oil shale, as well as to present a complete set of technical data on the test.

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(1) Rock sizes are designated throughout this memorandum as the dimension of a side of the square opening used for sizing.

II. SUMMARY

The Allis-Chalmers crushing test demonstrated that a single roll, tooth type crusher was technically acceptable as a primary crusher for oil shale. The crusher had no problem with even the largest piece of shale, which had dimensions of about 2 1/2 X 3 1/2 X 5 feet.

Calculations by Allis-Chalmers from the test data showed a 36 inch diameter by 60 inch single roll crusher would have a maximum capacity of 1100 tons per hour for a similar size commercial feed and would require 0.28 Hphr. of energy per ton crushed. Slightly over 2% of material smaller than one quarter inch was produced.

III. DETAILED DISCUSSION

A. Preparation of Shale Test Feed

The crushing research agreement with Allis-Chalmers called for shipment of 200 tons of oil shale to Florida for the test. Discussions with Allis-Chalmers showed that a 6"+ shale feed had the most advantages. Since a large capacity grizzly (a device usually made of heavy parallel bars and used for coarse screening) was to be built for mining research studies, it was decided to use this grizzly to prepare and size the test feed. The 200 tons of 6"+ shale was prepared in December, 1966, and shipped to Florida by rail in January, 1967. The above points are discussed in more detail in the next few paragraphs.

The mine run size distribution data obtained by the Bureau of Mines shows 40 to 50% of the material passing 6 inches. Therefore, a 6"+ test feed offered the following advantages:

1. Small material in the test feed would have either been removed by the grizzly feeder before the crusher or have passed through the crusher unaffected. Therefore, no useful information would have been obtained from the small material.

2. By shipping only 6"+ material to the test site, a high percentage of the shale was crushable, which increased the crushing time and therefore increased the accuracy of the test.

3. With the high percentage of small material in the mine run which would have passed through the grizzly or the crusher, the installation would have definitely been capacity limited by the auxiliary equipment, and a maximum crusher capacity could not have been obtained.

4. The product size distribution from the test represents only material that has been crushed. This can be calculated with the 6"- from the mine run to determine the size distribution leaving the primary reduction unit.

The method of running the test duplicated the most probable commercial oil shale crushing operation. With 40 to 50% 6"- in the mine run, the feed would definitely be scalped to maximize capacity of the primary crusher station and reduce wear on the crushing surfaces.

A grizzly was constructed at the mine level to make separations at 6 inches, 18 inches, and 36 inches for

sizing the mine run. Mechanical problems with the grizzly prevented sizing of the test feed, and the mine run was simply scalped at 6 inches to insure the feed would be ready on time. Picture 1[2] shows a top view of the grizzly.

Since no size distribution could be obtained on the material shipped to Florida, several pictures were taken to document the feed. Pictures 2 through 6 show some of the 6"+ feed. Early operations with the grizzly with all three decks working indicated the relative amounts of various cuts from our mine run were in rough agreement with the Bureau of Mines distribution. Based on this fact plus the observation made in Florida that the test material contained about 20% of material that passed through the grizzly feeder, an estimated feed size was prepared. This estimated feed size is given on Figure 1.

The most probable region for the test feed distribution as shown in Figure 1 was defined by making two assumptions. The assumption defining the upper limit was that all material below 6 inches was produced by inefficiency in scalping 6"+ material from the mine run. The other assumption which defined the lower limit was that the degredation product was normally distributed about 6 inches. The actual situation was that 6"- material was produced from both screening inefficiency and handling degredation, so that the most probable estimate is the region cross hatched on Figure 1.

The shale was trucked to the railroad, and loaded into four gondola cars for shipment to Florida. A total of 405,140 pounds of shale was shipped. Later assay of shale samples from the primary crusher test confirmed the shale was of average grade, or about 26 gallons per ton Fischer Assay.

B. Description of the Primary Crusher Installation

Figure 2 gives a schematic of the Camp Concrete installation. Pictures 7 through 16 were taken to document the test facility.

Material is dumped from trucks into a receiving hopper (Picture 7). A roll grizzly feeder at the bottom of the hopper transports oversize material to the crusher (Pictures 7 and 3). The grizzly, which has a 6 to 7 inch spacing

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(2) The pictures referred to in this memorandum have been distributed as 35 mm slides to the Participating Parties (see References). For convenience, the Appendix contains Xerox copies of prints made from these slides.

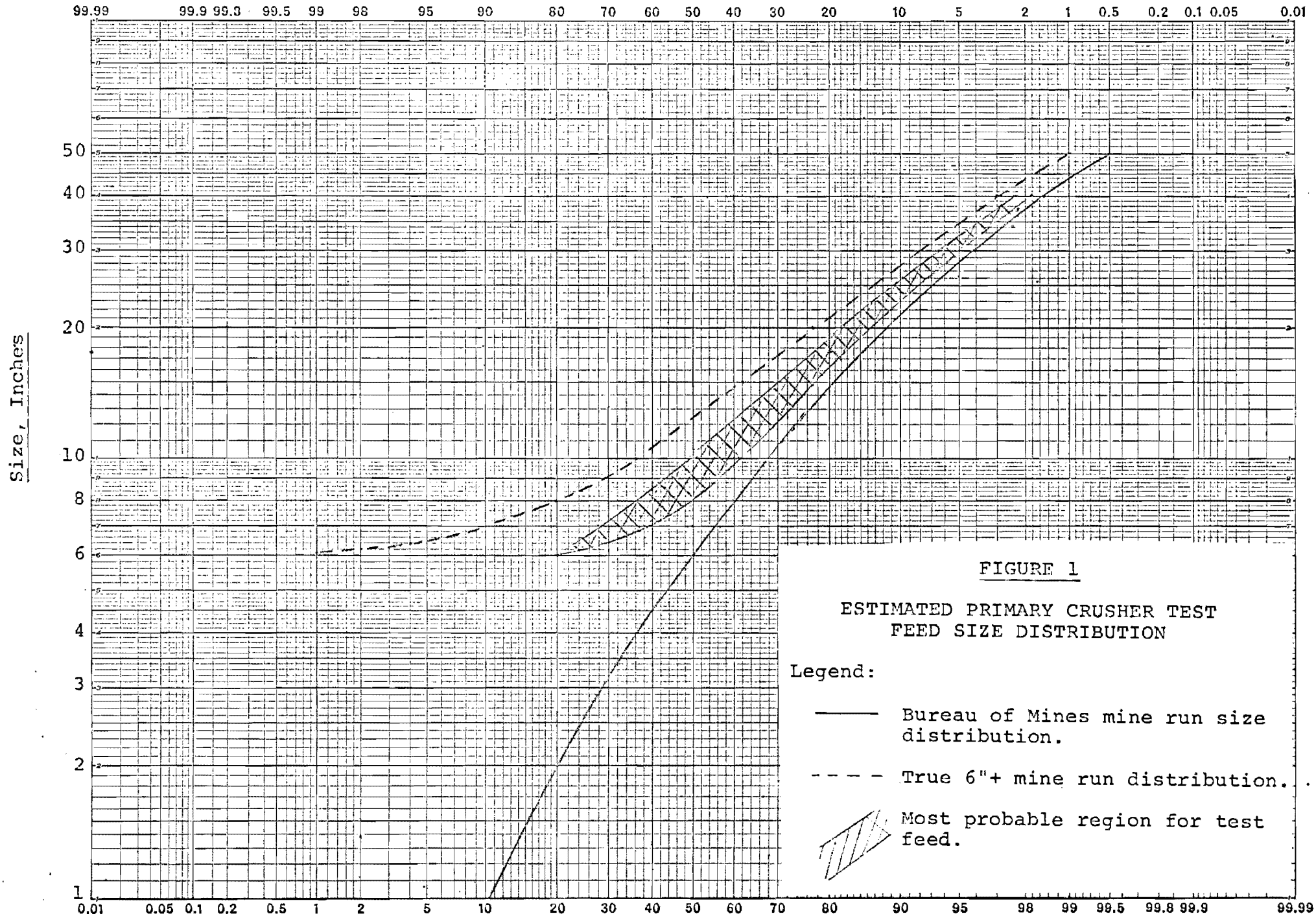

FIGURE 1

ESTIMATED PRIMARY CRUSHER TEST FEED SIZE DISTRIBUTION

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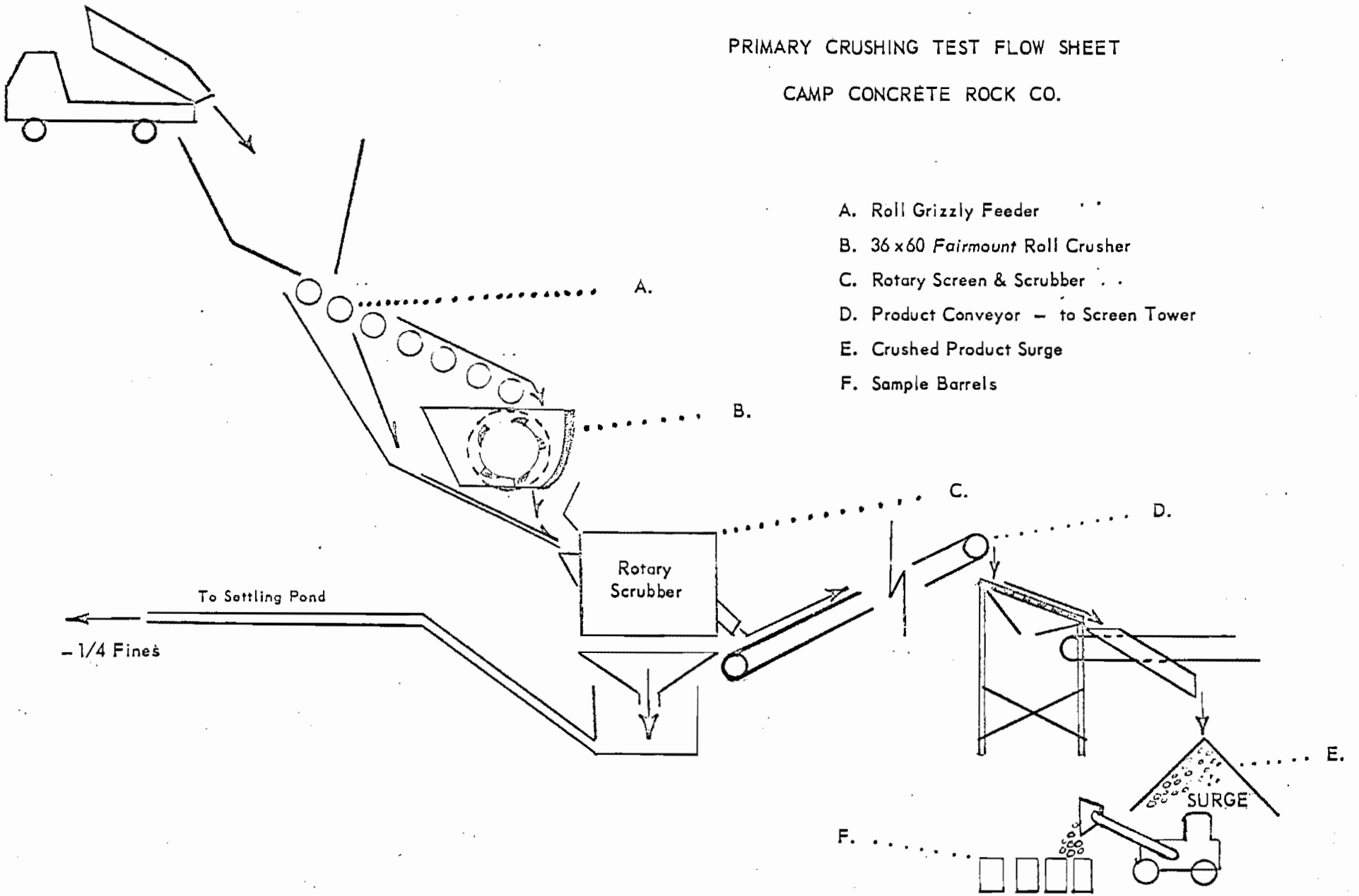
FIGURE 2

PRIMARY CRUSHING TEST FLOW SHEET

CAMP CONCRETE ROCK CO.



Reprinted from Allis-Chalmers Crushing Research Program Report.

between roll valleys, is used to bypass small material around the crusher. This roll grizzly feeder worked very well with oil shale; the shale moved easily, the crusher was fed uniformly, and it removed a high percentage of the undersize material.

The crusher was a Fairmount tooth type, single roll machine. The roll was 36 inches in diameter and 60 inches wide. Crushing is done by a combination of impaction and compression against a breaker anvil. Pictures 9 through 13 show details of the roll and teeth. Generally the teeth were arranged in alternate rolls of high (~3 inch) and low (~1 inch) teeth. An alloy called McKay 139[3] is used for hardfacing the teeth.

A 150 HP motor is used to drive the roll through a speed reduction gear (Picture 14), and the crushing roll turns at 42 RPM. The motor has a reverse jog feature that is extremely useful in breaking up rock jams in the crusher feed opening. The breaking anvil is sprung for relief should a piece of tramp metal or other hard material pass through the crusher (Picture 15).

The crusher product and grizzly undersize are recombined and sent to a rotary screen where 1/4"- material is removed. The 1/4"+ is then put on a conveyor for transportation to the plant area (Picture 16).

C. Observations During the Test

The day before the test, Allis-Chalmers personnel inspected the crusher and measured the settings. The setting was determined to be (on the average) 4 1/4 inches between roll shell and tips of the corrugations. Figure 3 gives a diagram used to estimate the setting. All teeth were hardfaced to agree with templates furnished by Allis-Chalmers.

The maximum capacity of the crusher with oil shale could not be determined because it was close to or greater than the capacity of installation. Camp Concrete had instructed their personnel that the feed rate should not get high enough to damage the product conveyor belt. However, Camp Concrete did keep the feed rate very high for periods as evidenced by the high average throughput, the highly loaded

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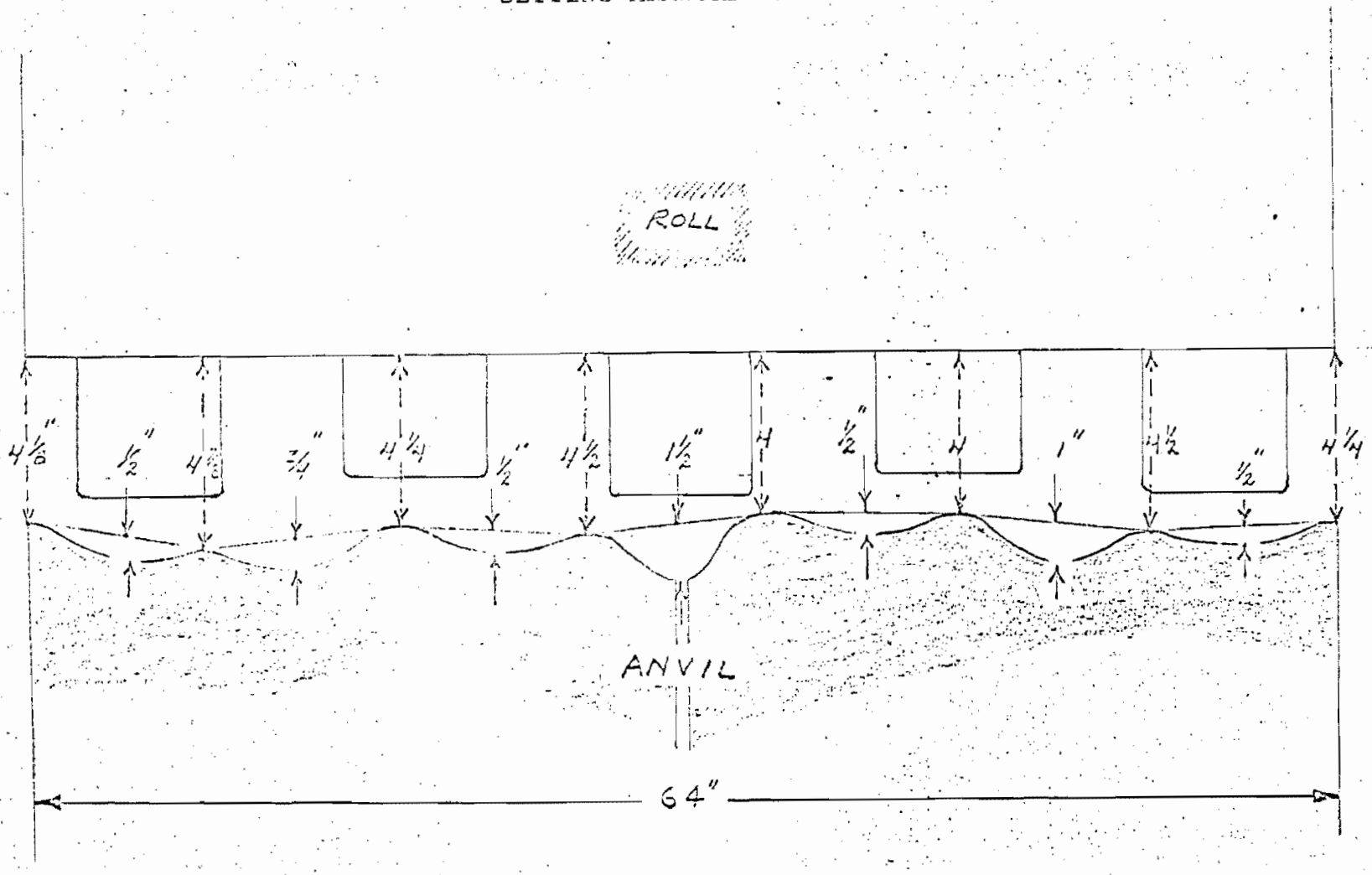
(3) Information obtained from McKay (Pittsburg, Pa.) is that No. 139 has been replaced by Hardalloy 40 TIC which has the following composition: 3.0% C, 1.25% Mn, 0.81 % Si, 8.25% Cr, and 1.5% Ti.

FIGURE 3

SETTING MEASUREMENTS FOR PRIMARY CRUSHER



The Anvil Profile Shown Was Taken At The Bottom Of The Anvil - The Point Of Minimum Setting.

CRUSHING CHAMBER PROFILE
FAIRMONT CRUSHER 36 X 60
CAMP CONCRETE ROCK CO.

Sketch prepared by Allis-Chalmers.

conveyor belt (Picture 23) and the wattmeter chart. Additional details on the test can be found in the Allis-Chalmers report.

Careful observations were made by the author on the crushing action. These observations are summarized below:

1. Smaller pieces were grabbed by the teeth and pulled into the crushing chamber (Picture 19).

2. Some pieces would split on tooth impact and the fragments would either pass through if they were small enough or undergo further crushing in the chamber (Picture 18, large piece on right).

3. No pieces were observed to avoid the crushing action for any significant length of time. This is in contrast to our jaw crusher where a piece can ride in the chamber without any significant breaking action taking place.

Pictures 18, 19, 20, 22, 24, and 25 showed the crusher in operation. Most of these pictures are of a relatively empty chamber because the dust level was low and the teeth were visible in this situation. The crusher had no problem with the large pieces shown in Pictures 21 and 24.

The test conclusively demonstrated that a single roll crusher works well with oil shale. Operation was satisfactory with either large pieces or with a choked feed mode of operation. Camp Concrete personnel, when questioned, thought the crusher did a better job on oil shale than on limestone.

D. Results of the Test

Test results were worked out by Allis-Chalmers personnel and fully covered in their report. However the results will be summarized here for convenience.

Product size distribution data is shown on Figure 4 and given on Table 1. Samples for size analysis were obtained by catching the total conveyor belt effluent in a front end loader and dumping it into 55 gallon drums. Although the sampling method appeared to be satisfactory, there was considerable difference in the size distributions between barrels. This data is given in the Allis-Chalmers report. The difference in size distribution between drums may have been dependent on the particular truckload being crushed, as the difference was larger than expected from normal sampling error based on other experience. Pictures 26 and 27 show the product pile and sample barrels.

FIGURE 4

PRIMARY CRUSHER PRODUCT SIZE DISTRIBUTION
Data Obtained From Allis-Chalmers

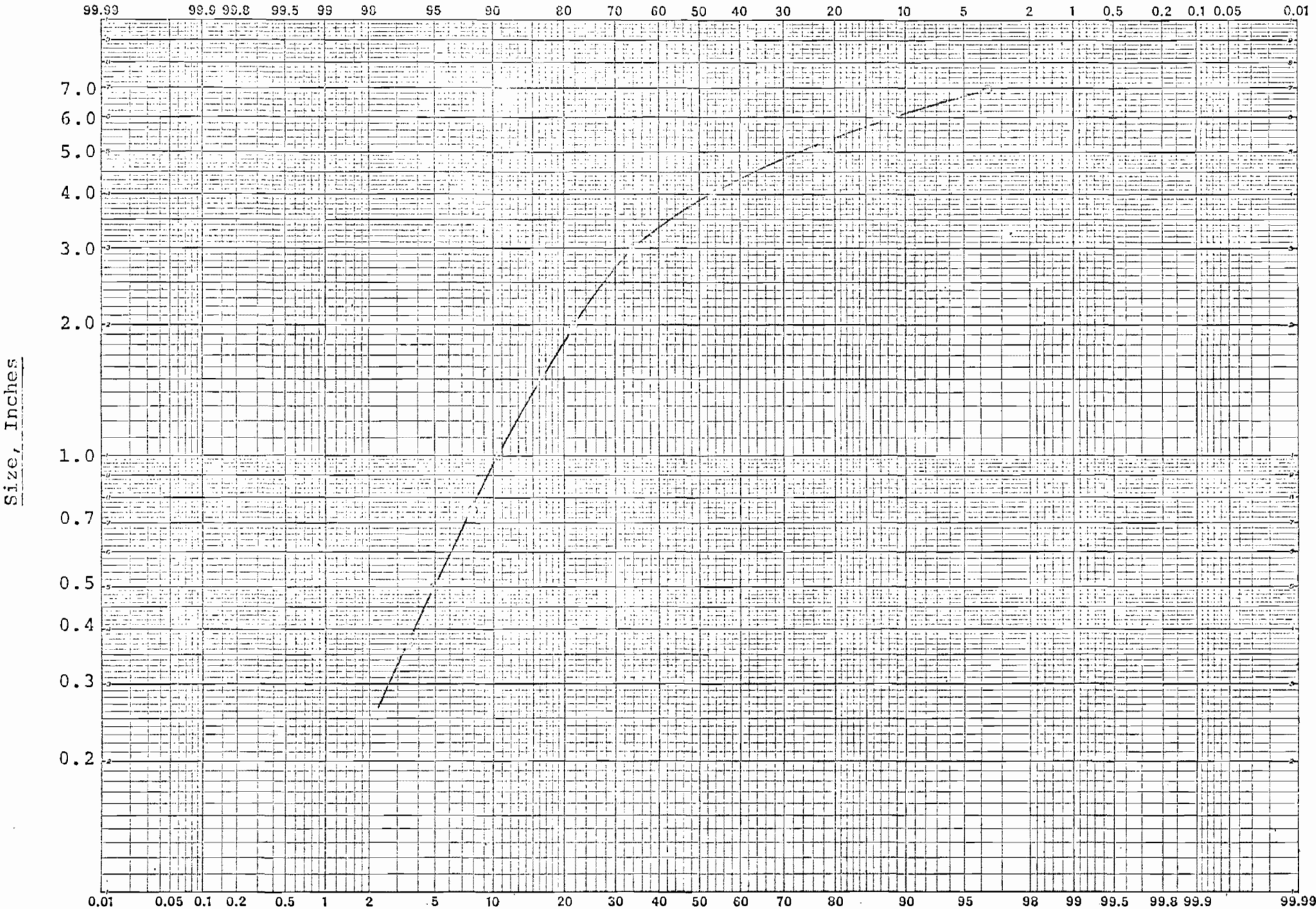


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TABLE 1

PRIMARY CRUSHER TEST PRODUCT SIZE DISTRIBUTION

Size	% Passing
7 inches	96.3
6 inches	88.5
5 inches	78.9
4 inches	53.3
3 inches	33.4
2 inches	21.5
1 1/2 inches	16.2
1 inch	10.7
3/4 inch	7.9
1/2 inch	4.9
3/8 inch	3.6
3 M	2.2

Basis: A total of 4678 pounds of primary crusher product screened. Also included is the estimated 0.26% 1/4"- fines lost in Florida.

Source: Allis-Chalmers

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The author took particular interest in the largest size pieces in the crusher product since these would be one of the limiting factors in the design of a secondary crusher. Pictures 28 through 30 show pieces around the bottom edge of the pile. Table 2 gives some measurements on the largest pieces found. The product tended to be slabby with a characteristic large, intermediate, and small side measurements. However, the roll crusher product was not as slabby as the Anvil Points' jaw crusher product in the author's opinion.

Capacity and power requirements were calculated by Allis-Chalmers to be 1100 tons per hour drawing 310 HP or 0.28 Hphr per ton. A back calculation of the Work Index for the test, assuming a reduction ratio of 3.5, gives a value of 16 which is quite reasonable. Allis-Chalmers reported a peak power draw of 560 HP, and an idle horsepower of 24.

E. Camp Concrete Operations

Pictures 31 through 35 show limestone crushing operations at Camp Concrete with a 24 inch diameter single roll crusher. The crushing mechanism for limestone and oil shale were very similar. However, the limestone product tended to be much more square and uniform than oil shale product as shown in Picture 35.

Several interesting comments on maintenance were obtained from Camp Concrete personnel and are given in the following paragraphs. In using any of the information presented below, it should be remembered that the installation was quite old.

Crushing is done for two shifts per day for five days per week. About four hours of the third shift is used for hardfacing and four is used for maintenance on auxiliary equipment (skirting, feeders, etc.). Regular plant maintenance is scheduled for Saturday with additional maintenance on Sunday if needed. Intermediate storage piles guarantee feed to the limestone processing plant.

Large pieces of limestone are common, but jams in the feeder are the usual cause of lost time rather than jams in the crusher. Occasionally extremely hard material will wear hardfacing down rapidly. When the teeth are worn, crusher throughput drops off severely so that it is more efficient to shut down and hardface then wait till scheduled maintenance. Teeth have broken off the roll occasionally.

Camp Concrete has considerable lengths of conveyor belts. Life for these belts is four to five years. Improper belt feeding, however results in belt cutting which reduces belt life to one to two years.

TABLE 2

DIMENSIONS OF LARGE PIECES IN PRIMARY CRUSHER TEST PRODUCT

15 X 12 X 3 1/2 inches	
14 X 10 X 3 inches	(rich shale)
14 X 8 X 3 1/2 inches	
14 X 6 X 3 1/2 inches	
13 X 6 X 5 inches	
12 X 7 1/2 X 2 inches	(rich shale)
11 X 7 X 6 inches	(rich shale)
11 X 7 X 4 inches	
9 X 9 X 4 inches	
9 X 7 X 5 inches	

The above pieces were picked at random from the pile with large size as the only criteria. The dimensions represent the maximum one way dimension, and generally the pieces were not true rectangular prisms in shape. The above distribution should in no way be construed as representative. Those pieces that appeared to have high oil content are so marked.

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10/3/67

IV. REFERENCES

General

1. "Articles of Agreement For Crushing Research Program on Oil Shale," between Colorado School of Mines Research Foundation, Inc. and Allis-Chalmers, dated September 13, 1966, signed October 4, 1966. (Copy available in Technical File 450.01).

2. "Crushing Research Program on Oil Shale for Anvil Points Oil Shale Research Center," submitted by Allis-Chalmers.

3. Letter of September 19, 1967 from R. D. Manninen to R. H. Cramer (raw data).

Specific

Mine Run Size Distribution

4. Matzick, A., Dannenberg, R. O., and Guthrie, B., "Experiments in Crushing Green River Oil Shale," Bureau of Mines Report of Investigations 5563, 1960.

Primary Crushing Test Pictures

5. Letter of August 31, 1967 from R. H. Cramer to Participating Parties' Data Recipients.

Monthly Progress Memoranda

6. Monthly Progress Memorandum, page 41, October 21, 1966.

7. Monthly Progress Memorandum, page 30, December 21, 1966.

8. Monthly Progress Memorandum, page 24, January 20, 1967.

9. Monthly Progress Memorandum, page 49, February 17, 1967.

10. Monthly Progress Memorandum, page 44, April 24, 1967.

APPENDIX

PICTURES OF ALLIS-CHALMERS PRIMARY CRUSHER TEST

The following six pages of pictures are for quick reference only. These pictures have been distributed to the Participating Parties as 35 mm slides (letter of August 31, 1967 R. H. Cramer/ Data Recipients) should you wish to examine details of any pictures.

EXPLANATIONS FOR PICTURES OF ALLIS-CHALMERS
PRIMARY CRUSHING TEST

1. Grizzly used to sort mine run shale into 6 inch plus fraction for crushing test. It has three decks for making separations at 36 inches, 18 inches and 6 inches.

2. Part of 6 inch plus mine run after preparation with grizzly. Note rule with 14 inch length (including case) toward left of pile.

3. Close up of pile in previous picture. Rule shows 12 inches excluding case.

4. Material hauled to rail head and loaded on to gondolas with a front-end loader.

5. Loaded gondola car. Note gloves for size comparison in center and upper portion of picture.

6. Loaded gondola car. Rule shows 14 inches including case.

Pictures of Florida Test Site

7. Feed hopper for crusher. Roll grizzly feeder starts at bottom of feed hopper.

8. Roll grizzly feeder with 6 inches to 7 inches spacing between valleys. Undersize is bypassed around primary crusher.

9. The 36" Ø X 60" roll of the Fairmount crusher. Note start of hardened wear plates of crushing anvil.

10. Another view of the crushing roll.

11. Detail of teeth rolls. Teeth alternate with one row of four high teeth and one row of five low teeth.

12. Close up of the compression crushing area. Crushing anvil constructed of hard metal sections.

13. Detail of the large teeth with a 6 inch pencil for size comparison. Note hardfacing on edges.

14. Speed reduction gears with 6 inch pencil in between to show size.

15. Roll relief mechanism that allows roll to move away from anvil should a piece of steel be encountered.

16. Conveyor belt which carries primary crusher product.

Start of Crushing Test (Note - Pictures at 1/30 to 1/60 of a second at f/1.8 to f/2.8 because of thick cloud cover and fog.) Pictures are usually of mostly empty crushing chamber situations since this was only time when dust was low enough to see details.

17. Roll grizzly feeder in operation with shale.

18. Small pieces drawn into chamber by teeth and nip action, and crushed by compression.

19. Larger pieces broken by teeth impact.

20. Crushing chamber relatively full. Again 60 inch width for crushing chamber.

21. A large piece on roll grizzly feeder.

22. Roll crushing shale.

23. Product conveyor belt showing overall high and consistent feed rate to crusher.

24. A large piece (not piece shown in No. 21) in crushing chamber. No problem except for reduction in throughput was caused by the large pieces. (Crushing chamber 60 inches wide.)

25. Roll crushing shale.

26. Primary crusher product pile.

27. Barrels of primary crusher product to be sent to Allis-Chalmers for additional test work. Product was caught directly from chute shown in picture 26 with front-end loader and dumped into barrels.

28. Some of the larger pieces of product. Note $\sim$ 6 inch pencil in picture for comparison.

29. Another picture of product with pencil for comparison.

30. Primary crusher product with ? inches of rule (excluding case) for comparison.

Pictures of Limestone Crushing (Crushing pictures at 1/500 of a second.)

31. Roll grizzly feeder with limestone.

32. A 24" X 60" roll crusher with limestone. Note breakage caused by impaction of limestone between tooth and crushing anvil.

33. Roll crushing limestone. Note lower piece on left side has just been split.

34. Large pieces of limestone crushed quite easily.

35. Limestone primary crusher product which tended to be smaller and squarer than oil shale product.

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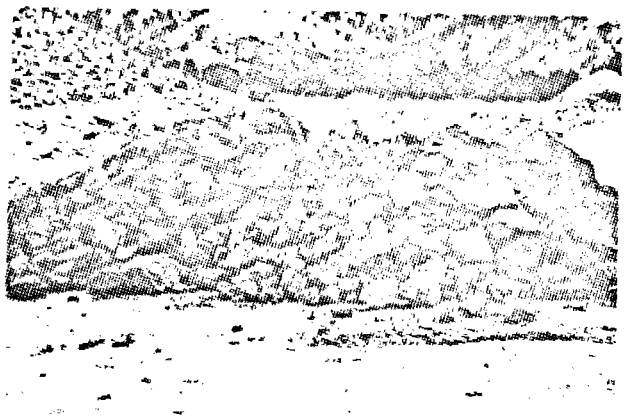

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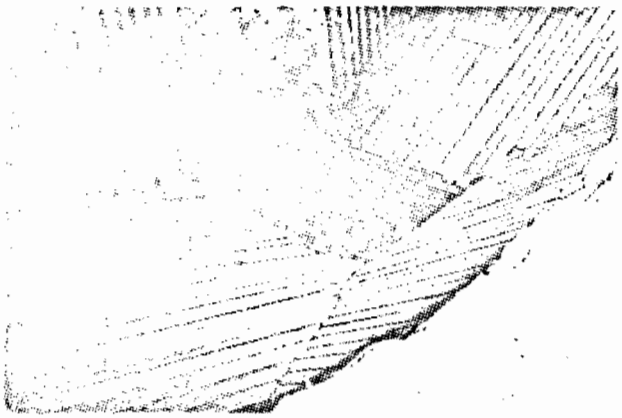

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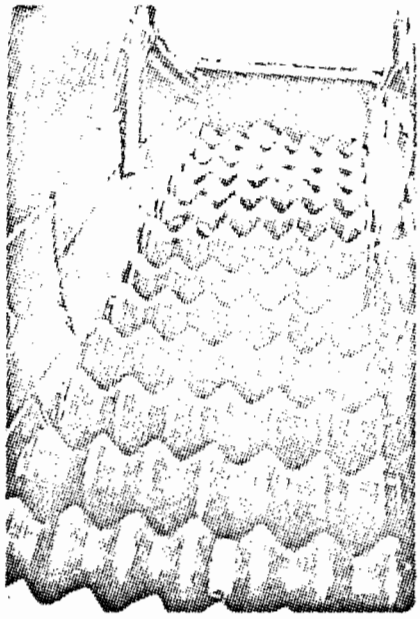

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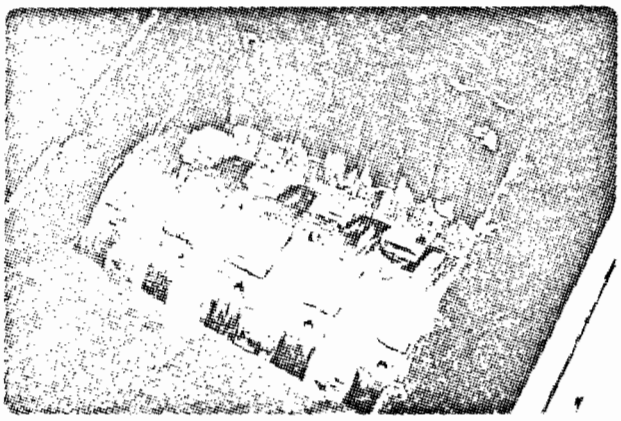

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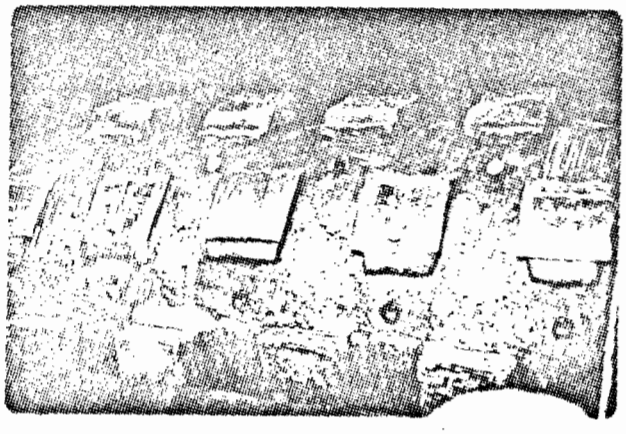

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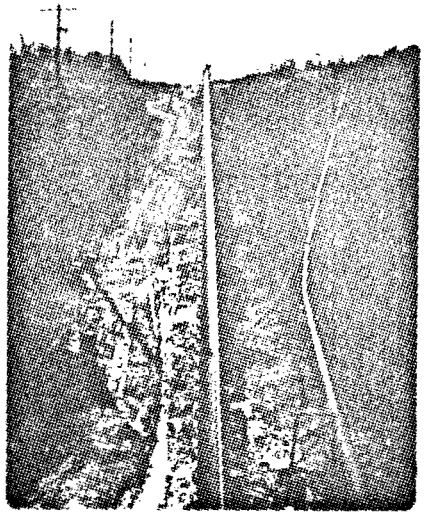

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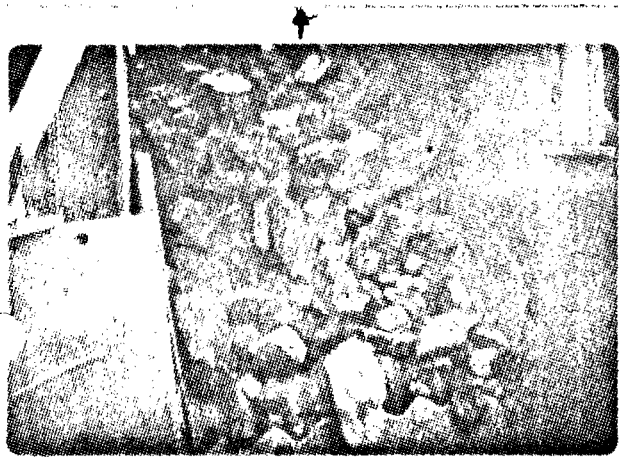

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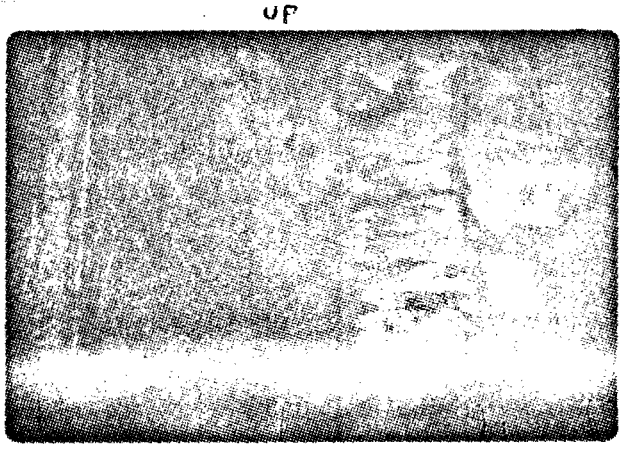

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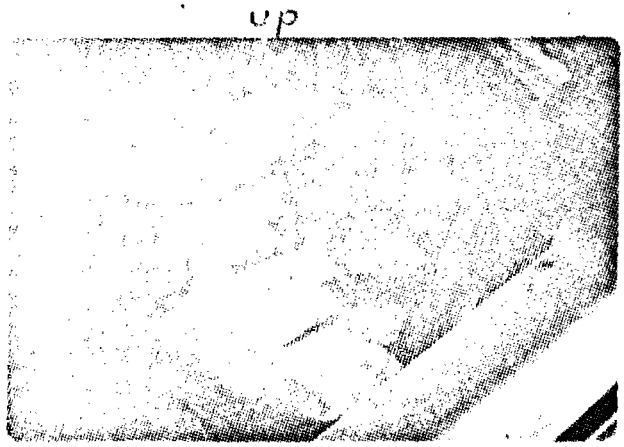

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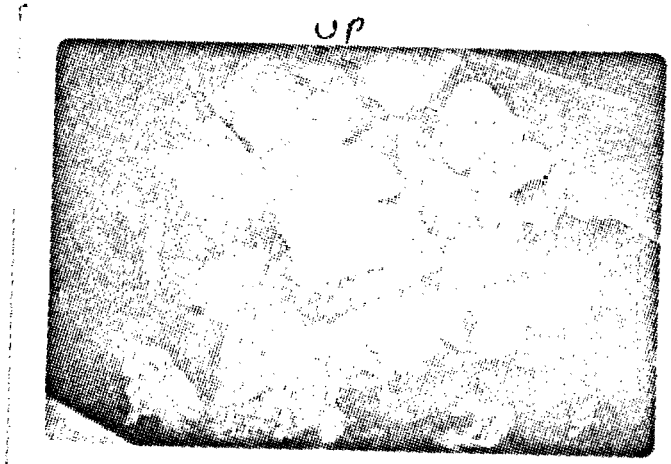

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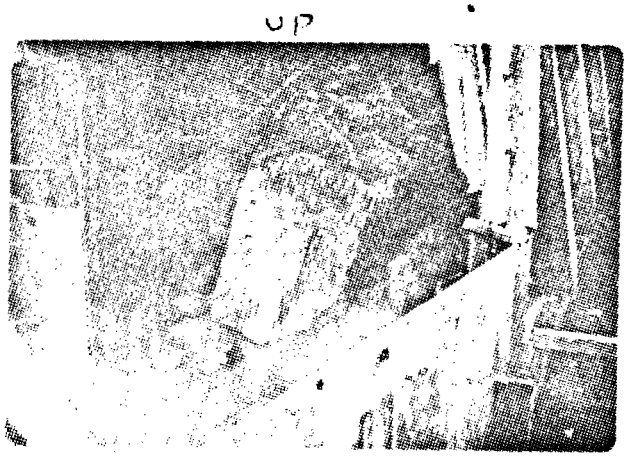

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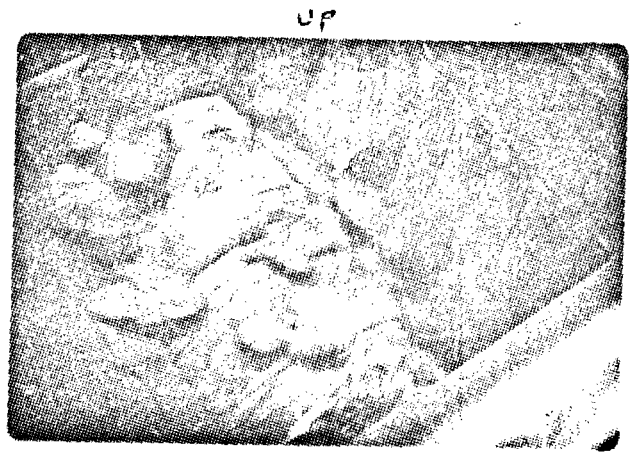

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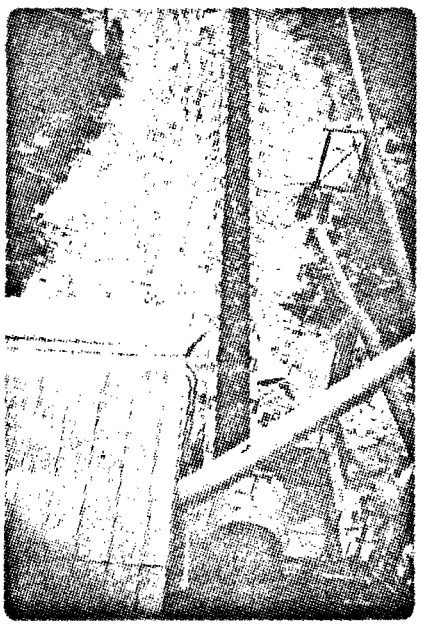

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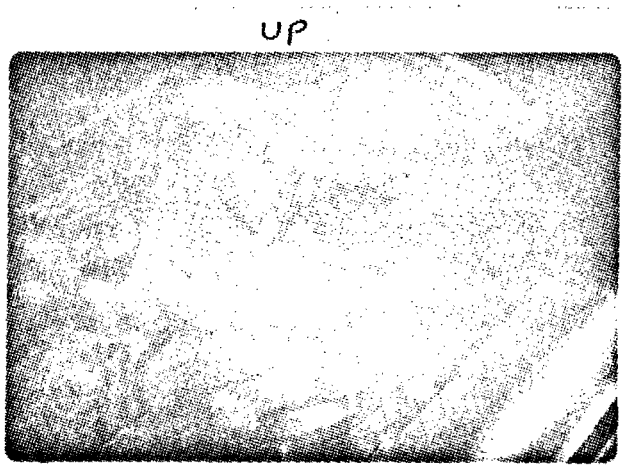

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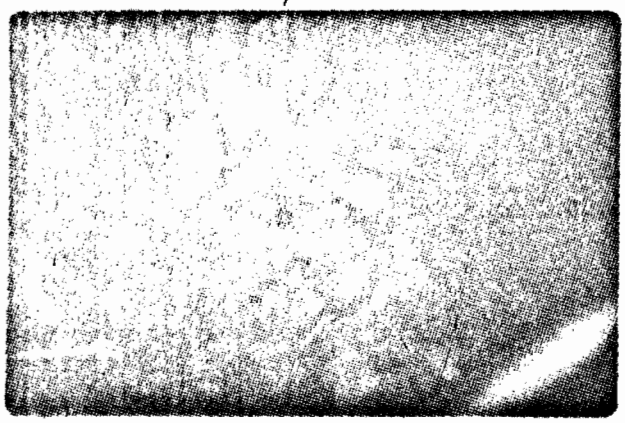

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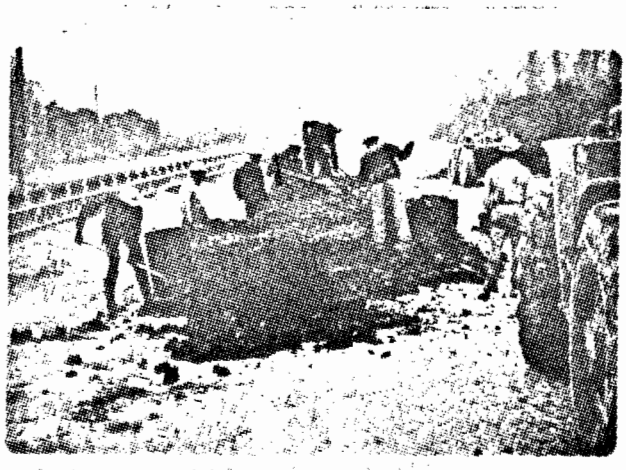

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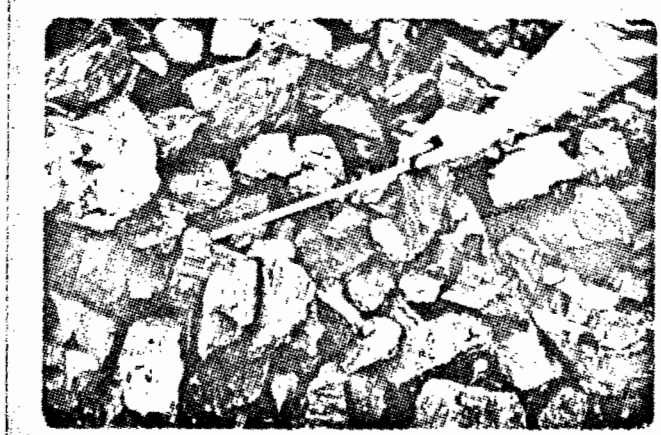
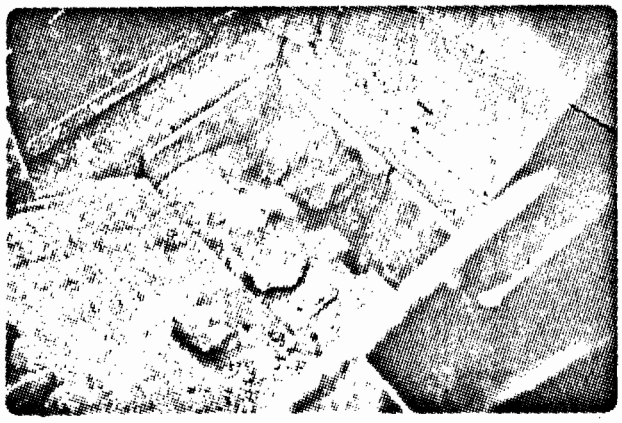
No. 28

No. 29

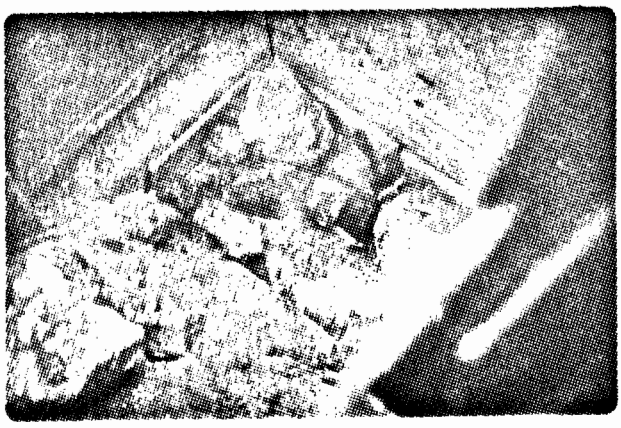


No. 30

No. 31

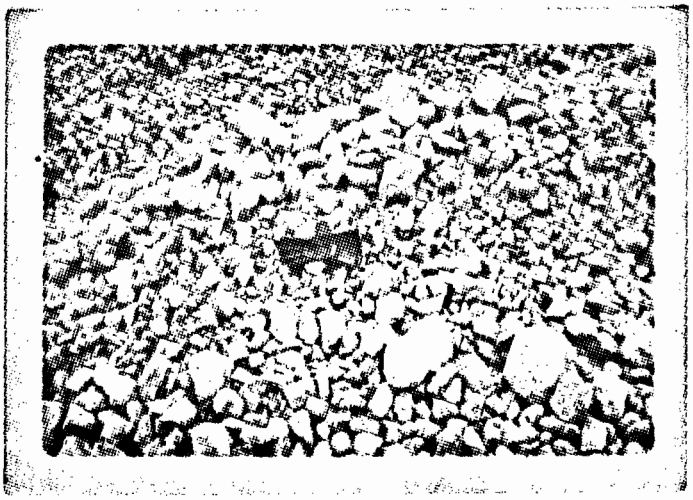


No. 32



No. 33

No. 34



No. 35