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FUEL RESEARCH INSTITUTE

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SUBJECT:
ONDERWERP: CRUSHING OF VEREENIGING COAL TO ONE AND A HALF INCHES TOP SIZE. (PRELIMINARY STUDY).

DIVISION:
AFDELING: CHEMISTRY.

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 4 OF 1952.

CRUSHING OF VEREENIGING COAL TO ONE AND A HALF INCHES TOP SIZE. (PRELIMINARY STUDY)

It is believed that Sasol is faced with the following crushing problem.

The run-of-mine coal is to be broken in such a manner that 55% of it has a top size of 1½ inches and that the ratio between top and bottom size does not exceed 5 to 1. This material represents the feed to the gas producers. The remaining 45 % of the coal is to be of a size suitable for feeding to a pulveriser for producing powder fuel. It is required to investigate the breaking of the coal with a view to selecting the most suitable type of crusher and crushing circuit. Due to a lack of adequate facilities it is not possible to make a detailed study of this problem, but the following suggestions may serve as a useful guide.

TYPES OF CRUSHERS WHICH MAY BE CONSIDERED.

The types of crusher usually considered for breaking hard or medium hard run-of-mine coal down to 1½ inches in one operation are:-

1. Roll crushers with teeth - either single or double roll.
2. Hammer crushers - Usually the "Flex tooth" or "Rotary ring" types.

Generally speaking, the roll crushers produce a lower proportion of fines than the Hammer type. However, at first sight this fact appears to be of little consequence for the purpose of the present investigation provided that the

coarse/.....

coarse fraction has a size ratio within the specified limits. Typical results obtained from these two types of crushers in the U.S.A. are shown in Table 1.

TABLE 1.

PERFORMANCE OF ROLL AND HAMMER TYPE CRUSHERS.

Feed Coal.	Medium hard kansas washed coal 6" x 1¼"	Medium hard West Virginia Egg and Nut Coal*	
Type of Crusher.	McNally Double Roll stoker coal crusher	Jeffrey Flextooth crusher Slow speed (1)	Higher speed (1)
Screen size, inches.	Percentage retained.		
1½	0	0	0
1¼	3.2	12.8	6.4
1	15.6	27.3	25.7
¾	40.0	45.3	41.6
½	62.5	63.6	59.8
⅜	71.8	72.2	68.9
¼	82.2	80.5	76.3

* Just as in South Africa, the commercial sizes in U.S.A. vary widely. Thus "Egg and Nut" coal may be anything from about 4" x 1" to 6" or 8" x 1¼". (1) Exact speed not known.

In the case of the roll crusher, a 1¼ inch product was aimed at and a small amount of oversize was produced, while the hammer crusher was set to produce a 1½ inch product. In addition, different coals were crushed hence the results are not strictly comparable. However, they give some indication of the type of screen analysis of crushed product to be expected. Thus the hammer type, when crushing medium hard coal to minus 1½ inches could be expected to yield a product in which the "55 % point" is in the region of ½ to ⅝ inch, which should

be/.....

be quite acceptable to Sasol. It should also be observed that variation of the speed of a hammer type crusher affords a simple method of changing this point within narrow limits. If the roll mill were set to produce a 1½ inch product of the same coal a "55 % point" at a slightly larger size could probably be expected, say, of the order of ⅝" to ¾" or possibly even greater.

It appears, therefore, that either of these types should be applicable for the problem under consideration, but their relative merits will naturally have to be carefully considered before the final selection is made.

As a next step, the ideal procedure would be to test run-of-mine coal from the Vereeniging area in both types of crusher under various operating conditions. Unfortunately neither of these types are available at the Fuel Research Institute at present. Tests at collieries provided with this type of equipment may be considered but this would impose severe limitations on the scope of the investigation and this possibility has, therefore, been neglected temporarily.

A small swing hammer pulveriser having a capacity of 3 to 4 tons per hour is available at the Fuel Research Institute and it was decided to use this crusher for a few preliminary tests.

LABORATORY SWING HAMMER PULVERISER.

This crusher is a Jeffrey Junior Type A, size 15" x 8".

The specifications are as follows:-

Diameter of hammer tip circle	14 inches.
Width of roter	8 inches.
Recommended speed for pulverising coal = 2000 to 3000 R.p.m.	
Minimum clearance between breaker plate and hammer tip	Approximately ⅜ inch.
Feed opening	8" x 8".

This crusher was primarily designed for pulverising coal to about minus 1/8 inch, hence the high rotor speed.

Now Flextooth and Rotary-ring crushers are generally operated with a tip velocity ranging from about 1900 ft/min. to 4500 ft/min. when used to break coal to about minus 1½ inches, the product becoming coarser the lower the speed (top size fixed). If the Junior type A crusher is operated at 800 r.p.m., the tip velocity is about 2900 ft/min. which can be regarded as an average value for the Flextooth type.

In a swing hammer crusher considerable breakage of coal occurs between the hammers and the bars forming the screen cage, while in a Flextooth or Rotary-ring crusher the hammers are free to move in a radial direction and this reduces the breakage between hammers and cage considerably except in the case of oversize material. In order to simulate the operation of a Flextooth crusher it was decided, therefore, to remove the screen cage entirely from the laboratory crusher and to recrush any oversize which may still be present.

The effective minimum clearance between the breaker plate and hammer tips is probably considerably smaller than would be the case in a Flextooth crusher adjusted to produce a minus 1½ inches product. This fact may have an important bearing on the size grading of the product as will be explained later. Thus by operating the laboratory crusher at 800 r.p.m. without a screen cage a product should be obtained which would give some indication of what could be expected from a Flextooth type hammer crusher.

CONDUCT OF THE TESTS.

A sample of run-of-mine coal was obtained from Cornelia Colliery, Bertha No. 1 shaft. Large pieces of

obvious/.....

obvious stone were removed by hand sorting and discarded. The whole sample was then screened at 1½ inches square with the following results.

	Weight in lb.	Percentage.
+1½ inches	6204	63.7
-1½ inches	3532	36.3
Total.	9736	100.0

The minus 1½ inches fraction was halved, and one half was screened. The screen analysis of the natural minus 1½ inches material (or "natural smalls") is reported in Table 2.

TABLE 2.

SCREEN ANALYSIS OF NATURAL -1½" MATERIAL.

Screen size*	Percentage.
-1½" + 1"	21.4
-1" + ¾"	15.4
-¾" + ⅝"	8.7
-⅝" + ½"	7.4
-½" + ⅜"	8.4
-⅜" + ¼"	7.7
-¼"	31.0
Total	100.0

* Square aperture screens.

The other half of the natural smalls was passed through the crusher at a rate of approximately 3 to 4 tons per hour and the product was screened with the results shown in Table 3.

TABLE 3/.....

TABLE 3.

SCREEN ANALYSIS OF THE CRUSHED NATURAL SMALLS.

Screen size.	Percentage.
-1½" + 1"	3.9
-1" + ¾"	8.3
-¾" + ⅞"	8.3
-⅝" + ½"	9.6
-½" + ⅜"	11.7
-⅜" + ¼"	12.4
-¼"	45.8
Total	100.0

The plus 1½ inches fraction of the original sample was halved and one half was passed through the crusher at a rate of approximately 3 to 4 tons per hour. Occasional lumps in the sample had a top size of approximately 24 inches cube. Since the feed opening of the crusher is only 8 inches square, all lumps larger than this size were split manually by means of a hammer prior to feeding them to the crusher. The screen analysis of the crushed product is reported in Table 4.

TABLE 4.

SCREEN ANALYSIS OF CRUSHED PLUS 1½ INCHES FRACTION (WITHOUT SCREEN CAGE).

Screen size.	Percentage of whole sample	Percentage of -1½" material in the product.	
		Fract.	Cumulative.
+2"	2.9	-	-
-2" + 1½"	6.4	-	-
-1½" + 1"	13.3	14.7	14.7
-1" + ¾"	13.3	14.7	29.4
-¾" + ⅝"	8.4	9.3	38.7
-⅞" + ½"	9.2	10.1	48.8

TABLE 4 (CONTD.)

Screen size.	Percentage of whole sample	Percentage of -1½" material in the product.	
		Fract.	Cumulative.
-½" + 3/8"	9.1	10.0	58.8
-3/8" + ¼"	9.6	10.6	69.4
-¼"	27.8	30.6	-
TOTAL	100.0	100.0	

The oversize in the crushed product (i.e. +1½" material, Table 4) was passed through the crusher again with the results shown in Table 5.

TABLE 5.

SCREEN ANALYSIS OF OVERSIZE FROM TABLE 4 AFTER RECRUSHING.

Screen size.	Percentage.
+1½"	7.7
-1½" + 1"	18.7
-1" + ¾"	13.6
-¾" + 5/8"	10.3
-5/8" + ½"	8.4
-½" + 3/8"	9.2
-3/8" + ¼"	8.8
-¼"	23.4
TOTAL	100.0

The other half of the original plus 1½" fraction was passed through the crusher fitted with a screen cage, the bars

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being spaced approximately 1 1/8". The screen analysis of the product obtained is shown in Table 6.

TABLE 6.

SCREEN ANALYSIS OF CRUSHED PLUS 1½" FRACTION.
(CRUSHER FITTED WITH 1⅛" SPACED CAGE).

Screen size.	Percentage.
-1½" + 1"	0.4
-1" + ¾"	1.2
-¾" + ⅝"	2.6
-⅝" + ½"	4.4
-½" + ⅜"	10.9
-⅜" + ¼"	17.0
-¼"	63.5
TOTAL	100.0

The results in Table 6 are of no interest in the present investigation but they do serve to illustrate the considerable amount of breakage occuring between the hammers and the cage in a swing hammer crusher (compare Tables 4 and 6.)

DISCUSSION OF RESULTS.

Since the crusher was operated without a screen cage a certain amount of oversize material must be expected. Thus, it will be noted in Table 4 that 9.3% of the product exceeded 1½ inches. In a practical Flextooth crusher fitted with a screen cage this material would be broken down between the hammers and the cage bars while the smaller sizes should suffer little reduction in size. In order to simulate these conditions the plus 1½ inches fraction was recrushed with the results

shown/.....

shown in Table 5. The screen analysis of the final product will, therefore, be given by a combination of Tables 4 and 5, in the appropriate proportions. Calculated values are shown in Table 7.

TABLE 7.

SCREEN ANALYSIS OF THE FINAL CRUSHER PRODUCT (COMBINATION OF TABLES 4 & 5).

Screen size.	Percentage of whole product	Percentage of -1½" material in the product.	
		Fractional	Retained
+1½"	0.7	-	-
- 1½" + 1"	15.0	15.1	15.1
- 1" + ¾"	14.6	14.7	29.8
- ¾" + ⅝"	9.4	9.5	39.3
- ⅝" + ½"	10.0	10.1	49.4
- ½" + ⅜"	10.0	10.1	59.5
- ⅜" + ¼"	10.4	10.5	70.0
-¼"	29.9	30.0	
TOTAL	100.0	100.0	

It will be observed in Table 7 that the amount of oversize remaining is almost negligible and further discussion will be confined to minus 1½ inches material. A curve of percentage retained versus screen size was plotted in Fig. 1. from the data in Table 7 together with the corresponding curves for a Roll crusher and a Flextooth crusher (Table 1). It will be observed that the curve actually obtained for the laboratory crusher is generally of the same form as those obtained for the Flextooth crusher in U.S.A., but that the "55 % point" is somewhat displaced. This displacement may be due to any or a

combination/.....

combination of the following factors:-

(1) Differences in the characteristics of the coal.

(2) The rather small clearance between the hammer tip circle and the breaker plate.

(3) Difference in the tip velocity of the hammer.

Vereeniging coal is generally classified as a medium hard bituminous coal as was the coal in the Flextooth crusher tests (Table 1), but this classification is naturally broad.

The tip velocity in the tests on the laboratory crusher may have been higher than it was in both of the tests on the Flextooth crusher and this may account to a certain extent for the displacement of the curves.

However, the small clearance between hammer tips and breaker plate is considered to be the major cause of the displacement of the curve. In effect, the crusher was probably set for a smaller top size than 1½" and by increasing this clearance a substantially coarser product could be expected.

It does not appear unreasonable to conclude from these tests that a Flextooth crusher when crushing the plus 1½" run-of-mine coal should be able to yield a product in which the "55 % point" is at least 0.4 inch and by suitably adjusting tip velocity and breaker plate clearance this value could probably be increased to ½" or 5/8".

Referring again to Fig. 1, it will be noted that the curve for the roll crusher is considerably steeper than those obtained for the hammer types indicating a coarser product. It was previously stated that the roll crusher had been adjusted to produce 1½" top size material (oversize is inevitable with a roll mill without recycling). If this crusher had been set for 1½" top size the major portion of the curve would probably have been in the region of the line

AB/.....

AB i.e. a relatively large 55 % point (say, $\frac{3}{4}$") could be expected from a roll crusher.

Thus if the size ratio of the gasifier feed should be as large as possible a hammer type crusher is indicated, while, if the size ratio should be as small as possible a roll crusher will probably be more suitable. In addition, several other factors will have a bearing on the selection, including the following:-

(a) The cost of the installations (including recycling of oversize from a roll crusher, if necessary; preliminary crushing of the pulveriser feed, if necessary, etc.).

(b) Maintenance cost.

(c) Power cost per ton treated.

(d) Flexibility.

THE CRUSHING CIRCUIT.

Many factors of a purely local nature (e.g. whether the gasifier feed is continuous or intermittent, variations in the characteristics of the coal seams etc.) will also have to be taken into account when designing the preparation flow sheet. Without this knowledge it is only possible to mention a few points which may form a basis for further study.

(a) Removal of natural smalls from the run-of-mine coal prior to crushing.

If the size ratio of the gasifier feed is to be as small as possible, there would be no object in further breaking the natural smalls and the run-of-mine should, therefore, be prescreened at $1\frac{1}{2}$". However, if a wide size ratio is desirable the question of including the natural smalls in the crusher feed should be considered. As previously stated a hammer type crusher will probably be most suitable under these circumstances and the discussion will, therefore, be confined to this type

of/.....

of machine.

Table 2 represents the screen analysis of the natural smalls and Table 3 the screen analysis of this material after passing through the crusher. Assuming that each size fraction in the run-of-mine (i.e. the +1½" and -1½" fractions) will be broken in the same way whether they are mixed or separate, the final screen analysis of the product obtained when crushing the total run-of-mine will be given by the combination of Tables 3 and 7 in the appropriate proportions. Calculated values are shown in Table 8. The final screen analysis of the total coal when only +1½" material is crushed (i.e. combination of Tables 2 and 7) is also given for purposes of comparison. In both cases +1½" material shown in Table 7 has been neglected.

TABLE 8.

FINAL SCREEN ANALYSIS OF THE TOTAL COAL.

Screen size.	Total R.O.M. crushed.	+1½" only crushed.
1½"	0	0
1"	11.0	17.4
¾"	23.4	32.4
⅝"	32.4	41.5
½"	42.4	50.7
⅜"	53.1	60.2
¼"	64.3	69.6
55 % Point	0.35	0.45

It thus appears from Table 8 that by passing the total run-of-mine coal through a suitably adjusted hammer type crusher it should be possible to obtain a sufficient quantity of gasifier feed with a size ratio very close to the allowable

maximum/.....

maximum if this should be desired.

(b) Other preparation prior to crushing.

It would probably be advisable to remove large stone from the coal by hand prior to crushing. The stone serves no useful purpose and it may damage the crusher (particularly a roll crusher) or cause unduly heavy maintenance. The natives employed on hand picking could also break down the occasional lump too large to enter the crusher. It may be advisable in this connection to pass only plus 3" or 4" coal over the picking belt in order to obtain more thorough cleaning.

(c) Screening after crushing.

In order to allow for variations in the size analysis of the final product and to ensure a sufficient quantity of feed to the gasifier at all times it will be necessary to have a flexible screening arrangement. There are several possible solutions to this problem but only one will be mentioned. By installing a double deck screen with the upper aperture chosen to correspond, say, to the "50 % point" of the curve and the lower aperture corresponding to, say, the "60 % point" (provided that it falls within the 5 : 1 limit), the coarsest fraction can be supplied continuously to the gasifier and a suitable proportion of the intermediate size can be sent to the gasifier as required i.e. quantity variations due to size variations are controlled by an intermediate size. This procedure ensures a steady feed to the gasifier and limits the top size sent to the pulveriser to a predetermined maximum.

(d) Precrushing of pulveriser feed.

Depending on the nature of the powdered fuel pulveriser, the amount of small stone present and the top size sent to the pulveriser, it may be desirable to precrush some or all of the coal in, say, a swing hammer crusher to minus 1/8 inch.

The/.....

The final flow sheet, although capable of considerable variation, will, therefore, approximate that shown in Figure 2. Alternative circuits are shown dotted.

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SENIOR TECHNICAL OFFICER.

PRETORIA.

11th February, 1952.

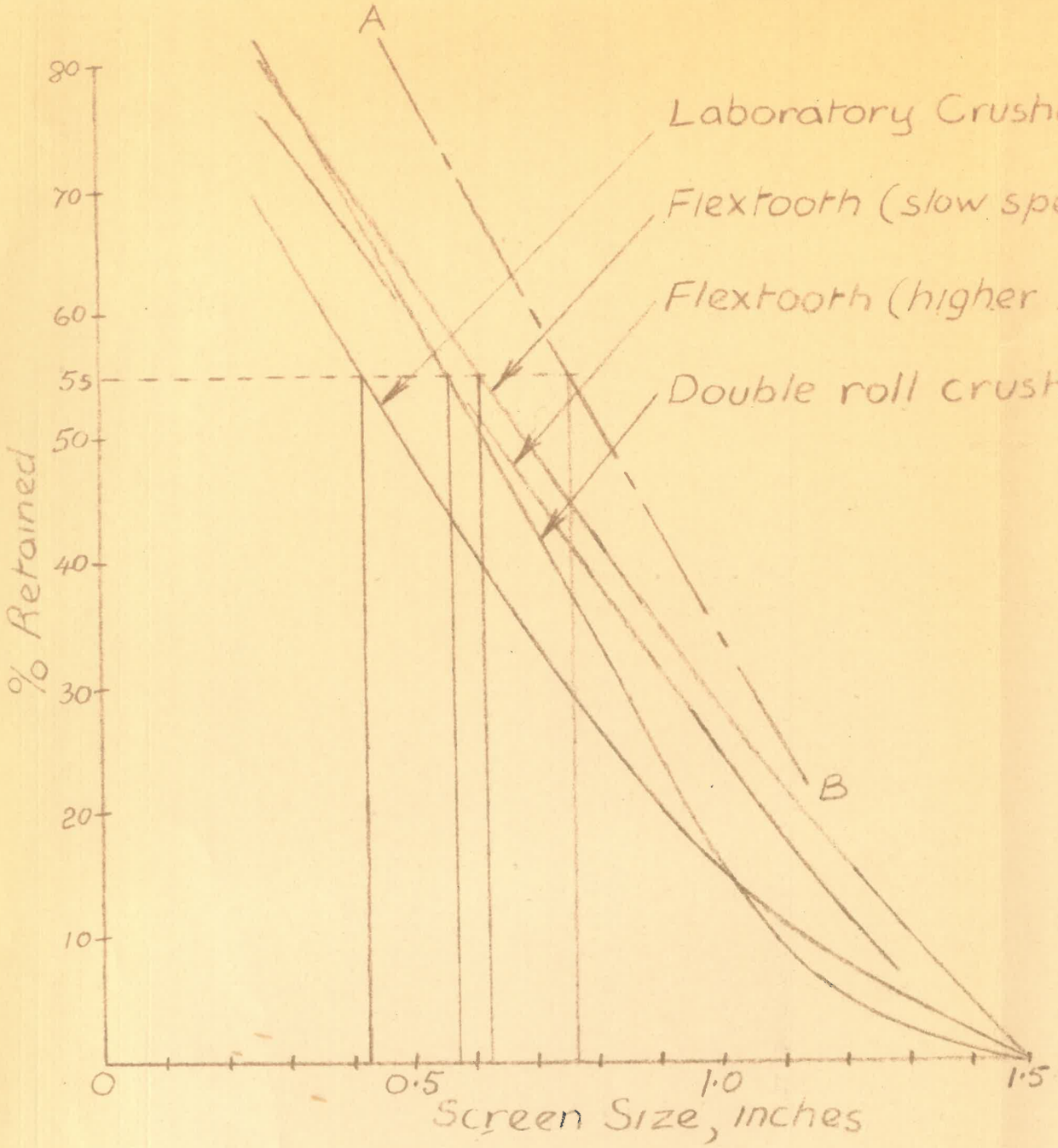

FIGURE 1

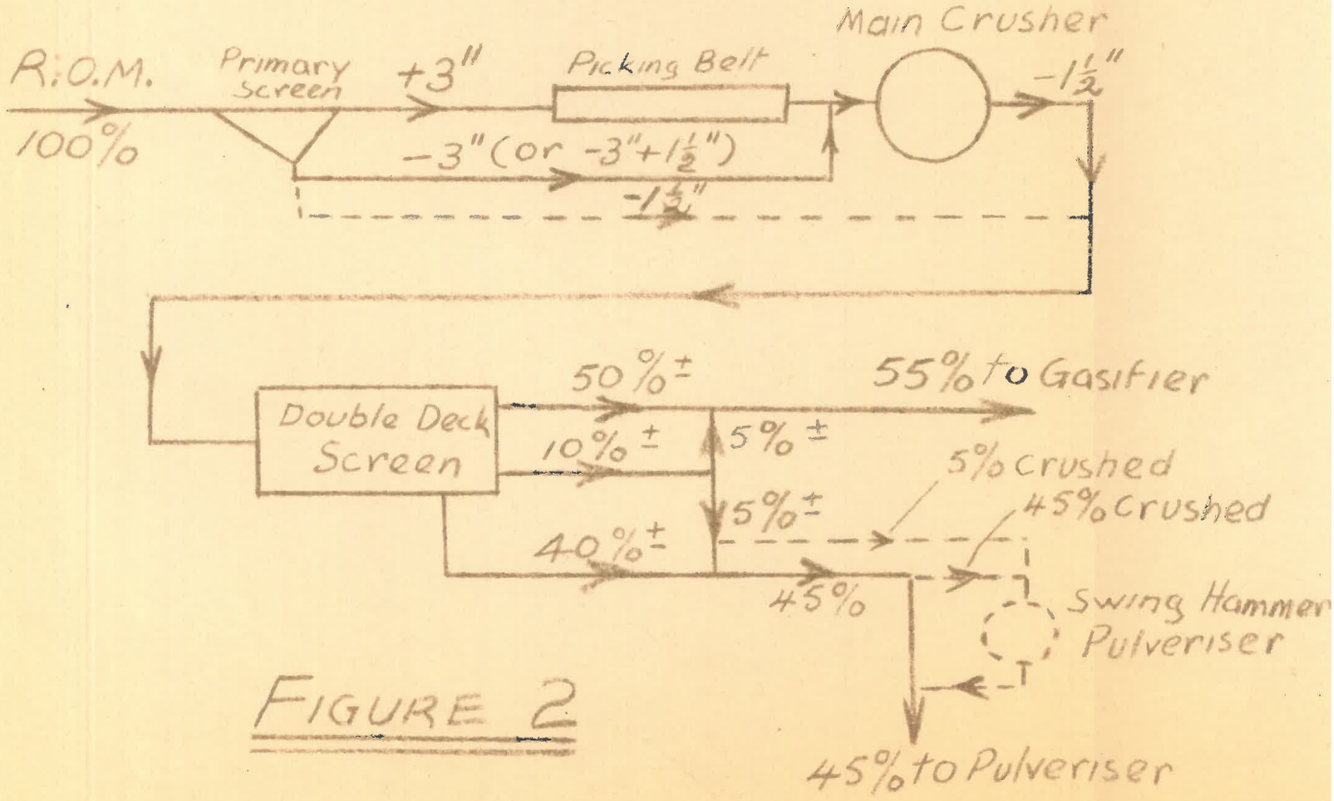

FIGURE 2