PJ v d Walt

FRI 17/1951

Form No. F.R.I. 47.

REPORT No. 17
OF 1951

RAPPORT No. 17
VAN 1951

U11/D/4/3

FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA.

BRANDSTOF-NAVORSINGS-INSTITUUT

VAN SUID-AFRIKA.

SUBJECT:
ONDERWERP: REPORT ON TESTS CARRIED OUT ON THE SWING PULVERIZER.

DIVISION:
AFDELING: CHEMISTRY.

NAME OF OFFICER:
NAAM VAN AMPTENAAR: C.E. BIRD.

W.P.—69328—17/1/50

FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

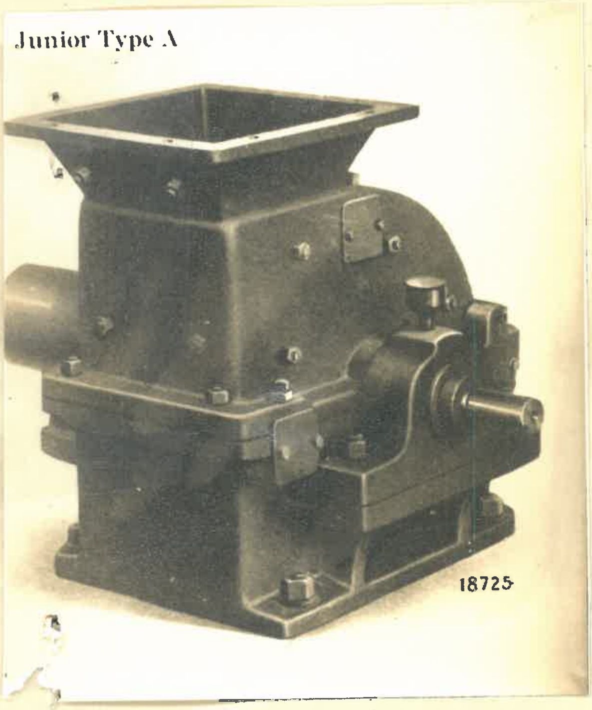
REPORT NO. 17 OF 1951.

REPORT ON TESTS CARRIED OUT ON THE SWING HAMMER PULVERIZER.

INTRODUCTION:

The swing hammer pulverizer available at the Institute is a comparatively small machine (Junior Type A) but it was considered that the information regarding its operating characteristics gained by a few experiments would be of considerable assistance when investigating the hammer mills used in practice.

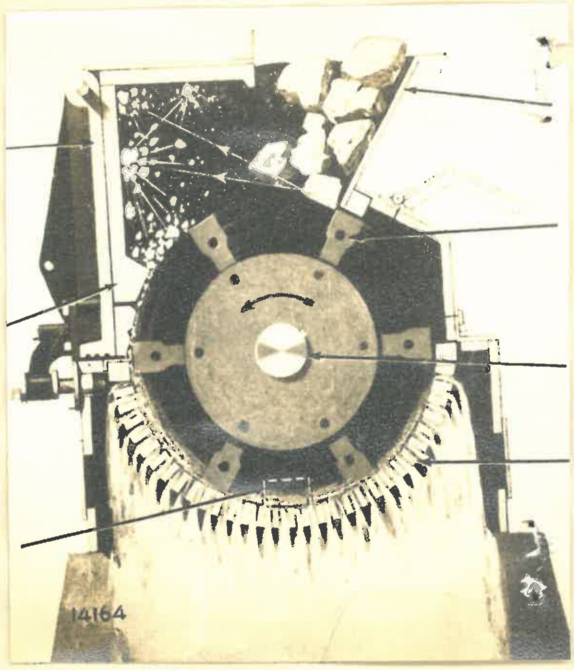
DESCRIPTION OF PULVERIZER:



The machine comprises, essentially, a pluraty of flailing hammers which strike the coal particles either while they are falling freely through the air or as they rest on the stationary metal breaker plate (Fig. 11).

In this particular machine the feed entry is so arranged that the entering material falls directly on rising hammers. The particles or fragments thereof are then thrown with great force by the hammers against the fixed surfaces surrounding the flailing hammers from which they rebound back into the hammer path, or, are pinched at an angle between the moving hammers and the breaker plate or the grid until the particles are sufficiently reduced in size to pass through the grid.

The screen consists of bars of triangular cross-section held in position (Fig. 11) by spacing racks. These spacing racks rest securely on ledges formed in the side frames of the machine. They divide the whole screening surface into three panels of a convenient size to be handled as a unit when assembled with the proper number of bars. For the same machine these panels are all of the same size and the number of bars in each panel vary inversely with the clear opening between them.



The manufacturer's ratings for this machine are as follows:

Diameter of outer circle of hammer travel	= 15"
Width of rotor	= 8"
Approximate horse power	= 7 - 8
Speed in r.pm.	= 1800-3000
Capacity (1/8" bar opening)	= 3/4 - 1 ton/hour.
Capacity (1" bar opening)	= 2 - 3 ton/hr.

The breaker plate is fixed at a distance of approximately 1/2 inch from the outer circle of hammer travel.

The rotor speed of the pulverizer as installed at the Institute was 1160 r.p.m.

OPERATING VARIABLES:

The following variables will have an effect on the performance of the swing hammer pulverizer.

(a) Type of coal.

(b) Rate of feed.

(c) Feed velocity.

(d)/...............

(d) Hammer clearance.

(e) Condition and number of hammers.

(f) Size of feed - average and maximum.

(g) Speed of rotor.

(h) Bar opening.

Of these only the rotor speed and the size of the bar openings were considered in this investigation.

The following notes will indicate steps taken in regard to the other factors:

(a) TYPE OF COAL USED.

All tests were conducted on 1 ton representative samples taken from a 15 ton bulk sample of Navigation No. 5 seam coal which had been procured for other tests.

Since previous tests have shown that coals from the Witbank coalfield do not differ appreciably in regard to friability characteristics (with the exception of coal from the No. 4 seam), this sample could be regarded to yield results that would hold generally for this area.

(b) RATE OF FEED:

It was found that no constant and continuous rate of feed could be maintained by hand feeding. A feed box having a capacity of about 125 lbs. was, therefore, installed over the feed entry. By always keeping this feed box full and the time taken to empty one bin (150lbs.) into it constant the predetermined rate of feed could be maintained. It was always kept at 1 ton per hour throughout the tests except in those where the maximum feed-rate was to be determined.

(c) FEED VELOCITY:

The feed must penetrate the hammer circle if the full area of the crushing surfaces is to be utilized. This necessitates a balance between the falling velocity of the particles and the rotor speed that will vary with the position and direction of the feed entry with respect to the rotor.

If the feeding velocity is too large, the rotor discs and hammer shanks wear excessively, if the penetration is insufficient the hammer heads round off at the outer ends; material is struck glancing blows with consequent lack of force and imposed velocity; capacity falls; circulating loads build up and the machine cannot be made to draw full power without quick overloads and clogging (in centre feed machines the feed box height is made adjustable to permit control of penetration. Adjustment is made with hammer head wear).

On examining the hammer heads of the pulverizer before commencing the tests it was found that penetration had been insufficient. The installation of the feed box, however, resulted in higher feed velocities. During the later experiments the rotor speed was reduced which also contributed towards greater penetration.

The effect of this adjustment was not yet noticeable on the hammers at the conclusion of the tests so that it is not possible to decide whether penetration had been unduly high.

(d) <u>HAMMER CLEARANCE</u>:

In many hammer mills the distance between the outer circle of hammer travel and the breaker plate is adjustable by moving the breaker plate. In this particular machine, however, the breaker plate is fixed. This is unfortunate as the effect of the setting of the anvil clearance on the size distribution of the product might have been of great interest.

Similarly the clearance between the hammers and grid - referred to as the cage clearance - is also fixed.

Taggart,[1] however, shows that within the usual range of anvil adjustment the variation in crushing - when crushing river gravel from 4½" to 1¼ in; 420 r.p.m. - due to change in clearance is not great, but is definite and that crushing increases with reduction in clearance. The effect is shown to be the greatest in the coarse end of the product as is to be expected. This author, further shows that with a cage type mill, crushing a

---

1) Taggart A.F. "Handbook of Mineral Ore Dressing" (Wiley).

moderately hard bituminous coal, decrease in cage clearance has a consirable effect on the size of the product. Approximately 5 % more fines (- 1/8" square mesh) are produced by reducing the cage clearance from ¾" to ¼". No mention is made of the size of the bar openings.

(e) <u>CONDITION AND NUMBER OF HAMMERS</u>:

The condition of the ten hammers as found in the pulverizer was good. Only the outer tips of the hammers were slightly rounded. The number of hammers were kept constant throughout the tests. Taggart[1)] shows that the loss in crushing effect due to worn hammers when the speed is sufficiently high for effective breakage, is quite appreciable. When the speed is too low the condition of the hammers makes little difference but in a grid machine stalling occurs speedily unless the feed rate is greatly reduced. Furthermore Taggart[1)] shows that if the crushing zone is completely swept by the hammers (as is the case with this pulverizer) an increase of 50 % in the number of hammers produces only a small additional crushing effect, which becomes less appreciable the higher the rotor speed.

(f) <u>SIZE OF FEED</u>:

The Navigation No. 5 seam coal was handcrushed to pass a 4 inch square mesh screen before being used for the tests. In Fig. V111 the cumulative distribution of this feed size can be seen.

No experiments were made to determine the effect of feed size on the size of the product but in one series of tests, where 1" bar openings had been used, the +¼" material was removed and recrushed using 3/16 inch bar openings. Subsequent screening tests yielded the following results:

Rotor/................

Rotor Speed	Feed Size	% -1 mm. Material in Product.
1160 r.p.m.	-4" to 0"	39
1160 r.p.m.	-1" to +¼"	26
800 r.p.m.	-4" to 0"	27
800 r.p.m.	-1" to +¼"	20.5

Although these figures are not strictly comparable, since the fines (-¼") had not been screened out in the one case, the difference in the percentage -1 mm. material in the products is so large that one can conclude safely, that, the smaller the feed size the less fines will be produced.

Taggart[1)] states that if the 50 % point may be considered as a measure of the average size of the commuted product it may be concluded that this type of mill is decidedly more effective in the reduction of the coarser material than of the finer.

CAPACITY:

Before proceeding with the tests in which the rotor speed and bar openings were to be varied it was considered advisable to conduct a few tests to determine the capacity of the mill in order to establish what constant rate of feed could be used throughout the tests.

The capacity of the machine using the smallest bar opening ($\frac{3}{16}$") and the lowest rotor speed (600 r.p.m.) would determine the maximum rate of feed that could be used throughout the tests.

The maximum feed rate, or capacity, was taken as that rate of feed where the crusher just did not clog causing the over-load switch to stop the motor.

The following results were obtained:

Speed/..............

Speed.	Capacity with $3/16$" bar opening.
1160 r.p.m.	6750 lbs./hour.
800 r.p.m.	6650 lbs./hour.
600 r.p.m.	4500 lbs./hour.

A feed rate of 1 ton per hour could therefore be handled with ease at all proposed speeds and bar openings.

Although these figures do not, perhaps, represent the true capacities they show the manufacturer's ratings to be somewhat on the conservative side.

The capacity remained nearly constant when the rotor speed was reduced to 800 r.p.m. showing that the speed was still sufficiently high for effective breaking. The 30 % drop in capacity from 800 r.p.m. to 600 r.p.m. shows that the efficiency of the machine was being impared. Although the force of the hammer blow was still large enough to cause the fracture of a piece of clean coal the presence of a few comparatively large pieces of stone would cause the machine to clog. (This was shown to be the case when a sample of refuse had to be crushed).

ROTOR SPEED:

The fineness of a product is, to a large extent determined by the intensity of the hammer blow which in turn is directly proportional to the speed of hammer travel. Speed, therefore, is of primary importance particularly in the production of fines.

Blows of insufficient force to produce fracture i.e. too low a rotor speed, will soon cause the machine to stall or cause a serious decrease in capacity whereas when the rotor speed is unnecessarily high the blows will cause the feed particles to disintegrate to sizes smaller than the grid setting and thus causing excessive fines.

When/.........

When pulverizing it is, therefore, essential that the rotor speed should be as high as possible and, on the other hand, when a coarse product is required, that the rotor speed should be as low as possible without affecting the capacity unduly.

Figs. 1, 11, 111, 1V, V and V1 show the cumulative and fractional distribution curves of the products obtained when varying the speed and bar opening, all the other variables being kept constant.

Bar opening	Speed.	Fig.
1/8"	1160, 800 & 600 r.p.m.	Figs. 111 & V1.
13/16"	1160, 800 & 600 r.p.m.	Figs. 11 & V.
3/16"	1160, 800 & 600 r.p.m.	Figs. 1 & 1V.

It can be seen from these curves that the amount of fines produced decreases with reduced rotor speed as well as with an increase in bar opening.

Rotor Speed	Bar Opening. % -1 mm. Material in Product *		
	1/8"	13/16"	3/16"
1160 r.p.m.	15	19	38
800 r.p.m.	10	12	22.5
600 r.p.m.	8.5	9	17.5

* The feed contained 3% -1 mm. material.

The decrease in fines is more than directly proportional to the decrease in speed between 1160 r.p.m. and 800 r.p.m. but slightly less from 800 to 600 r.p.m.

Using the Rosin-Rammler equation, the curves of log x plotted against log log $\left(\frac{100}{Wr}\right)$ showed that the distribution

constant/........

constant, n, does not vary significantly for the different speeds and bar openings but that $\bar{x}$, the absolute size constant increases with reduced rotor speed.

Dispersion or Distribution Constant

Rotor Speed.	Bar opening.		
	1 1/8"	13/16"	3/16"
1160 r.p.m.	1.032	1.055	1.009
800 r.p.m.	1.032	1.033	0.972
600 r.p.m.	0.970	1.045	0.945

Taking the deviations in the value of n as due to experimental and sampling errors only, the mean dispersion constant can be taken as 1.031 which means that within the range of validity this method of breaking approximates to the ideal condition of simple fracture.

Rotor Speed.	Absolute Size Constant, $\bar{x}$. Bar opening		
	1 1/8"	13/16"	3/16"
1160 r.p.m.	0.549 cm.	0.436 cm.	0.1885 cm.
800 r.p.m.	0.741 "	0.692 "	0.331 "
600 r.p.m.	1.126 "	0.956 "	0. 372 "

From the constant value of n and these different values of $\bar{x}$ it can readily be seen that the size grading of the products remained the same but that the products obtained at the lower speeds were as a whole coarser than those produced at the highest speed.

Bar Opening:

The grate bar spacing determines the thickness of the

largest/.........

particles of the product but the size of the product is normally much finer than would be expected from the grid acting as a simple screen.

For example, using a 1 1/8" bar opening and a rotor speed of 1160 r.p.m. the product contained only 5% of plus ½ inch material. The size of the bar spacing was approximately 10 times that at the 50% point (i.e. the screen opening that will pass 50% of the product).

Calculating the ratio of absolute size constant, $\bar{x}$, to bar opening it was found:

Rotor Speed.	Ratio: $\frac{\bar{x}}{\text{Bar opening}}$		
	Bar Opening.		
	1 1/8"	13/16"	3/16"
1160 r.p.m.	0.19	0.21	0.40
800 r.p.m.	0.26	0.33	0.69
600 r.p.m.	0.40	0.46	0.78

The size of the product as given by $\bar{x}$, does not rise proportionally with the bar openings.

It is fairly reasonable to assume that when the size of the bar openings exceeds that of the anvil clearance and/or the cage clearance they will have a large effect on the size of the product. Even when the screen bars are removed the absolute size constant is approximately only 1 inch.

STAGE CRUSHING:

Fig. VII. shows the effect of crushing in two stages as opposed to one stage direct crushing.

The one ton sample was crushed to minus one inch in the pulverizer, the minus ¼" product was screened out and the plus ¼" material recrushed using a 3/16" bar opening. These two portions were then remixed and screened. The results of these tests are shown below:

Speed/...............

Speed.	Stage Crushing. % -1 mm. material	Direct Crushing. % -1 mm. material
1160 r.p.m.	23.5	38
800 r.p.m.	19.5	27

CONCLUSIONS:

1. The size distribution of a product depends not only on the bar openings but also on the peripheral speed of the hammers. Where a hammer mill is, therefore, producing excessive fines a reduction in the speed of the rotor may improve matters considerably. The reduction of speed is limited by the requirement that the capacity may not drop below requirements.

2. As the sise of the product is normally much finer than would be expected if the grate were acting as a simple screen it might be advantageous to install a grate with bar openings larger than the top size of the product. Ten percent or so of oversize might be tolerated or it may be justifiable to remove and recirculate the oversize considering that the product as a whole will be coarser.

3. Although no tests have been done to determine the effect of the anvil clearance and cage clearance it would seem as if these factors have a large effect on the size of the product. An anvil clearance smaller than the bar openings might cause an unnecessary production of fines and might, in addition, affect the capacity adversely. A clearance larger than the bar openings might cause large circulating loads to build up and, if the cage clearance is smaller than the anvil clearance unnecessary strain is put on the racks.

When it is known what size of product is required it would be advisable, in the case of a machine where the breaker-plate is non-adjustable, to select a hammer mill having an anvil clearance slightly smaller than the bar openings and a cage clearance the same or slightly larger than the bar openings.

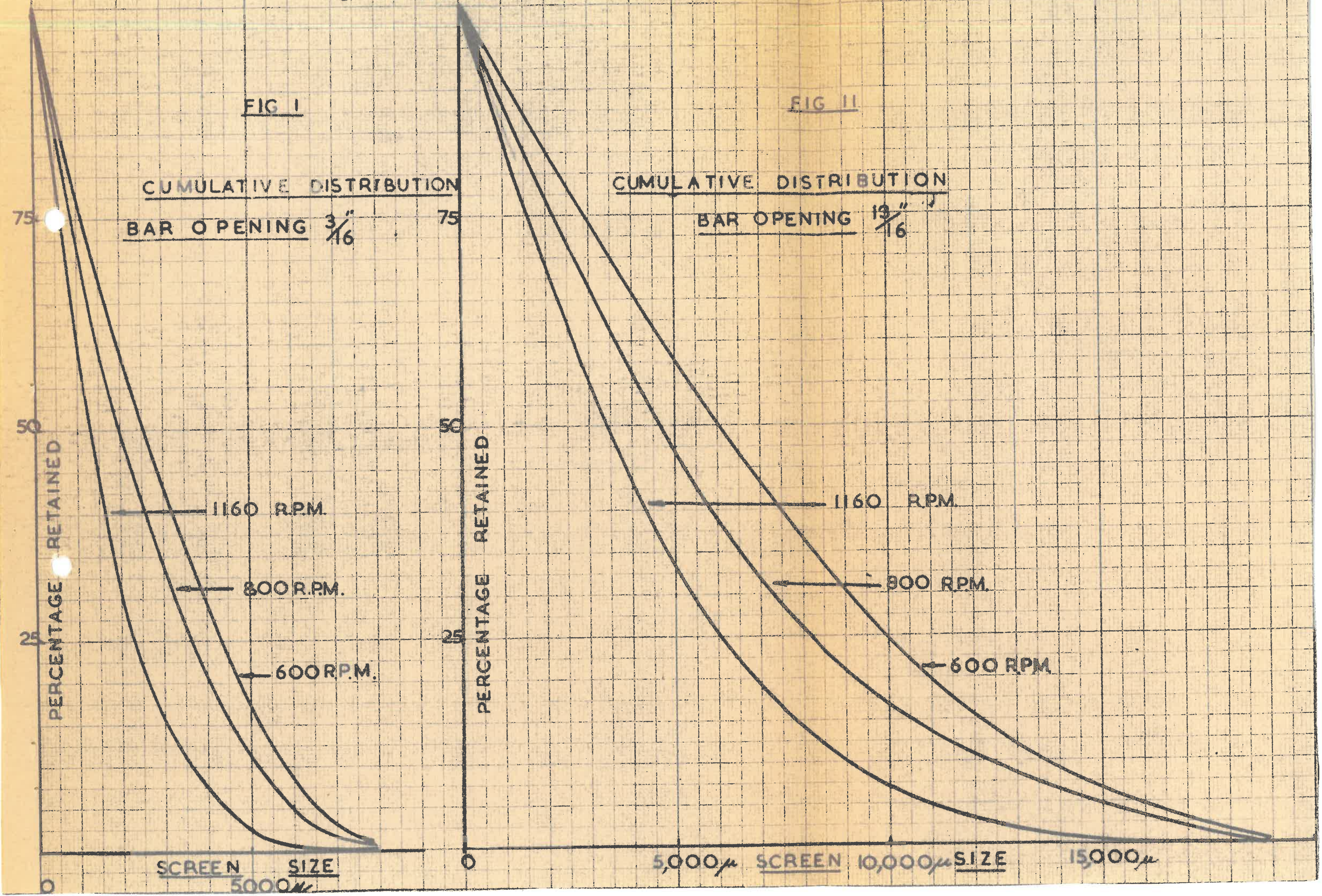
4./............

4. When using this machine for the communition of survey samples the speed of the rotor should preferably be kept at 1160 r.p.m. If, however, bulk samples are to be reduced to -3/16" for coking purposes and/or it is desired to have a minimum of minus 60 mesh material, a rotor speed of 800 r.p.m. would be more suitable. The danger of the machine clogging, especially if the samples contain stone and pyrite nodules makes it advisable never to use the machine with a rotor speed of 600 r.p.m.

C.E. BIRD.
RESEARCH OFFICER.

C.E.B./M.T.
9th August, 1951.

CUMULATIVE DISTRIBUTION CURVE



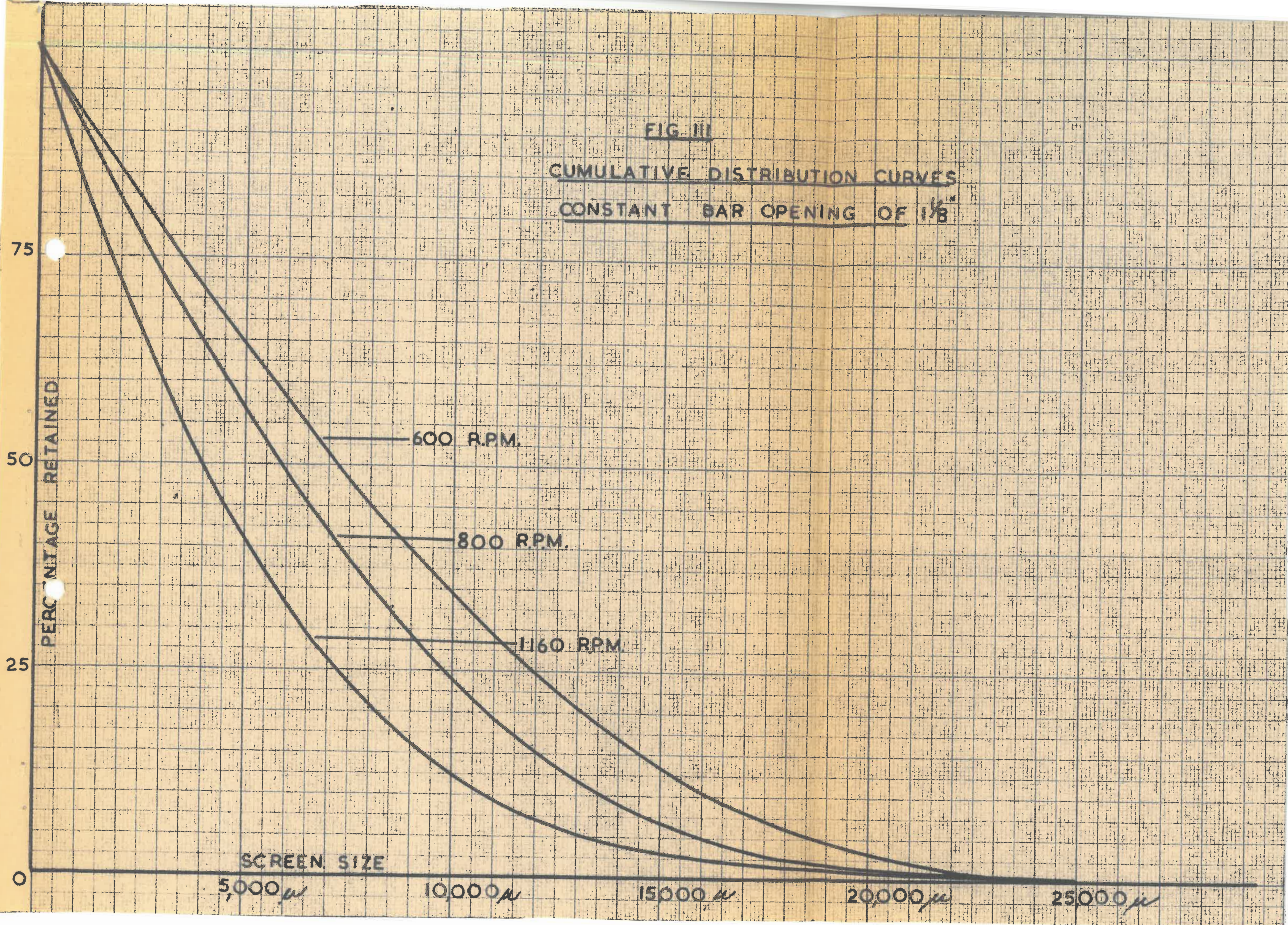


FIG III
CUMULATIVE DISTRIBUTION CURVES
CONSTANT BAR OPENING OF 1⅛"
PERCENTAGE RETAINED
75
50
25
0
600 R.P.M.
800 R.P.M.
1160 R.P.M.
SCREEN SIZE
5,000 μ
10,000 μ
15000 μ
20,000 μ
25000 μ

FIG IV

FRACTIONAL DISTRIBUTION

BAR OPENING $\frac{3}{16}$"

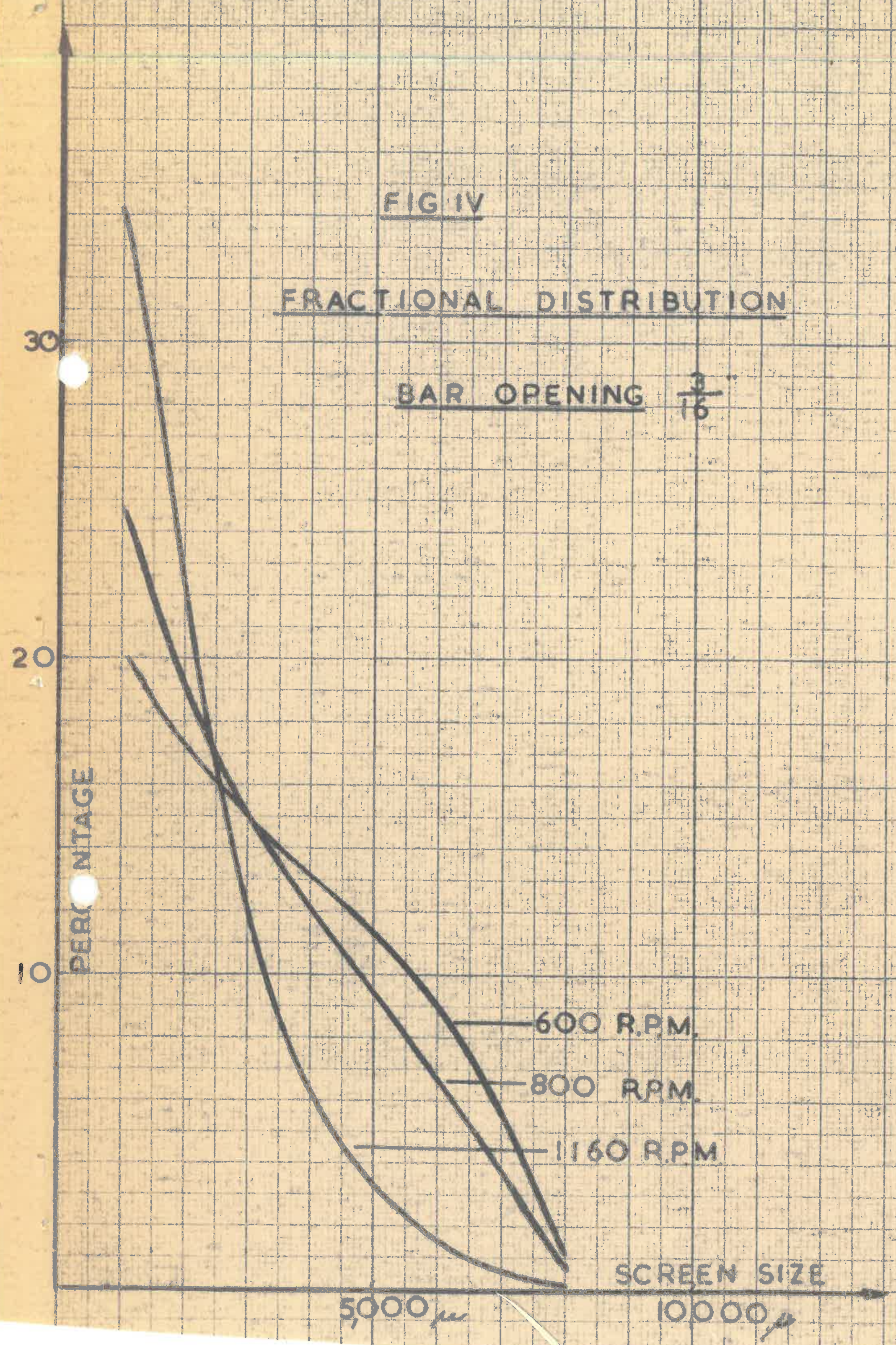


FIG V

FRACTIONAL DISTRIBUTION

BAR OPENING $\frac{13}{16}$"

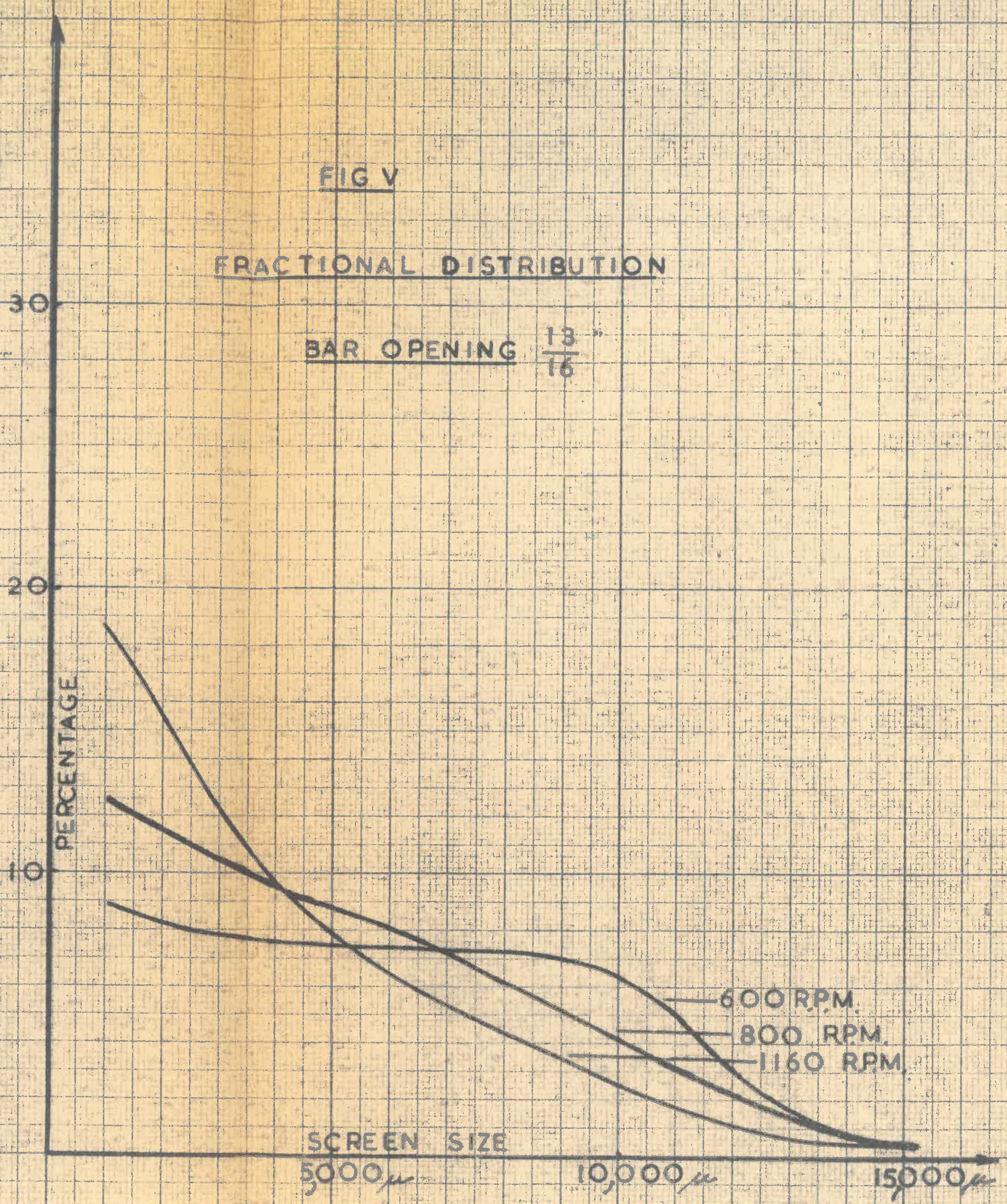
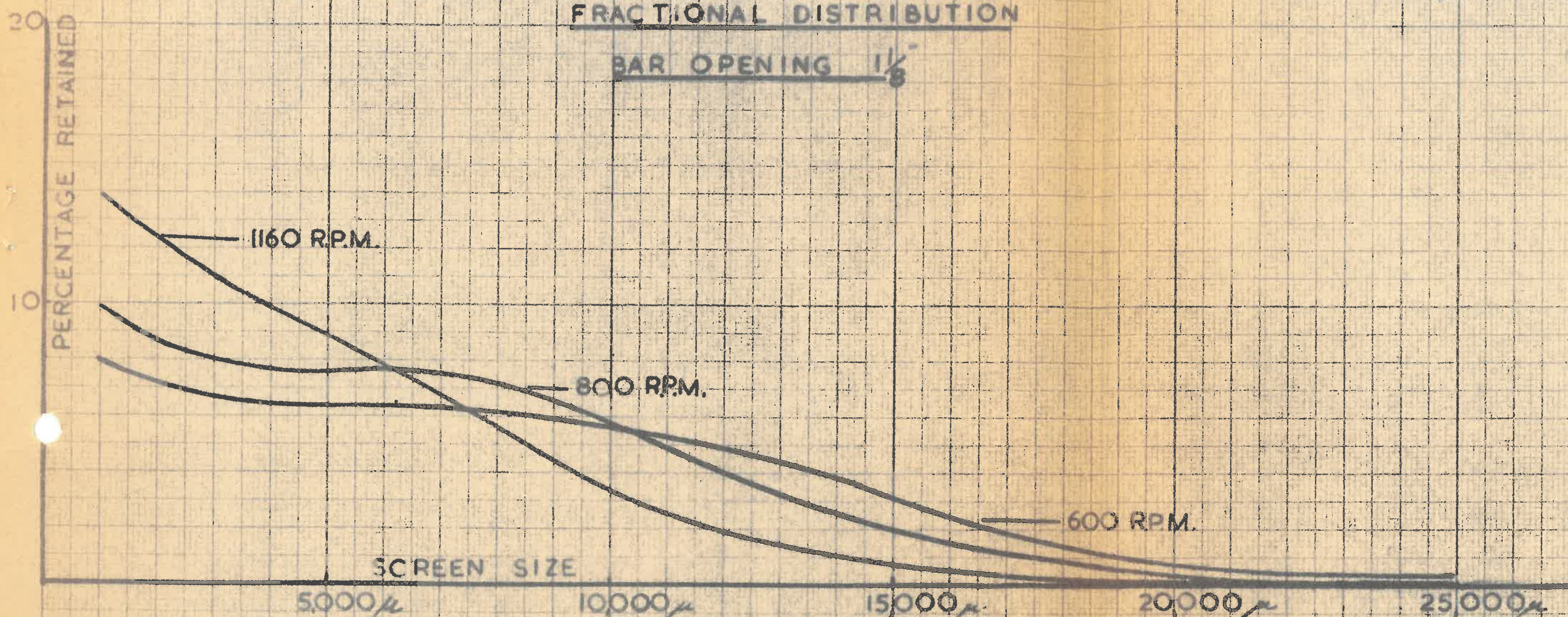


FIG VI

FRACTIONAL DISTRIBUTION

BAR OPENING 1⅛"



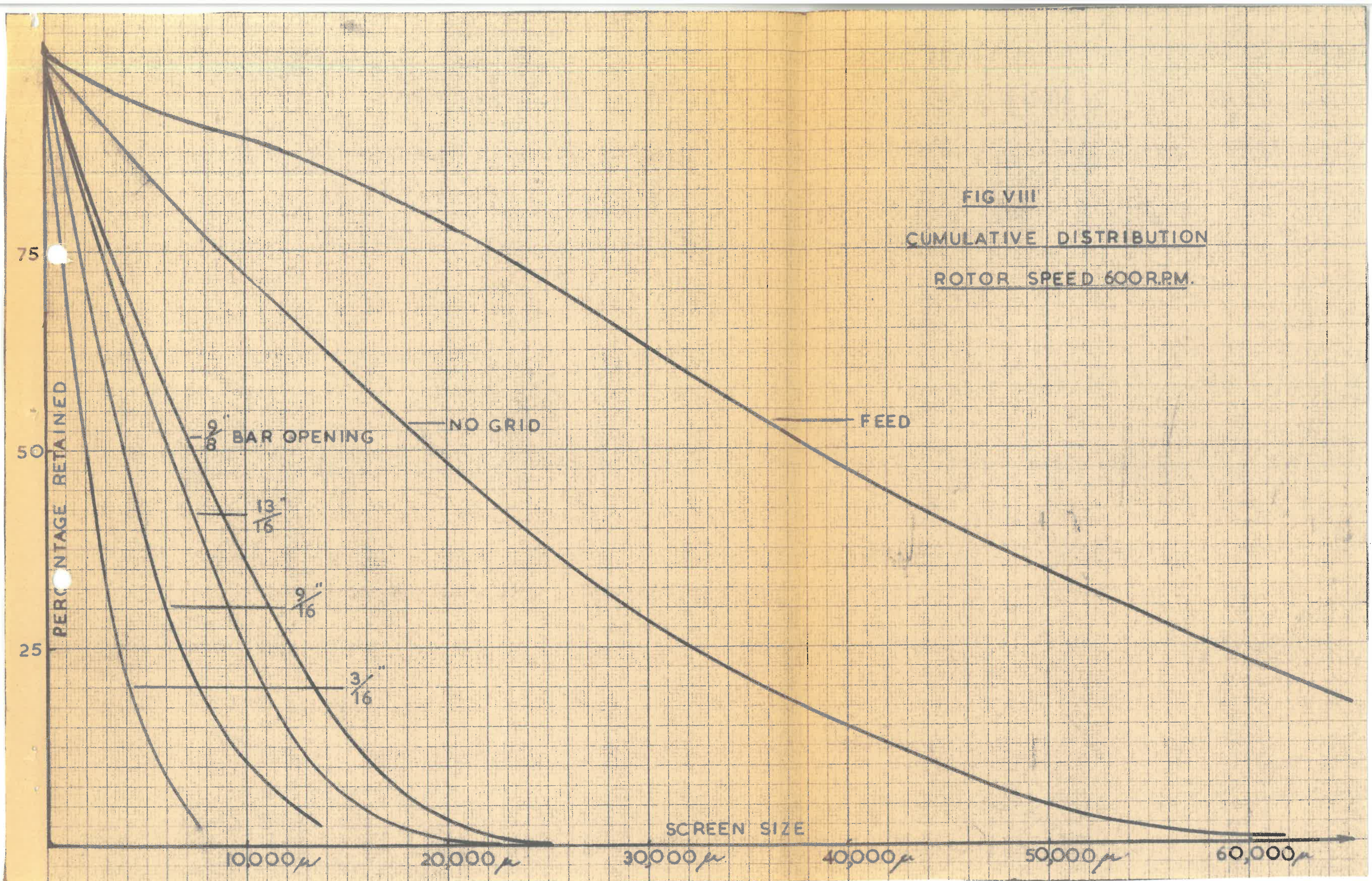


FIG VIII
CUMULATIVE DISTRIBUTION
ROTOR SPEED 600 R.P.M.
PERCENTAGE RETAINED
75
50
25
SCREEN SIZE
10000 μ
20,000 μ
30,000 μ
40,000 μ
50,000 μ
60,000 μ
FEED
NO GRID
9/8" BAR OPENING
13/16"
9/16"
3/16"

FIG VII

EFFECT OF STAGE CRUSHING ON THE CUMULATIVE DISTRIBUTION CURVE