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PRELIMINARY STUDIES OF THE EFFECT OF CERTAIN VARIABLES ON THE PERFORMANCE OF SHALLOW BATH, DENSE MEDIUM WASHERS.

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S U M M A R Y

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Experimental work on a pilot plant Drewboy washer having a nominal feed capacity of 20 t.p.h. (18 tonnes/hr.) is discussed in this paper.

After describing the installation and the method of operation, attention is given to the evaluation of results, especially the accuracy of determining probable errors. It is concluded that, to achieve reliable results the specific gravity interval chosen for the float and sink analysis of washery products should not be much larger than the expected probable error (at least not in the vicinity of the specific gravity of separation). Naturally, precautions must be taken in such an analysis to minimise experimental errors. If care is taken, however, specific gravity intervals of 0.02 can be used confidently in the float and sink analysis.

During experiments to determine the effect of load on the efficiency of separation it was found that, provided that the washer was not overloaded on either the clean coal or the refuse side, the load

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had no appreciable effect on the efficiency of separation. The limiting load of clean coal or of refuse was practically equal to the nominal raw feed capacity of the washer.

The performance of the washer was also hardly affected by the specific gravity of separation although the percentage of ± 0.1 S.G. near gravity material varied from about 60% to 25% at the various specific gravities of separation.

Finally, attention was given to the effect of the viscosity of the heavy medium suspension. The viscosity of clean shale or magnetite suspensions, within the range of specific gravities where they would be used in South Africa, had no appreciable effect on the efficiency of separation. A contamination of the heavy medium suspension by fine coal could, however, result in a very appreciable drop in efficiency.

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Most of the experimental work described in this paper was done on a shallow bath, dense medium pilot plant washer, of a nominal feed capacity of 20 tons* per hour (18 tonnes/hr)(of -3 inch +¼ inch or approximately -76 +6mm coal) being one unit in the Institute's coal preparation pilot plant.

This pilot plant, which was described in detail in 1957[1)] was planned to deal with coal having a top size of about 3 inches (approximately 76mm). The coal of a size range of about 3 inches to ¼ inch (76mm to 6mm) can be treated either in one of two dense medium separators or in a jig washer; coal of about ½ inch to 1mm (12mm to 1mm) in a Dutch State Mines cyclone separator and minus 1mm fines can be cleaned by froth flotation.

All the dense medium units can be operated with either a magnetic or a non-magnetic medium (e.g. ground shale).

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*1 Ton South Africa = 2,000 lb.

As the plant was designed for research work, adequate provision was made for controlling the feed and weighing it, as well as for the sampling and weighing of all products. Thus the following procedure was adopted in the experimental work on the shallow-bath separator:

All the raw coal brought to the plant was reduced to minus three inches (-76mm) in stages to avoid the production of excessive quantities of fines as much as possible. The minus three inch coal was passed over screens to eliminate minus $\frac{1}{4}$ inch (6mm) fines and the -3 inch +$\frac{1}{4}$ inch coal was stored in service bunkers in the pilot plant building.

The rate of withdrawal of coal and maintenance of a constant feed rate was achieved by the use of vibro-feeders and "Adequate" belt-weighers, the latter also serving to determine the total tonnage of coal used in an experiment.

Before entering the washer the coal was wet-screened to remove any fines adhering to it. These fines could be recovered and weighed.

Products leaving the bath were passed over conventional drainage, rinsing and dewatering screens and passed to product bunkers. Sampling devices were installed at the end of the dewatering screens and were so designed that the entire stream of coal leaving the screen could be diverted to sample containers. The frequency and duration of this stream diversion, during the course of an experiment, was regulated to obtain an adequate number of increments and a large enough gross sample for a subsequent accurate, detailed analysis.

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The products were transferred from the product bunkers to tubs which were weighed on a weighbridge, suitable samples being taken for moisture determination so that the necessary correction for the moisture content of products could be made*.

THE SUPPLY OF HEAVY MEDIUM SUSPENSION TO THE SEPARATING VESSEL.

The shallow-bath vessel installed at the pilot plant is a Drewboy washer which is so well known that no detailed description is necessary. The vessel was designed for supplying the heavy medium suspension at liquid level height at the feed-end of the bath, the bulk overflowing at the clean coal lip while a small proportion was to be drawn off at the bottom of the bath through an orifice of suitable aperture.

This method of operation did not yield satisfactory results. There was a tendency for a high specific gravity zone to build up in the lower levels of the bath and for the orifice to block. Provision was, therefore, made for feeding the heavy medium suspension at the normal entry ("top feed") and also at the bottom of the bath ("bottom feed") and for varying the ratio between the top and bottom feed.

By supplying some medium at the bottom of the vessel the specific gravity of the bath was more uniform throughout and better washing results were obtained.

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* The weight of all samples taken was naturally allowed for in determining the yield of products.

One can visualise, however, that if too much bottom feed were supplied, the resulting upward current would affect the separating efficiency and also the specific gravity of separation especially of the smaller sizes. Some indications of such a trend have actually been observed.

On the other hand experience on this washer has shown that a fair rate of top feed is necessary so that the float coal is carried towards the clean coal lip, and rafting, which also affects the results, is avoided.

For optimum results one would, therefore, have to regulate the top and bottom feeds within certain definite limits, the limits depending i.al. on the load on the washer.

Sufficient experimental work has not yet been done to establish these optimum operating conditions at various loads exactly, but after a number of trials a "standard" setting, yielding satisfactory results was adopted whereby the supply of top feed was 200 gallons per minute (900 litres/min.) and the bottom feed 80 gallons per minute (360 litres/min.) This setting was used in the experiments discussed in this paper.

COAL USED IN THE PILOT PLANT STUDIES.

The coal selected for the initial studies at the pilot plant was hard coal having quite difficult washing characteristics. Being hard, the degradation in handling was small and it was possible to recombine the bulk of the products from any experiment and to use

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the mixture once or twice for other experiments, either alone or mixed with fresh coal.

Various consignments were obtained from the collieries in the course of this investigation and some variation in the properties of the coal used is therefore possible

The characteristics of the coal given in Table 1 and in Figure 1, must, therefore, be regarded as typical of the coal used rather than as specific of the coal used in any particular experiment.

TABLE 1.

Proximate Analysis of Coal Used
(Air Dry Basis)

	H_2O %	Ash %	V.M. %	F.C. %
Colliery A	3.4	21.5	25.5	49.6
Colliery B	2.4	21.5	25.9	50.2

EXPERIMENTAL PROCEDURE:

The experimental procedure adopted in all experiments was as follows:

The heavy medium suspension was circulated through the washer and the specific gravity was adjusted to the desired level. The automatic control was then brought into operation, but no coal was fed until the automatic control of the specific gravity of the bath was fully established.

The vibro-feeder was then started and adjusted to feed the coal steadily at the desired rate. The plant was then run until stable conditions had been established (usually 10 to 20 minutes).

At this stage the experiment proper was started. This was usually of 30 to 45 minutes duration and during this period sample increments (about 15 lb. or 7.5 kg.) were taken of all the products at 15 to 20 second intervals.

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The heavy medium suspension in the bath was also sampled at regular intervals so that its properties could be determined.

ANALYSIS OF PRODUCTS:

Having combined all the increments representing a specific product, the resulting bulk samples were air dried, weighed and then separated into size fractions using square mesh screens of apertures $1\frac{1}{2}$ inch, $\frac{3}{4}$ inch and $\frac{1}{4}$ inch (approximately 38, 20 and 6mm).

After again saturating the coal with water, a detailed float and sink analysis was done on each size fraction, or a representative portion thereof; over a sufficiently wide band in the range of specific gravities: 1.30 to 1.70, to establish the specific gravity of separation.

Zinc chloride solutions were used for the float and sink separation of all plus $\frac{1}{4}$ inch (6mm) coal and mixtures of carbon tetrachloride and petrol for the minus $\frac{1}{4}$ inch fines.

In the analysis of products from all these experiments as well as experiments conducted on commercial washers, the Institute has taken special care to determine the partition curve as accurately as possible.

Consideration has been given to the amount of detail required in the float and sink analysis to achieve this.

In practice float and sink analysis of washery products are done stepwise, adopting a convenient

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specific gravity interval from one heavy liquid bath to the next. Distribution values are worked out from these results and the distribution values are usually plotted at the mid points of the specific gravity interval (the arithmetic mean of the limiting specific gravities of the interval).

Accepting this procedure, one may consider the effect of the specific gravity interval, chosen for the float and sink analysis, on the partition curve as follows:

Assume that the "true" partition curve in a particular separation has the shape ABODE shown in Figure 2. Let the specific gravity interval "Δ" chosen be equal to twice the probable error (ε) and assume that the specific gravity of separation is exactly at the boundary of two such intervals. It will now be clear from a study of Figure 1, that for the two intervals adjacent to the specific gravity of separation the distribution values will be 75% and 25% respectively, and those for the next pair of intervals 100% and 0% respectively. To the left and right of these intervals all other distributions will be either 100% or 0%. If a smooth curve is drawn through these points it will obviously not coincide with the hypothetical "true" curve. The error area will be exaggerated but the probable error determined will be the same as the "true" probable error.

Now, if the specific gravity interval is doubled, quadrupled etc., the distribution values will be as shown in Table 2.

TABLE 2. ../

TABLE 2.

Effect of the S.G. Interval on the Form of a Partition Curve.

S.G. Interval Δ as multiple of ε	Distribution values found	Curve in Fig.1 Indicated by
	a) Boundary of central intervals at S.G. of separation.	
2	... 100 : 75 : 25 : 0	⊙
4	... 100 : 87.5 : 12.5 : 0	⊡
8	... 100 : 93.8 : 6.2 : 0	◬
16	... 100 : 96.9 : 3.1 : 0	X
	b) S.G. of separation in middle of interval.	
2	... 100 : 87.5 : 50 : 12.5 : 0 ...	
4	... 100 : 100 : 50 : 0 : 0 ...	

It will be noted that the points move rapidly from the important section of the partition curve where distribution values range from say 80% to 20%. Therefore, the partition curves, and hence the probable error deduced therefrom become progressively more indefinite. (It must be borne in mind that point 0 is generally not known). In fact when $\Delta = 16\varepsilon$ (points X in Figure 2) a whole family of possible curves could be drawn through the available points.

As shown in the second half of Table 2, the position is not improved when the specific gravity of separation falls midway in an interval although point 0 would then be established.

In this hypothetical case the effect of a large Δ is somehat overstated as the practical "true" partition curve would be smoother than the hypothetical one shown in Figure 2. Nevertheless, it is obvious

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that, in order to obtain a reliable value of the probable error one requires points as close as possible to the 75% and 25% distribution values and to achieve this the specific gravity interval Δ should not - at least in the range of distribution values of say 80% and 20% - be much greater than the anticipated value of the probable error. One should probably aim at a $\Delta < 2\varepsilon$ for even $\Delta = 4\varepsilon$ causes a loss of much detail.

The exact determination of the probable error of an efficient washer is, therefore, no simple matter, and the concept may become of doubtful value when dealing with highly efficient washers, since it may become impossible to measure this parameter sufficiently accurately to do justice to the washer.

Conversely, it appears from this theoretical approach that, in view of the inaccuracies arising in their evaluation, the probable errors of a washer should not be reported more accurately than, ideally, $\frac{\Delta}{2}$ and certainly not better than $\frac{\Delta}{4}$.

The significance of these theoretical findings was tested by conducting a detailed float and sink analysis - at 0.02 specific gravity intervals - on products obtained during a particular experiment on the pilot plant Drewboy washer. The results of this analysis and the distribution factors calculated from these results are given in Table 3a.

Individual experimental results were then grouped to provide results on the basis of 0.04, 0.06, 0.08 and 0.10 specific gravity intervals. To save space these results will not be tabulated here.

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TABLE 3a

FLOAT AND SINK ANALYSIS OF WASHERY PRODUCTS.

Size Range →	$+1\frac{1}{2}$" (38mm)			$-1\frac{1}{2}$" + $\frac{3}{4}$" (-38 + 19mm)			$-\frac{3}{4}$" + $\frac{1}{4}$" (-19 + 6mm)			
S.G. Interval	Fractional Product	Yield Discard	Distr. Factor	Fractional Product	Yield Discard	Distr. Factor	Fractional Product	Yield Discard	Distr. Factor	Mean S.G.
	%	%	%	%	%	%	%	%	%	
>1.38	22.10	0	100	29.58	0	100	31.18	0.04	99.9	–
1.38 - 1.40	7.72	0	100	6.98	0	100	5.73	0.01	99.8	1.39
1.40 - 1.42	7.13	0	100	5.49	0	100	5.47	0.01	99.8	1.41
1.42 - 1.44	4.63	0	100	5.37	0.01	99.8	5.09	0.01	99.8	1.43
1.44 - 1.46	4.07	0	100	4.91	0.01	99.8	4.18	0.02	99.5	1.45
1.46 - 1.48	5.01	0	100	3.50	0.01	99.7	3.33	0.02	99.4	1.47
1.48 - 1.50	4.56	0	100	2.61	0.01	99.6	3.21	0.04	98.8	1.49
1.50 - 1.52	1.74	0	100	2.76	0.07	97.5	2.30	0.06	97.4	1.51
1.52 - 1.54	1.88	0.08	95.8	1.88	0.27	87.4	2.52	0.20	92.6	1.53
1.54 - 1.56	0.18	1.39	11.5	0.79	1.40	36.1	1.11	0.90	55.2	1.55
1.56 - 1.58	0	1.95	0	0.13	2.04	6.0	0.55	1.63	25.2	1.57
1.58 - 1.60	0	1.87	0	0.07	2.43	2.8	0.09	2.13	4.1	1.59
1.60 - 1.62	0	2.16	0	0	1.71	0	0.27	1.71	13.6	1.61
1.62 - 1.64	0	2.25	0	0	2.69	0	0.13	2.55	4.9	1.63
1.64 - 1.66	0	2.95	0	0	2.29	0	0.07	2.21	3.1	1.65
>1.66	0	28.33	0	0	22.93	0	0.05	23.18	2.2	–
	59.02	40.98		64.07	35.93		65.28	34.72		

The results were then used to plot the relevant partition curves and those for the $-1\frac{1}{2}$ inch $+\frac{3}{4}$ inch (-38mm +19mm) and the $-\frac{3}{4}$ inch $+\frac{1}{4}$ inch (-19mm +6mm) size fractions are shown in Figure 3. These have been drawn, on probability paper and the zero point of the specific gravity scale has been shifted for each curve, the better to show up maximum detail.

The probable errors determined from the curves are given in Table 3b, for interests sake to more dicimal places than would probably be warranted in practice. These results substantiate the theoretical conclusions. In the case of the plus $1\frac{1}{2}$ inch (+38mm) size fraction, and when using 0.02 specific gravity intervals, the only distribution values enabling one to obtain the gradient of the curve at the specific gravity of separation are: 95.8% and 11.5% and an exact evaluation of the probable error is, therefore, very difficult even with this small specific gravity interval.

With the other size grades the specific gravity interval could be increased to probably 0.04 without affecting the result significantly, but a greater interval should not be used in the vicinity of the anticipated specific gravity of separation.

TABLE 3b.

Effect of Specific Gravity Interval on Calculated Probable Error.

Size Range →	$+1\frac{1}{2}$" (+38mm)	$-1\frac{1}{2}$" $+\frac{3}{4}$" (-38mm +19mm)	$-\frac{3}{4}$" $+\frac{1}{4}$" (-19mm +6mm)
S. G. Interval	Probable Error acc. to Diagram		
0.02	better than 0.005	0.01	0.013
0.04	-	0.012	0.013
0.06	-	0.016	0.017
0.08	-	-	0.020
0.10	-	-	0.024

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One may, therefore, conclude that when testing such a washer it would be desirable to do a float and sink analysis on the larger coal at specific gravity intervals even smaller than 0.02.

Now, there are limits to the decrease in the specific gravity interval chosen for float and sink analysis, as analytical errors may become so large that the results obtained are of little significance.

Thus, it was found at the Institute that anomalous results were often obtained when the float and sink analysis was done on thoroughly air dried or dry coal samples. Ideally, the float and sink analysis must be done on coal in the same condition as that in which it is fed to the washer, i.e. usually, under bed moisture conditions. The nearest approach to this condition in laboratory tests was found to be coal saturated with moisture, and, therefore, it is the practice at the Institute to place samples under water for at least 24 hours prior to conducting the float and sink analysis.

Furthermore, the specific gravity of the heavy solutions used in the analysis must be adjusted accurately and must be kept constant. Now it was found that under the climatic conditions obtaining in South Africa the changes in the ambient temperature during the day are sufficiently large to affect the specific gravity of heavy solutions significantly.

This problem was solved at the Institute by encasing the battery of separating vessels - a sufficient number of vessels to cover the entire range of

FIGURE 4.

FLOAT AND SINK ANALYSIS.

Battery of Heavy Liquid Vessels as used at the Fuel Research Institute of South Africa.

specific gravities of interest in the study - in a water bath and providing for circulation of the water (see Figure 4). This bath has proved quite effective in maintaining the temperature of the solutions practically constant during a working day, thus reducing the periodic checking of bath specific gravities and their adjustment to a minimum. A periodic check and adjustment is, of course, still necessary (e.g. to counteract dilution effects) to ensure that reliable results will be obtained.

Finally, one must ensure that the particle count in every specific gravity fraction is large enough for the analysis to have meaning[2)]. Therefore, if a very small specific gravity interval is chosen for an analysis a rather large bulk sample will have to be treated.

Bearing all this in mind, the Institute adopted the practice of doing float and sink analyses at 0.02 specific gravity intervals, at least in the region of about 0.1 specific gravity units above and below the specific gravity of separation.

Even so, it should be realised that drawing the partition curve through the points thus obtained, introduces a subjective factor, causing a further uncertainty in the probable error in addition to that resulting from the finite size of the specific gravity interval*.

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* The magnitude of this "subjective" error may be gauged from a test carried out at the Institute. Data pertaining to three distribution curves were given to 10 persons for plotting on ordinary squared paper and on probability paper. The probable errors were then read off by others. The fluctuations about the mean value were found to be of the order of one fifth of the specific gravity interval; the use of probability paper generally resulted in smaller deviations.

THE EFFECT OF LOAD ON THE PERFORMANCE OF THE WASHER.

The results of experiments to establish the effect of load on the performance of the washer are given in Table 4. In studying this table it should be borne in mind that the washer had a nominal feed capacity of 20 t.p.h. (18 tonnes/hr.).

In the first three experiments listed in Table 4, the feed to the washer was increased progressively until in experiment 5 the refuse extraction wheel was fully loaded. A higher feed rate could, therefore, only have been used after increasing the speed of the extraction wheel, but such a step was not deemed to be advisable as the resulting turbulence in the bath would probably have affected the efficiency of separation. It is interesting to note that in experiment 5 the efficiency of separation was as good as in the previous experiments, although the total load was almost double the nominal capacity of the washer and the refuse load was almost equal to it.

Experiment 18 was done to determine the maximum product load. In this experiment a mixture of raw coal and a float fraction of the same coal (float s.g. 1.45) was fed to the washer giving a product load of about 26 t.p.h. (23.5 tonnes/hr.). The efficiency of separation was poorer on the coarser sizes, suggesting that the maximum permissible product load and been exceeded. Since better results had been obtained in experiment 5 (float load 19.2 t.p.h. or 17.3 tonnes/hr.) one may conclude that the maximum permissible float load lies between 20 and 26 t.p.h. (18 and 23.5 tonnes/hr.);

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TABLE 4.

THE EFFECT OF LOAD ON THE PERFORMANCE OF THE WASHER.

Coal Used: Coal A (Test 18. Float at S.G. 1.45 added to the Raw coal to increase float load)

± 0.1 Near Gravity material at S.G. 1.50

Approx. for	$-3'' +1\frac{1}{2}''$	(-76 +38mm)	coal	62%
Approx. for	$-1\frac{1}{2}''+\frac{3}{4}''$	(-38 +19mm)	coal	39%
Approx. for	$-\frac{3}{4}'' +\frac{1}{4}''$	(-19 + 6mm)	coal	50%

Medium Used: Ground shale.

Medium Feed: Top 200 g.p.m. (900 l.p.m.) Bottom 80 g.p.m. (300 l.p.m.)

Bath Specific Gravity: 1.50.

Exp. No.	Size Fraction	Load: Tons per hour: Product	Reject	Total	Separation: S.G.	Prob. Error
2	$+1\frac{1}{2}''$ (ca. 38mm)	3.8	4.9	8.7	1.49	0.005
	$-1\frac{1}{2}+\frac{3}{4}''$ (-38+19mm)	3.8	3.2	7.0	1.50	0.010
	$-\frac{3}{4}+\frac{1}{4}''$ (-19+ 6mm)	4.0	2.5	6.5	1.52	0.020
	$-\frac{1}{4}''$ (- 6mm)	0.2	0.1	0.3		
	Total feed	11.8	10.7	22.5		
4	$+1\frac{1}{2}''$ (38mm)	5.7	4.7	10.4	1.49	0.005
	$-1\frac{1}{2}+\frac{3}{4}''$ (-38+19mm)	4.0	4.7	8.7	1.50	0.010
	$-\frac{3}{4}+\frac{1}{4}''$ (-19+ 6mm)	4.9	3.7	8.6	1.53	0.025
	$-\frac{1}{4}''$ (- 6mm)	0.2	0.1	0.3		
	Total feed	14.8	13.2	28.0		
5	$+1\frac{1}{2}''$ (38mm)	5.6	4.7	10.3	1.50	0.005
	$-1\frac{1}{2}+\frac{3}{4}''$ (-38+19mm)	5.5	6.4	11.9	1.50	0.010
	$-\frac{3}{4}+\frac{1}{4}''$ (-19+ 6mm)	7.8	6.8	14.6	1.52	0.020
	$-\frac{1}{4}''$ (- 6mm)	0.3	0.2	0.5		
	Total feed	19.2	18.1	37.3		
18	$+1\frac{1}{2}''$ (38mm)	4.5	2.0	6.5	1.49	0.015
	$-1\frac{1}{2}+\frac{3}{4}''$ (-38+19mm)	9.7	3.2	12.9	1.50	0.020
	$-\frac{3}{4}+\frac{1}{4}''$ (-19+ 6mm)	11.9	3.8	15.7	1.52	0.020
	$-\frac{1}{4}''$ (- 6mm)	0.4	0.1	0.5		
	Total feed	26.5	9.1	35.6		

or again wellnigh the nominal feed load of the washer.

It would appear that as long as the washer is not overloaded either on the floats (product) or the sinks (refuse) side the load has no appreciable effect on the efficiency of separation.

THE PERFORMANCE OF THE WASHER WHEN DEALING WITH VARIOUS SIZE FRACTIONS OF COAL.

The ability of a washer to deal efficiently with a wide range of particle sizes presents distinct economic advantages. Preliminary experiments have, therefore, been done to determine whether the efficiency of separation of particles is affected by the presence of larger or smaller particles.

In these experiments particular attention was paid to the $-\frac{3}{4}$ inch $+\frac{1}{4}$ inch (-19mm +6mm) size fraction. In every set of experiments an effort was made to keep the washer load of this size grade constant while altering the load of other size fractions.

The results shown in Table 5 are by no means conclusive. In the case of coal A the presence of larger size fractions appears to have impaired the efficiency of separation of the $-\frac{3}{4}$ inch $+\frac{1}{4}$ inch (-19mm +6mm) size fraction whereas in the second set of experiments (on coal B) a somewhat higher efficiency of separation was obtained in the presence of the larger coal. In the latter set appreciable quantities of $-\frac{1}{4}$ inch (-6mm) material were present and this may also have affected the issue. Incidentally, it would appear as if the efficiency of separation of this $-\frac{1}{4}$ inch (-6mm) coal was affected by the presence of large coal (exp.108).

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TABLE 5.

PERFORMANCE OF THE WASHER WHEN DEALING WITH VARIOUS SIZE GRADES OF COAL.

COALS USED: A & B.

MEDIUM USED: Shale (S) or Magnetite (M)

SIZE RANGE EQUIVALENTS: 1½" ca 38mm, ¾" ca 19mm, ¼" ca 6mm.

Exp. No.	Coal	Size Range	Medium	Load Conditions: Size Fr. (ins.)	t.p.h. of Prod.	t.p.h. of Ref.	t.p.h. of Total	Separation (from part Curves) S.G.	Prob. Error
8	A	-3"+¼"	S	+1½	3.3	1.2	4.5	1.56	0.010
				-1½+¾	4.8	1.5	6.3	1.58	0.020
				-¾ +¼	5.5	1.5	7.0	1.59	0.025
				-¼	0.1	0.1	0.2		
				Total feed	13.7	4.3	18.0		
10	A	-¾" +¼"	S	-¾+¼	6.4	1.6	7.9	1.57	0.020
108	B	-3" +⅛"	M	+1½	1.1	0.9	2.0	1.52	better than 0.005
				-1½+¾	2.1	1.2	3.3	1.52	0.010
				-¾ +¼	4.1	2.3	6.4	1.54	0.010
				-¼	1.7	0.8	2.5	1.56	0.030
				Total feed	9.0	5.2	14.2		
109	B	-¾"+⅛"	M	-¾+¼	4.6	2.2	6.8	1.58	0.015
				-¼	5.0	1.5	6.5	1.62	0.025
				Total feed	9.6	3.7	13.3		

These experiments must be regarded as orientative and they will be followed up by more detailed experiments.

THE PERFORMANCE OF THE WASHER WASHING AT VARIOUS SPECIFIC GRAVITIES.

The results of experiments conducted at various specific gravities of separation are given in Table 6. The results seem to indicate that the performance of the washer was hardly affected by the specific gravity of separation although the viscosity of the heavy medium suspension increased appreciably with rising specific gravity of the suspension.

THE EFFECT OF VISCOSITY OF THE HEAVY MEDIUM SUSPENSION ON THE EFFICIENCY OF SEPARATION.

The results reported in Table 6 suggest that an increase in the viscosity of the suspension to the levels shown in that table had no appreciable effect on the efficiency of separation and it was, therefore, interesting to establish the limiting viscosity above which the efficiency of separation would be definitely impaired.

One way of increasing the viscosity would be to increase the specific gravity of the suspension (or the concentration of heavy medium particles in the suspension).

However, when using shale medium, a specific gravity of 1.6 was about the maximum specific gravity that could be maintained, with the present set-up at the pilot plant. On the other hand, the specific gravity at which the viscosity of a pure magnetite

suspension .../

TABLE 6.

PERFORMANCE OF THE DREWBOY WASHING AT VARIOUS SPECIFIC GRAVITIES.

Coal Used: A.

Size Grading of coal: -3" +¼" (ca. -38mm +6mm)

Medium Used: Ground shale.

Medium Feed: Top 200 g.p.m. Bottom 80 g.p.m.

Test No.	Properties of Medium		Total Load	Separation (Part Curve)			Near Gravity ±0.10 %
	Diff.* Viscosity (poise)	Value Yield (grams)	(t.p.h.)	Size Fraction	S.G.	Prob. Error	
6	0.020	3.7	19.2	+1½" **	1.44	0.01	51.6
				-1½"+¾"	1.44	0.01	58.0
				-¾" +¼"	1.45	0.015	52.6
2	0.068	5.7	22.5	+1½"	1.49	0.005	62.2
				-1½"+¾"	1.50	0.01	38.6
				-¾" +¼"	1.52	0.02	47.3
3	0.089	6.5	22.5	+1½"	1.53	0.005	57.8
				-1½" +¾"	1.53	0.01	49.6
				-¾" +¼"	1.56	0.02	45.8
17	0.089	5.2	17.7	+1½"	1.59	0.005	37.1
				-1½" +¾"	1.59	0.01	33.4
				-¾" +¼"	1.61	0.02	25.6

* For a description of the methods used in determing viscosity and yield value see Lit. Ref. 3.

** 1½" = 38mm
¾" = 20mm
¼" = 6mm

suspension might become too viscous would probably not be of interest in coal washing.

Attention was, therefore, given to the alternative possibility of increasing the viscosity of a heavy medium suspension by adding fine particles of relatively low specific gravity e.g. coal particles; whereby the specific gravity of the suspension would not be affected very appreciably.

As the pilot plant could not be operated for extensive periods so as to achieve a "natural" contamination of the suspension by fine coal, finely crushed coal or coal slimes from the settling tank were added to the suspension.

In this way the range of differential viscosities[3] could be extended, from the 0.020 - 0.089 poise shown in Table 6, to a maximum of 0.36 poise.

The results of 11 experiments are now available and they were used to plot the viscosity against the probable error values to see whether any trend could be observed. These plots are shown in Figure 5. Unfortunately sufficient points were not available in the high viscosity range to establish the position of the "best curve" exactly. Nevertheless, there is evidence of a definite trend and therefore of a relation between the viscosity of the suspension and the efficiency of separation.

Other factors, e.g. the yield value of the suspension and currents in the bath, would also affect the efficiency of separation and as these could not be expected to be constant in all experiments, the evidence of a relation between viscosity and probable

error .../

error shown in Figure 5 is quite good.

One may expect the points for the finer sizes to scatter more than those for the larger sizes, one reason being that any degradation of large particles in the clean coal or the refuse during handling after their leaving the separating vessel would result in the formation of smalls that would appear in the finer size fractions subjected, ultimately, to float and sink analysis to determine the relevant partition curves.

Accepting then, that the actual position of the best curves relating viscosity and probable error for various size fractions is not necessarily that shown in Figure 5, it is, nevertheless, interesting to draw a few tentative conclusions.

The curves suggest that the efficiency of separation of the +1½ inch (38mm) size fraction is hardly affected by the viscosity of the suspension until the differential viscosity exceeds about 0.2 poise. The smaller size fractions are affected sooner, the -1½ inch +¾ inch (-35 +19mm.) from about 0.1 poise and the -¾ inch +¼ inch (-19mm +6mm) size fraction from about 0.09 poise onwards, and they are apparently rather more sensitive to a further increase in viscosity than the larger coal.

These results explain why in the experiments shown in Table 6 no definite effect of viscosity on the efficiency of separation could be noted.

The results also suggest that the viscosity of a clean shale medium suspension or a magnetite suspension should have no effect on the efficiency of

separation .../

separation within the specific gravity ranges wherein they may be used for coal washing in South Africa.

However, the results tend to emphasise that care should be taken in practice to avoid excessive contamination of heavy medium suspensions with coal slimes and especially "coarser" fines (say -20 +200 mesh);* at least in South Africa where one frequently has to deal with coal having a high percentage of ± 0.1 S.G. near gravity material at the specific gravity of separation.

The practical significance of contamination of a heavy medium suspension by coal slimes can be illustrated by the following test conducted on a commercial shallow vessel, heavy medium washer. This washer had a rated feed capacity of 100 tons p.h. (of 60mm x 6 mm. or 2½ inches x ¼ inch coal), but was operated in this case at a feed load of 65 t.p.h. (58.5 tonnes/hr.).

A magnetite suspension was used and separation was to be effected at about s.g. 1.52. The grain size and size distribution of the available magnetite was not entirely satisfactory with the result that the clean magnetite suspension was not entirely stable. Nevertheless, as shown in the first part of <u>Table 7</u>, quite good results were obtained.

After completion of the test on the clean magnetite suspension; the plant was run for about 6 hours under the same conditions, but with the sprays on the prebath wet screen shut off. After contaminating the suspension in this way another test run was made (detailed sampling of feed and products over a period of one

hour .../

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* Studies at the Institute have proved that the increase in the viscosity of a heavy medium suspension by the addition of a given weight of ultra fine coal slimes is smaller than that resulting from the addition of the same weight of say - 60 +200 mesh B.S.S. coal.

hour). The results are given in the second part of Table 7. Unfortunately it was not possible to determine the exact degree of contamination of the heavy medium suspension at this stage, but it was extensive and one can conclude from Table 7, that it would be unwise, under South African conditions to allow coal slimes to build up in the suspension to this extent.

TABLE 7.

The Effect of Coal Slimes in a Magnetite Suspension.

Size Fraction	Clean Medium (Somewhat unstable suspension)			Medium Contaminated with fine coal.		
	S.G. of Separation	Probable Error	Org. Efficiency [1]	S.G. of Separation	Probable Error	Org. Efficiency
$+2\frac{1}{2}$" (+60mm.)	1.52	0.010	99.0	1.54	0.015	92.4
$-2\frac{1}{2}$"$+1\frac{1}{2}$" (-60+35mm.)	1.52	0.010	99.0	1.51	0.040	84.9
$-1\frac{1}{2}$"$+\frac{3}{4}$" (-35+19mm.)	1.52	0.010	98.7	1.55	0.080	78.4

1)

$$\text{Organic Efficiency} = \frac{\text{Yield of clean coal obtained}}{\text{Theoretical yield of clean coal at the ash content of the clean coal actually obtained.}} \times 100$$

CONCLUSION:

In this short review of the studies conducted at the Institute's pilot plant it was only possible to touch on a few aspects of the research programme. It would appear that, provided the washer is operated under conditions of relatively low viscosity of the

heavy .../

heavy medium suspension, the efficiency of separation of the shallow-bath, heavy medium washer is not materially affected by quite appreciable changes in either the load, its size distribution or the specific gravity of separation (which, incidentally, implies (Ref. Table 6) appreciable changes in the percentage of ± 0.1 S.G. near gravity material at the specific gravity of separation).

LITERATURE REFERENCES.

1. van der Walt, P.J. Collins, F.W. and Needham, L.W.; "Coal and Base Minerals of Southern Africa", June, 1957, vol. 5, No. 4.

2. Techn. Paper No. 3, "Methods for Float and Sink Analysis of Coal". (Panel No. 1) B.C.R.A. Jan., 1952.

3. van der Walt, P.J. and Fourie, A.M.; "Determination of the Apparent Viscosity of Suspensions in a Stormer Viscosimeter". Second International Coal Preparation Congress, Essen, Sept. 20 to 25, 1954.

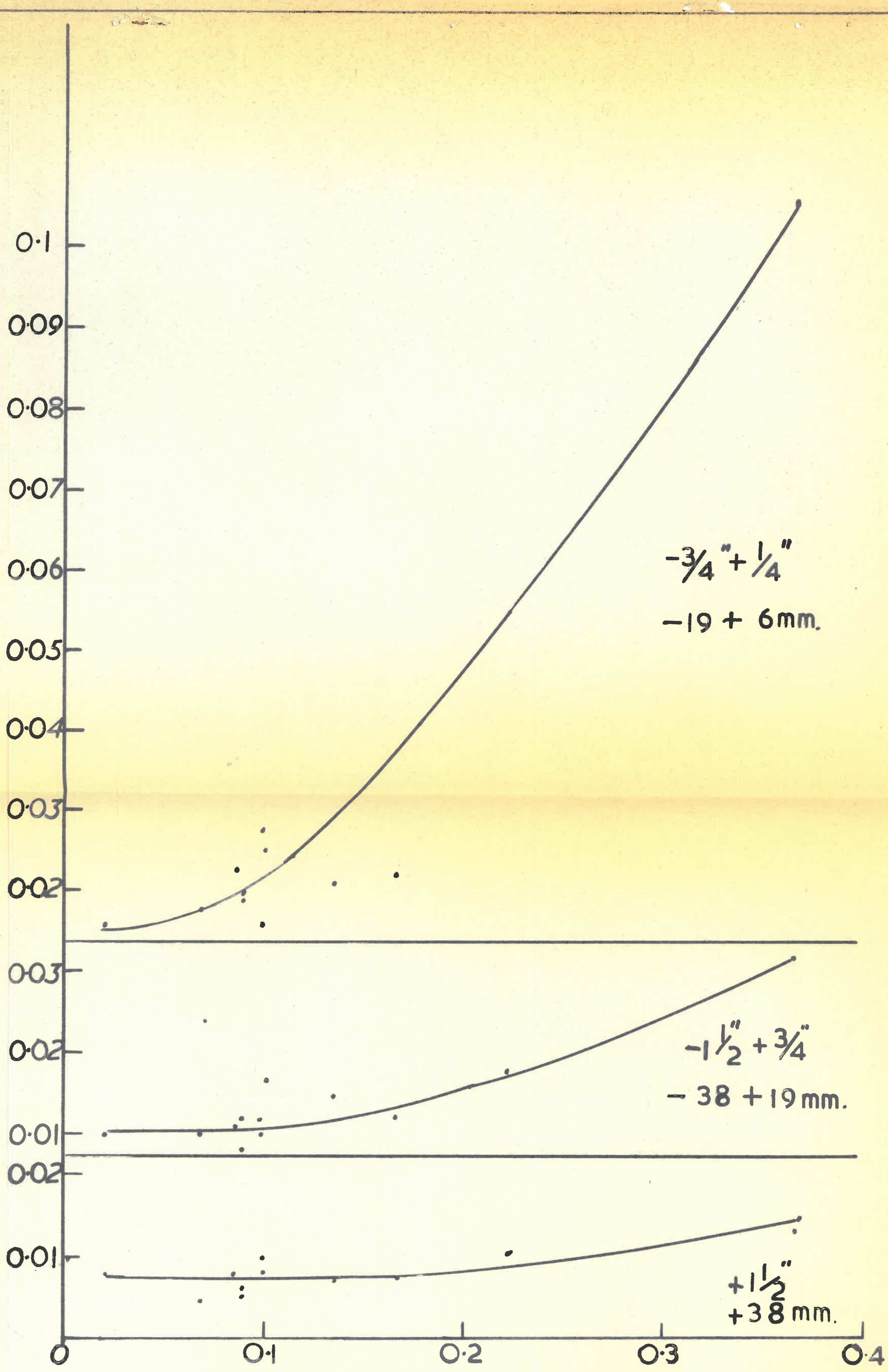
0·1
0·09
0·08
0·07
0·06
0·05
0·04
0·03
0·02
0·03
0·02
0·01
0·02
0·01
0
0·1
0·2
0·3
0·4
-3/4" + 1/4"
-19 + 6mm.
-1 1/2" + 3/4"
- 38 + 19 mm.
+1 1/2"
+38 mm.

FIG. 5

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PERSONAL FACTOR IN EVALUATION OF DISTRIBUTION CURVES.

In order to evaluate this factor, Tromp Distribution Curves were drawn by 10 different persons, using the data of Table No. 1.

TABLE NO. 1.

	Distribution			Distribution
S.G.	I	II	S.G.	III
< 1.38	100	99.9	< 1.40	99.8
1.38 - 1.40	100	99.8	1.40 - 1.48	99.7
1.40 - 1.42	100	99.8	1.48 - 1.56	88.4
1.42 - 1.44	100	99.8	1.56 - 1.64	11.5
1.44 - 1.46	100	99.5	> 1.64	0
1.46 - 1.48	100	98.4		
1.48 - 1.50	100	98.8		
1.50 - 1.52	100	97.4		
1.52 - 1.54	95.8	92.6		
1.54 - 1.56	11.8	55.2		
1.56 - 1.58	0	25.2		
1.58 - 1.60	0	4.1		
1.60 - 1.62	0	13.6		
1.62 - 1.64	0	4.9		
1.64 - 1.66	0	3.1		
> 1.66	0	2.2		

The results of the Probable Error Evaluation were as indicated in Table No. 2, overleaf.

TABLE NO. 2.

Calculator	Probable Error (10^{-3} S.G. Units)					
	using probability paper			using linear Paper		
	I	II	III	I	II	III
1	4	14	15	6	15	21
2	3	12	22	6	11	20
3	4	13	21	1	13	17
4	4	15	21	1	12	20
5	4	14	21	4	12	16
6	4	14	22	5	14	20
7	5	12	22	3	11	9
8	5	11	13	5	12	19
9	4	9	12	1	4	20
10	5	13	20	1	9	27
Average	4	13	19	3	11	18
Largest Deviation (absolute)	1	4	4	3	4	9
Largest Deviation %	25	31	21	100	36	50
% of S.G. interval	5	20	5	15	20	12

This illustrates that the personal factor in evaluating a distribution curve is considerable, further that the use of probability paper generally reduces the scatter.

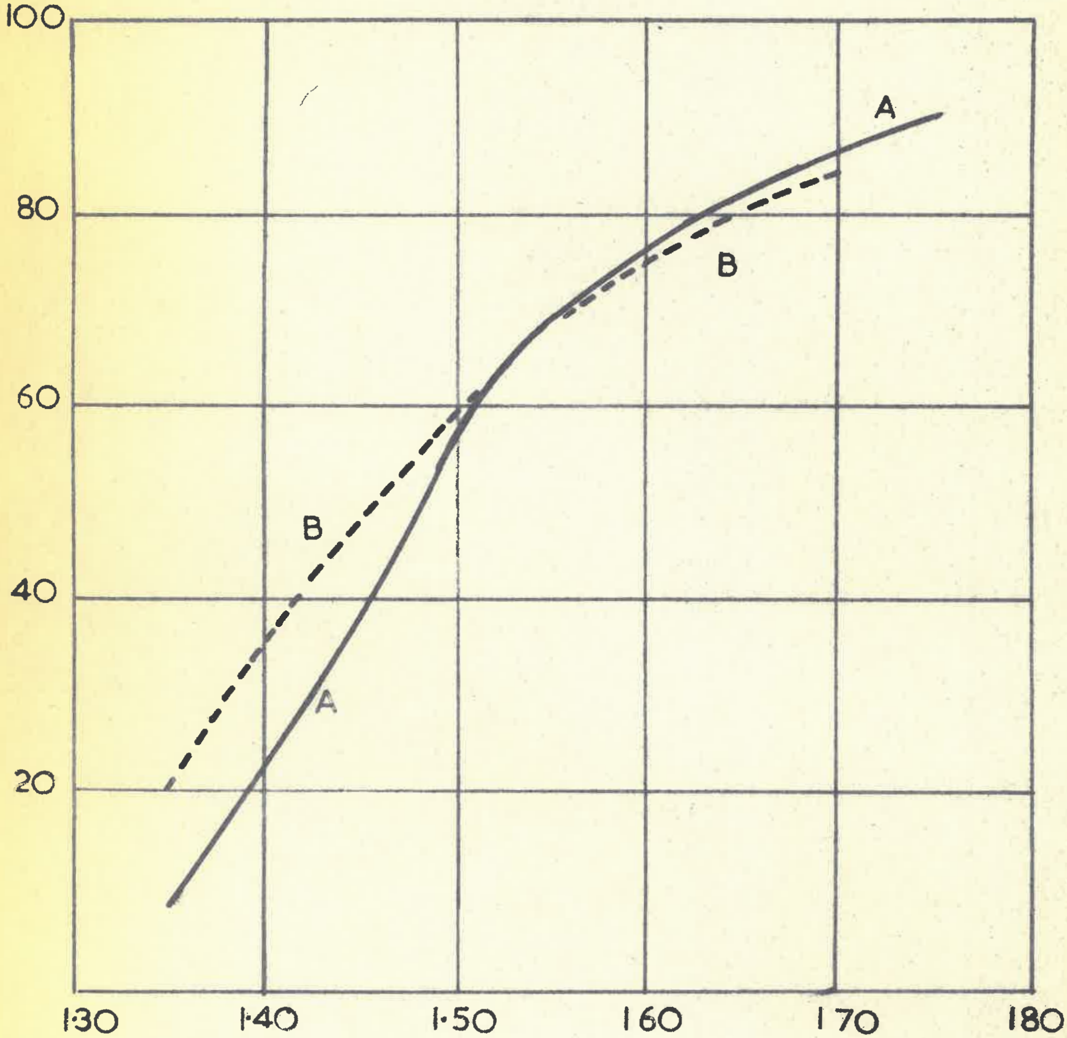

FIG.1

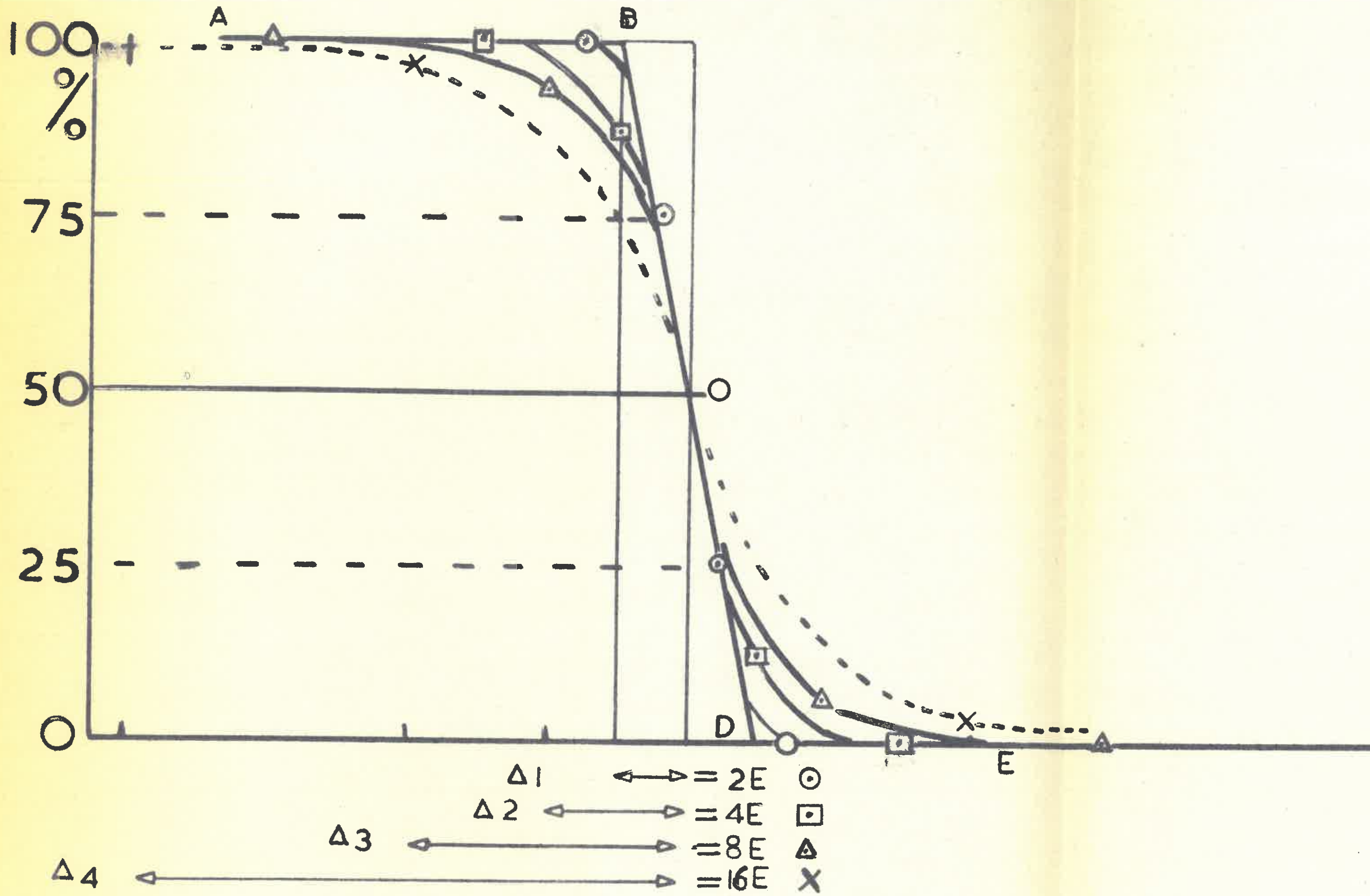

FIG. 2

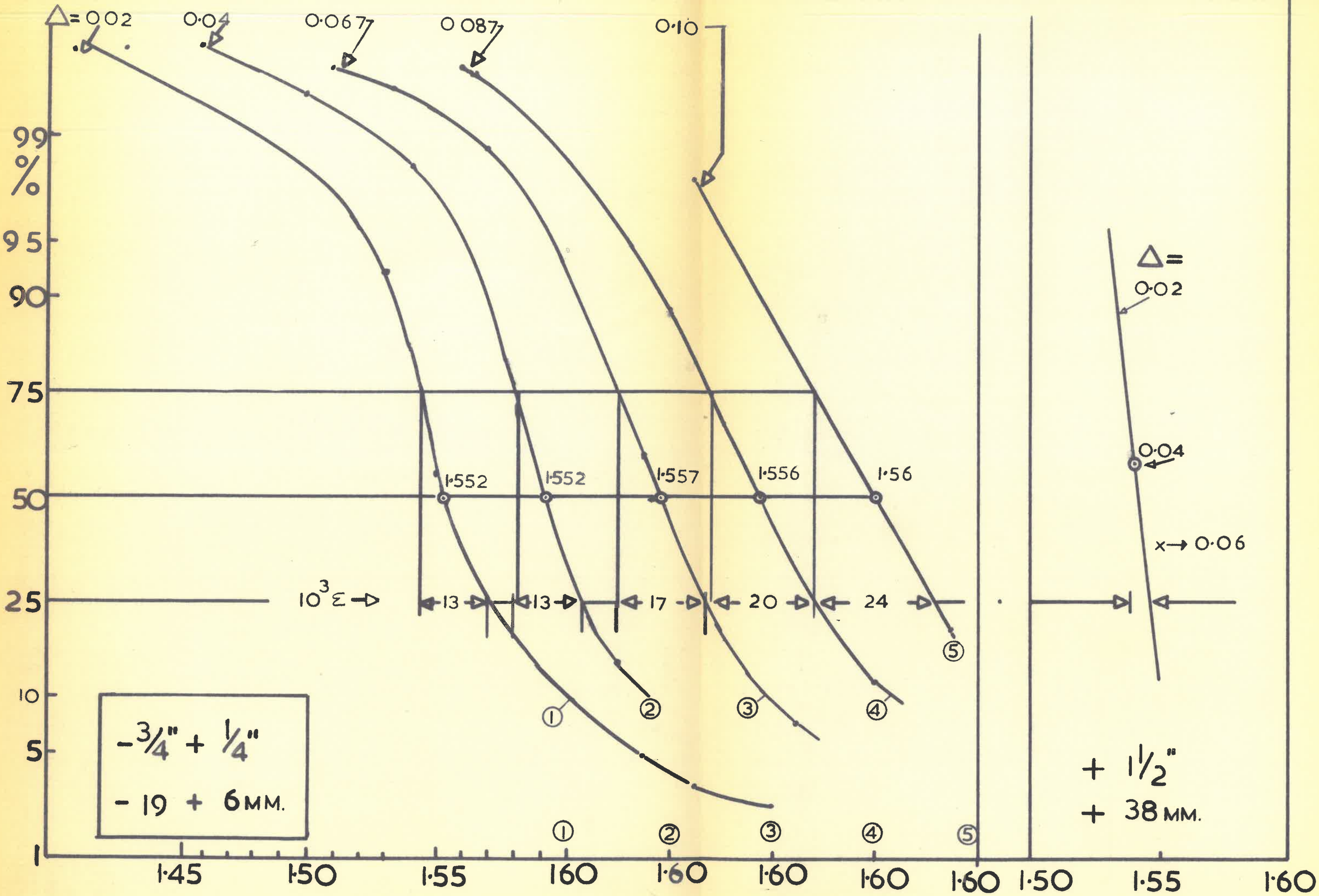
Δ = 0·02
0·04
0·067
0·087
0·10
99
%
95
90
75
50
25
10
5
1
1·552
1·552
1·557
1·556
1·56
$10^3 ε$ →
13
13
17
20
24
① ② ③ ④ ⑤
$-\frac{3}{4}" + \frac{1}{4}"$
− 19 + 6 MM.
1·45
1·50
1·55
1·60
1·60
1·60
1·60
1·60
1·50
1·55
1·60
Δ =
0·02
0·04
x → 0·06
$+ 1\frac{1}{2}"$
+ 38 MM.

FIG. 3