Mr. Savage.

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FUEL RESEARCH INSTITUTE

OF SOUTH AFRICA.

BRANDSTOF-NAVORSINGS-INSTITUUT

VAN SUID-AFRIKA.

SUBJECT:
ONDERWERP: THE EFFECT OF VARIATIONS IN THE MOISTURE CONTENT ON THE FLOAT AND SINK ANALYSIS OF LARGE COAL.

DIVISION:
AFDELING: CHEMISTRY.

NAME OF OFFICER:
NAAM VAN AMPTENAAR: W.H.D. SAVAGE.

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FUEL RESEARCH INSTITUTE OF SOUTH AFRICA.

REPORT NO. 18 OF 1951.

THE EFFECT OF VARIATIONS IN THE MOISTURE CONTENT ON THE FLOAT AND SINK ANALYSIS OF LARGE COAL.

INTRODUCTION:

A previous publication[1] has indicated that South African coals show appreciable changes in apparent* specific gravity with varying moisture content, the two effects running parallel. Only coal smaller than ¼" had at that time been studied. The present paper is an extension of the investigation dealing with large coal.

In the course of another investigation[2] comparative specific gravities of individual lumps of coal with varying moisture contents were done. Two series of experiments were carried out, the lumps saturated by prolonged immersion under water being compared with the same lumps (a) after air-drying for four to five days and (b) after oven-drying at 105°C for two days. The results of these tests were not given in detail in that communication, and a summary of the results by type of coal is given in Table 1. The samples tested came from the No. 2 Seam of the Landau No. 2 Colliery in the Witbank district. The experiments show a tendency for the decrease in specific gravity to be greater for the denser types of coal. The average decrease for the air-dried samples was 0.015 units, and for the oven-dried samples was 0.025 units of specific gravity. Apparently in neither case, however, was equilibrium attained, for duplicate determinations were carried out with intermediate redrying and the second determination was on the average 0.005 units lower for the air-dried samples, and 0.006 lower for the oven-dried samples.

PRESENT INVESTIGATION:

In the present investigation samples of approximately cobble sized coal from five typical collieries in the major coal-fields were taken. No attempt was made to get representative samples, and in fact where it was possible the sample consisted

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* During the remainder of this report, "apparent" will be dropped, but it must be understood unless inconsistent with the test.

of a mixture of washed coal and secondary discard from Baum type washing plants in order to get the specific gravity distribution of the sample up to 1.70 as even as possible. The samples weighed between 1300 and 1500 pounds, but a second sample from Greenside Colliery weighed only 1100 pounds. The samples were kept moist during transportation to the Institute, and placed under water on arrival. The samples were separated into fractions of 0.05 specific gravity units ranging from 1.30 to 1.70, for which a coalometer with zinc chloride solutions was used. The method of operation was to drain off the water from the sample, take an increment of not more than 40 pounds, rinse in a bath of zinc chloride solution of the correct specific gravity to avoid diluting the solution in the coalometer, and then place in the coalometer for separation into floats and sinks. The products obtained were washed free of zinc chloride and then stored under water pending separation at the next specific gravity. The normal procedure was to separate the sample first at 1.50 specific gravity, and to retreat the floats and sinks so obtained sequentially in 0.05 S.G. stages down and up to obtain the full range of fractions. As soon as a fraction had been completely separated and washed free of zinc chloride, it was placed in the open air until surface dry and then stored in an open shed for a week*. After air-drying the fractions were weighed and any fines less than ½" screened out. The fractions were then refloated at their lower limiting specific gravity, care being taken that the specific gravity of the bath was the same as for the original separation. The floats and sinks so obtained were dried and weighed. Due to differences in moisture content and the removal of fines the total of the final weights was always less than the original, and the original weights of the fractions were adjusted to agree with the final weights. The results of the tests are given in Tables 2 to 4 and

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* The Cornelia sample was allowed to air-dry for 10 days, as the weather was rainy initially, and the coal still appeared clammy after 3 days drying.

Figures 1 to 3 at the end of the report. Table 2 contains the cumulative yield/specific gravity data of the saturated and air-dried samples, and Table 3 gives the refloats at the various specific gravities expressed as percentages of (a) the whole samples and (b) the fractions from which the refloats were derived. In Table 4 the refloats are expressed as the shift in specific gravity which has occurred on air-drying, the (a) results being derived from the values in Table 3 (b) by multiplying by a factor of 0.0005 (i.e. assuming a straight line relationship between yield and specific gravity over each fraction), and the (b) results being obtained from the graphs in Figures 1 to 3. In these graphs the curves refer to the cumulative yields of the saturated samples at the various specific gravities. These curves were drawn as best curves passing through all the determined points. The refloats on air-drying are indicated by the vertical lines arising from the 0.05 S.G. intervals, the specific gravity shifts being represented by the horizontal lines from these vertical lines to their point of intersection with the curves. The curves were coupled as shown in the figures merely to avoid overlapping as far as possible.

DISCUSSION OF RESULTS:

The cumulative yields (Table 2) show considerable differences between the saturated and air-dried samples in the lower and middle portions of the specific gravity range, but only slight differences at high specific gravities. These differences are more obvious in Table 3 (a), from which it is apparent that the greatest difference is generally found at 1.40 S.G., the Burnside sample showing a maximum effect at 1.35 S.G. The sample from Witbank Consolidated Coal Mines exhibited only slight changes in amounts of refloats over the range 1.40 to 1.50 S.G., and the Greenside No. 1 sample shows a distinct tendency towards increased refloats at the highest specific gravities. The maximum refloats varied from 16.5 % for Natal Anthracite to 3.0 % for the first

Greenside/..........

Greenside sample. The total number of refloats between these limits for all the fractions tested was twelve, and forty-one refloats were less than 3.0 % of the whole sample. These results indicate that quite large differences can be expected in the apparent specific composition of a particular sample of coal with changes in humidity.

It can be shown that the moisture content influences the amount of near gravity material (material within ± 0.1 S.G. units), which is a measure of the ease with which coal can be washed. Generally the air-dried samples had smaller amounts of near gravity material except at low specific gravities. The difference, however, is not more than 5 % when the near gravity material does not exceed 30 %, so that this effect is not of very great importance. The Greenside samples showed only minor differences over the whole range of specific gravity.

The amount of refloat obtained is obviously dependent on the quantity of material just denser than the specific gravity at which the test is carried out, and the values given in Table 3(b), where the refloats are expressed as percentages of the originating fraction of 0.05 S.G. range, show much less variation proportionally than those in Table 3 (a). The values for the lightest fractions of all the samples are low, due partly at least to the change of slope (tail effect) at the low specific gravity end of the graphs; for the rest the values lie between 10 and 53 %. In general the Greenside samples show less refloats than the other samples, although at the high specific gravities the Burnside sample gave the lowest figures. On the average the refloats amount to about 25 % of the original fractions.

In Table 4 (b) the refloats are expressed as the shift in specific gravity that has occurred on air-drying. The (a) values are purely for comparison to determine, together with the abnormalities of the curves, in how far the (b) values are reliable. When the slopes are steep and regular the (b) values should be

correct/.............

correct within 0.001 units. Where the curves are nearly horizontal or abnormalities occur the error may be several times this value. This is partly due to errors in drawing the curve and reading off the specific gravity interval, and partly due to the small weight and thus the small number of particles (minimum perhaps less than 20) in the fractions as originally separated. Where the sample is so small, an even distribution of material over the specific gravity range cannot be expected. Excluding the original floats at 1.30 S.G. and sinks at 1.70 specific gravity, ten of the fractions weighed less than 50 pounds, and four of these weighed 25 pounds or less.

The specific gravity shifts at 1.70 are not very accurate as the curves had to be extrapolated to obtain these values. The values for Burnside, Greenside No. 1, and possibly W.C.C.M., at 1.50 S.G. are too high due to analytical error. Analytical errors are at a maximum here, due to the whole sample being treated at this specific gravity. The Natal Anthracite results appear to be incorrect at 1.35 and 1.60 S.G. due to graphical errors.

If due regard to possible errors is taken, a certain pattern in the results is evident. Burnside and to a lesser extent Cornelia show larger effects at lower specific gravities, while the two Greenside samples show the reverse tendency. The results vary between 0.005 and 0.020 S.G. units with a mean value of 0.0115. The last column of Table 4 gives the mean shift for the different samples at all specific gravities. The two Greenside samples give the lowest values and the W.C.C.M. and Cornelia samples the highest. The range is not very great (0.009 to 0.013), and indicates that most South African coals can be expected to give fairly large but not widely divergent results. The average values for all the samples at the different specific gravities are also fairly constant, varying from 0.009 to 0.014.

The effects of air-drying on the specific gravity in view of their extent cannot be ascribed to analytical errors. It was, nevertheless, decided to test the accuracy of the method.

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For this test the second sample of Greenside coal was obtained. Greenside coal was chosen because it had shown the least effect on the largest fractions. This sample was separated and air-dried as before. The fractions were then refloated at their upper limiting specific gravities, dried for a further day, and then refloated at their lower limiting specific gravities. The amount of resinks was in all cases negligible, being from ½ to 1½ pounds for the fractions 1.35 - 1.4 to 1.50 - 1.55 S.G. and less than ¼ pound for the rest, out of a total sample weight of 1100 pounds. Expressed as a percentage of the originating fraction, the maximum value was 1.2 %. The refloats and residual fractions of this sample were crushed and their ash contents determined. The results are given in Table 5. If the mean specific gravities are plotted against ash contents the results lie almost on a straight line, confirming that the refloats are due to a shift in specific gravity on drying, and not to analytical errors.

SUMMARY AND CONCLUSIONS:

Samples of approximately cobble sized coal from five collieries in the major producing coalfields of South Africa were subjected to separation into fractions of 0.05 S.G. range from 1.300 to 1.700 in the saturated state using zinc chloride as medium. These fractions were air-dried for a week and then refloated at their lower limiting specific gravities. These refloats were calculated as percentages of the original samples and also of the fractions from which they were derived, and estimated graphically as a shift in the apparent specific gravity of the coal. Three of the samples had maximum refloats representing more than 10 % of the whole sample. Expressed as percentages of the originating fraction, the refloats averaged about 25 with a maximum of 53. The specific gravity shift varied from 0.005 to 0.020 units, averaging 0.0115 units. There was no constant tendency, some samples showing larger effects at low and others

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at high specific gravities. If the results are averaged only slight variations are shown, either for all coals at the various specific gravities, or for the separate coals at all specific gravities, and these latter showed no definite relationship with the rank of the samples.

The effect of variations in the moisture content on the apparent specific gravity of large coal can thus be large, and it is desirable to standardise the moisture content of samples to be tested by float and sink methods. The simplest method of doing this is to keep the samples under water or in an atmosphere saturated with water vapour. This method is desirable as it simulates the condition of new-wrought coal. The specific gravity determinations on individual lumps of coal indicate that equilibrium in the air-dry or oven-dry state is not easily attained, and excessive drying of samples, especially where these are of low rank, is likely to be accompanied by undesirable size degradation. It is particularly desirable that results should be accurate when carrying out efficiency tests on washing plants, and for such tests samples should be kept surface wet until separated into the final fractions. While a certain amount of extra handling and time are involved in storing samples under water, some compensating advantages occur, namely that the water removes adherent dust from the coal thus minimising the build-up of fine coal in the separating medium, that the samples are more easily freed of zinc chloride solution, and that the slacking of low rank samples due to weathering is kept at a minimum.

ADDENDUM:

Although the following remarks would have been more in place in a previous communication,[1] they are included in this paper.

Nine samples of weathered coal were taken in the Utrecht district, Natal, in 1946 by one of the authors, and these samples were subjected to float and sink tests in carbon tetrachloride/benzol mixtures at 1.45 and 1.58 S.G. on air-dried -16 mesh B.S. coal. Sixteen normal samples were taken from the same vicinity and subjected to the same analytical procedures. Summarised data for all these samples are given in the following table:-

COMPARATIVE DATA FOR NORMAL AND WEATHERED SAMPLES.

Source of Samples	Weathered (Surface Exp.)	Weathered (Mine)	Normal (Mine)
No. of Samples	6	3	16
Proximate Analysis (Air-dry)			
Moisture %	12.8-16.3	6.4-10.6	1.0- 2.8
Ash %	10.4-18.7	8.7-15.9	10.1-32.0
Volatile Matter %	19.6-21.7	13.4-21.3	15.6-30.3
Separation at 1.45 S.G.			
Float Yield %	0	0	9.3-89.7
Float Ash %	-	-	4.9- 8.8
Sink Ash %	-	-	25.5-42.5
Separation at 1.58 S.G.			
Float Yield %	38.1-87.9	51.3-88.7	33.0-94.6
Float Ash %	8.1-12.8	6.9- 9.1	5.9-15.6
Sink Ash %	19.9-31.2	22.9-27.8	40.4-58.1

In the above table two distinctions between the weathered and normal samples are apparent, namely the much higher moisture content and lack of floats at 1.45 S.G. of the former. All the normal samples contain some float at 1.45 S.G., and those (12 in number) with less than 20 % ash have more than 45 % floats. At 1.58 S.G. the same 12 normal samples all have over 80 % floats, while four of the weathered samples have less 70 % floats. Further the ash contents of the sinks at S.G. 1.58 of the weathered coal are abnormally low. In general they are lower than those of the sinks at S.G. 1.45 of the normal samples, for only 5 of the latter are lower than the highest ash (31.2 %) on the sinks at S.G. 1.58 of the weathered coals. The ashes of the sinks of the weathered samples at S.G. 1.58 correspond to average apparent specific gravities of normal South African coals ranging from 1.50 to 1.65.

The/...........

The above data indicate that the specific gravities of the weathered samples are at least 0.1 units higher than normal coals of the same ash and volatile matter contents, but differing considerably in moisture content. Weathering involves a change in the coal substance and an increase in moisture content, but if the latter is the main change it is difficult to understand how this can increase the specific gravity, seeing that water is lower in specific gravity than coal. The coal substance may well increase in specific gravity, but it seems unlikely that this increase would be sufficient to counterbalance the effect of the additional moisture and still cause the marked increase in specific gravity noted. It appears that the molecular association between the constituents of the weathered coal is closer than in normal coals.

That weathering does not always have a very pronounced effect on specific gravity is exemplified by the following analysis of a sample also taken in 1946 near Newcastle:-

Sample No.	Moisture %	Ash %	Volatiles %	Float 1.45 S.G. %	Ash On Float %	Ash on Sink %
P 294 E	15.9	13.6	25.2	48.4	9.2	20.8

Though the float yield is rather less than would be expected, the specific gravity displacement must be very definitely less than 0.1 units.

It is interesting to note (Fuel 1951) that the apparent S.G. of coal with less than 80% C shows a tendency to increase to 1.4-1.5, and weathering may have an analogous effect on coal to intrinsic low rank.

W.H.D. SAVAGE.

ASSISTANT DIRECTOR.

W.H.D.S./M.T.
15th August, 1951.

REFERENCES.

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2. T.J.F. Hübrig, J.M. v.d. Merwe and W.H.D. Savage. Jnl. Chem. Min. Met. Soc. S.A. Vol. 51 P. 321. (F.R.I. Report No. 1 of 1951).

TABLE 1.

EFFECTS OF AIR-DRYING AND OVEN-DRYING ON THE SPECIFIC GRAVITY OF LUMPS OF COAL.

A. AIR-DRIED COMPARISONS..

Type of Coal	No. of Samples	Weight (gm.) Min.	Max.	Spec. Gravity Min.	Max.	Average Decrease in S.G. for dry samples
Gas	6	36	158	1.29	1.31	0.008
Smithy	8	21	230	1.31	1.33	0.016
Mixed	7	35	198	1.37	1.48	0.012
Dull	6	58	177	1.42	1.53	0.021
Holing Band	6	34	232	1.47	1.70	0.017

Weighted Average Decrease in Specific Gravity = 0.015 units.

B. OVEN-DRIED COMPARISONS.

Type of Coal	No. of Samples	Weight (gm.) Min.	Max.	Spec. Gravity Min.	Max.	Average Decrease in S.G. for dry samples.
Gas	4	84	131	1.29	1.38	0.021
Smithy	3	65	101	1.30	1.41	0.021
Mixed	4	41	129	1.36	1.41	0.028
Dull	1	98		1.45		0.028
Holing Band	1	98		1.43		0.033

Weighted average Decrease in Specific Gravity = 0.025 units.

TABLE 2.

SPECIFIC GRAVITY COMPOSITION OF SATURATED AND AIR-DRIED SAMPLES.

Colliery	Area	Size of Coal	Condition	Percentage Yield at Specific Gravity. F 1.30	F 1.35	F 1.40	F 1.45	F 1.50	F 1.55	F 1.60	F 1.65	F 1.70	S 1.70
Cornelia (Betty)	Vereeniging	2½"-1¼"	Saturated	0.0	2.6	18.6	42.7	57.5	68.6	78.0	84.3	88.4	11.6
			Air-dried	0.3	5.4	29.4	46.4	60.2	71.2	79.6	85.0	89.4	10.6
W.C.C.M.	Witbank (No. 4 Seam)	3½"-1½"	Saturated	0.0	2.0	14.6	34.4	51.9	64.6	73.6	78.6	82.1	17.9
			Air-dried	0.1	3.8	19.4	38.9	56.3	67.4	75.5	79.6	82.7	17.3
Greenside No. 1	Witbank (No. 2 Seam)	6" -1½"	Saturated	2.3	15.8	31.7	48.9	59.5	67.4	73.2	77.7	83.8	16.2
			Air-dried	3.6	17.9	34.7	50.4	61.9	68.2	74.1	79.5	86.5	13.5
Greenside No. 2 *	Witbank (No. 2 Seam)	6" -1½"	Saturated	2.1	14.6	36.9	62.6	77.1	84.8	88.8	90.5	92.7	7.3
			Air-dried	3.3	16.4	40.5	64.8	78.6	86.2	89.2	91.0	93.7	6.3
Burnside	Klip River	1¾"- ¾"	Saturated	0.9	21.3	52.1	67.7	73.2	77.4	80.8	85.6	87.5	12.5
			Air-dried	4.1	33.2	58.0	68.9	75.2	77.8	81.3	85.8	87.8	12.2
Natal Anthracite	Vryheid	4" - 1"	Saturated	0.0	0.2	17.2	65.1	76.6	82.4	90.7	93.4	95.1	4.9
			Air-dried	0.0	0.5	33.7	68.1	77.7	84.4	92.1	93.9	95.5	4.5

* The second sample from Greenside was separated into S.G. fractions, the fractions were then refloated at the higher S.G. limit of each fraction, dried for a day, and the fractions then refloated at their lower S.G. limits. Percentages refer to the coal as finally separated.

TABLE 3.

PERCENTAGE YIELDS OF REFLOATS ON AIR-DRYING.

	Sample.	Specific Gravity of Re-treatment.								
		1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70
A.										
Refloats as percentage of whole Sample	Cornelia	0.3	2.8	10.8	3.7	2.6	2.5	1.6	0.7	1.0
	W.C.C.M.	0.1	1.8	4.8	4.4	4.4	2.8	1.9	1.0	0.6
	Greenside No. 1*	1.3	2.1	3.0	1.6	2.5	0.8	0.9	1.8	2.6
	Greenside No. 2	1.2	2.0	3.7	2.4	1.6	1.5	0.4	0.5	0.9
	Burnside	3.2	11.9	5.9	1.2	2.0	0.4	0.5	0.2	0.3
	Natal Anthracite	-	0.4	16.5	3.0	1.1	2.0	1.4	0.5	0.4
B.										
Refloats as percentage of originating fraction of 0.05 S.G. range	Cornelia	10	18	45	25	23	27	26	18	-**
	W.C.C.M.	7	14	24	25	34	31	38	29	-**
	Greenside No. 1*	10	13	18	15	31	15	20	29	-**
	Greenside No. 2	10	9	14	17	20	37	22	21	-**
	Burnside	16	39	38	21	48	11	10	12	-**
	Natal Anthracite	-	2	34	26	18	25	53	30	-**
	Mean	10.6	17.5	28.8	21.5	29.0	24.3	28.2	26.2	-

* See footnote to Table 2.

** No figures are given here because the originating fraction contained all material sinking at 1.70 S.G.

TABLE 4.

SPECIFIC GRAVITY SHIFT ON AIR-DRYING.

(a) By calculation (b) Graphically.

Colliery.		Specific Gravity. 1.30	1.35	1.40	1.45	1.50	1.55	1.60	1.65	1.70	Mean S.G. shift
Cornelia	(a)	0.005	0.009	0.022	0.012	0.012	0.013	0.013	0.009	-	
	(b)	?	0.015	0.020	0.011	0.011	0.012	0.014	0.007	0.014	0.013
W.C.C.M.	(a)	0.004	0.007	0.012	0.013	0.017	0.015	0.019	0.014	-	
	(b)	?	0.011	0.012	0.012	0.016**	0.014	0.016	0.011	0.011	0.013
Greenside No. 1	(a)	0.005	0.007	0.009	0.007	0.016	0.007	0.010	0.015	-	
	(b)	0.006	0.007	0.008	0.006	0.014**	0.005	0.010	0.017	0.016	0.010
Greenside No. 2*	(a)	0.005	0.004	0.007	0.008	0.010	0.019	0.011	0.010	-	
	(b)	0.008	0.005	0.007	0.006	0.008	0.013	0.009	0.014	0.013	0.009
Burnside	(a)	0.008	0.019	0.019	0.011	0.024	0.006	0.005	0.006	-	
	(b)	0.016	0.017	0.014	0.009	0.024**	0.006	0.007	0.006	0.011	0.012
Natal Anthracite	(a)	-	0.001	0.017	0.013	0.009	0.012	0.026	0.015	-	
	(b)	-	0.004	0.014	0.009	0.010	0.014	0.021	0.013	0.014	0.012
Mean of samples	(b)	0.010	0.010	0.013	0.009	0.014	0.011	0.013	0.011	0.013	0.0115

* See footnote to Table 2

** Probably high due to analytical error.

TABLE 5.

ASH CONTENTS OF GREENSIDE NO. 2 SAMPLE SPECIFIC GRAVITY FRACTIONS.

Residuals.		Refloats.	
Ash %	Specific Gravity Fraction	Ash %	Specific Gravity Fraction
7.4	Float 1.300	7.3	1.300 - 1.308
7.7	1.308 - 1.350	8.5	1.350 - 1.355
10.3	1.355 - 1.400	11.7	1.400 - 1.407
13.4	1.407 - 1.450	15.3	1.450 - 1.456
17.1	1.456 - 1.500	20.1	1.500 - 1.508
20.6	1.508 - 1.550	21.5	1.550 - 1.563
24.9	1.563 - 1.600	26.9	1.600 - 1.609
27.9	1.609 - 1.650	30.2	1.650 - 1.664
31.8	1.664 - 1.700	35.3	1.700 - 1.713
50.2	Sink 1.713.		

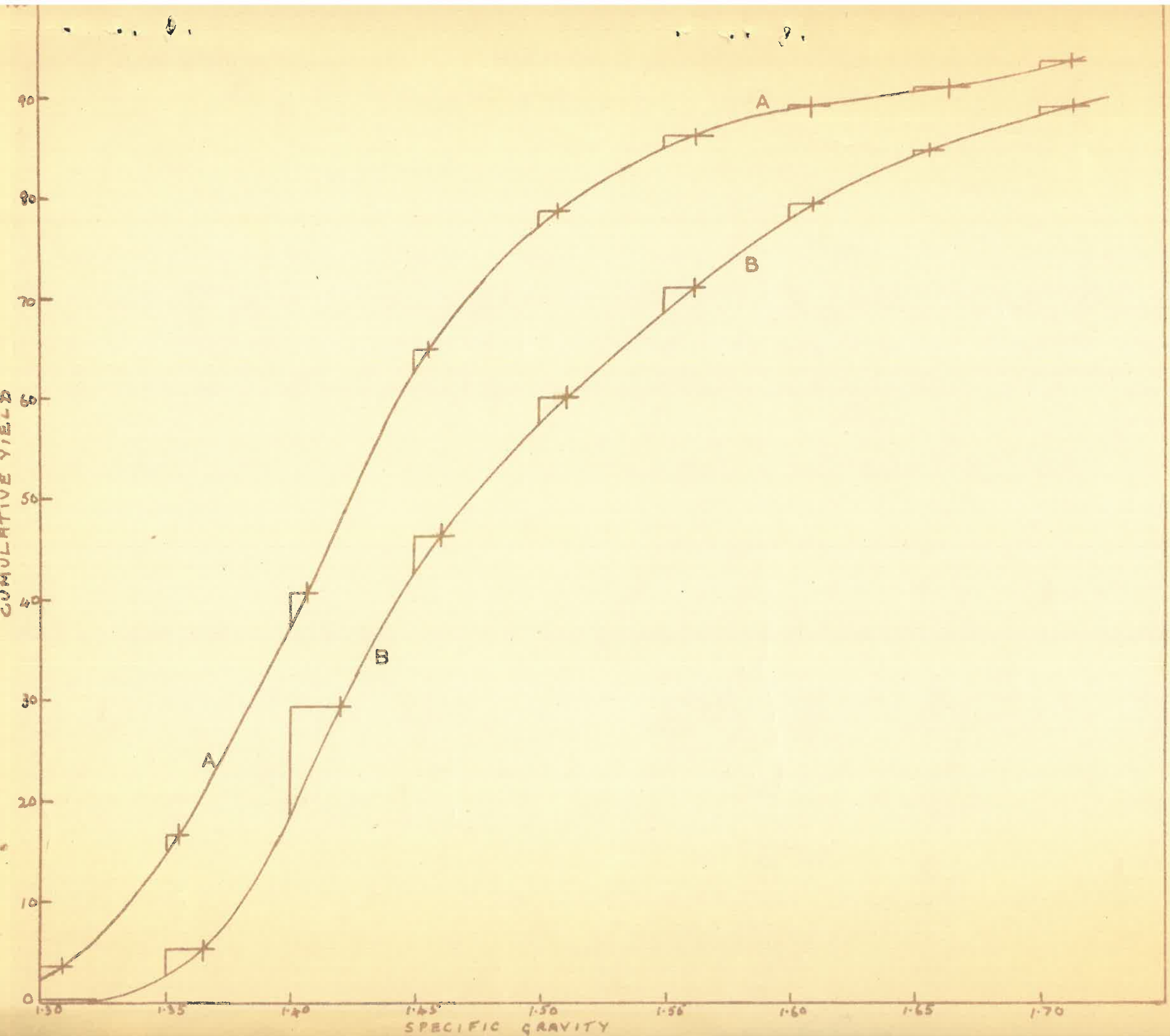

FIGURE 1

A. GREENSIDE No 2

B. CORNELIA (BETTY)

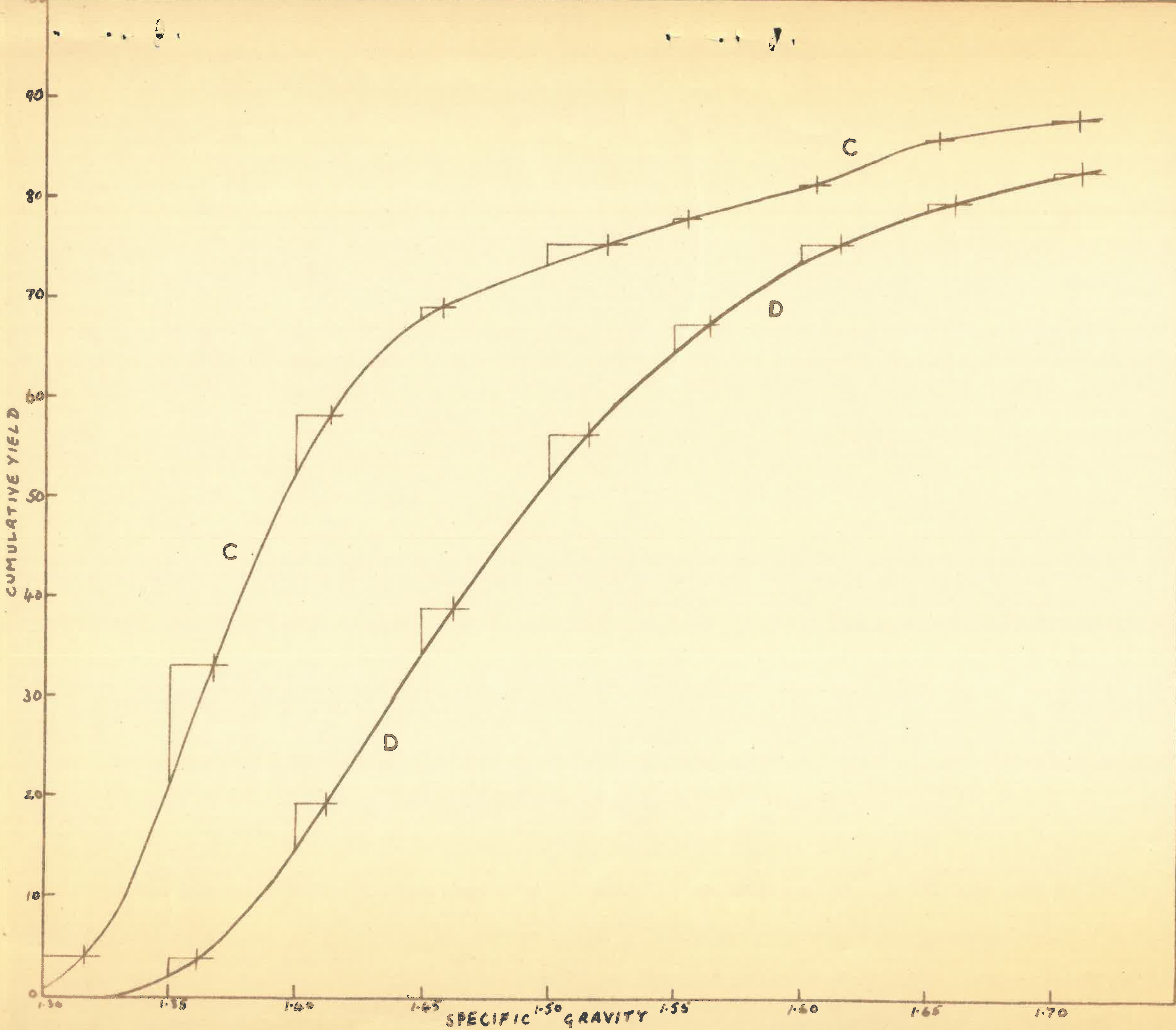

FIGURE 2

C. BURNSIDE
D. W.C.C.M.

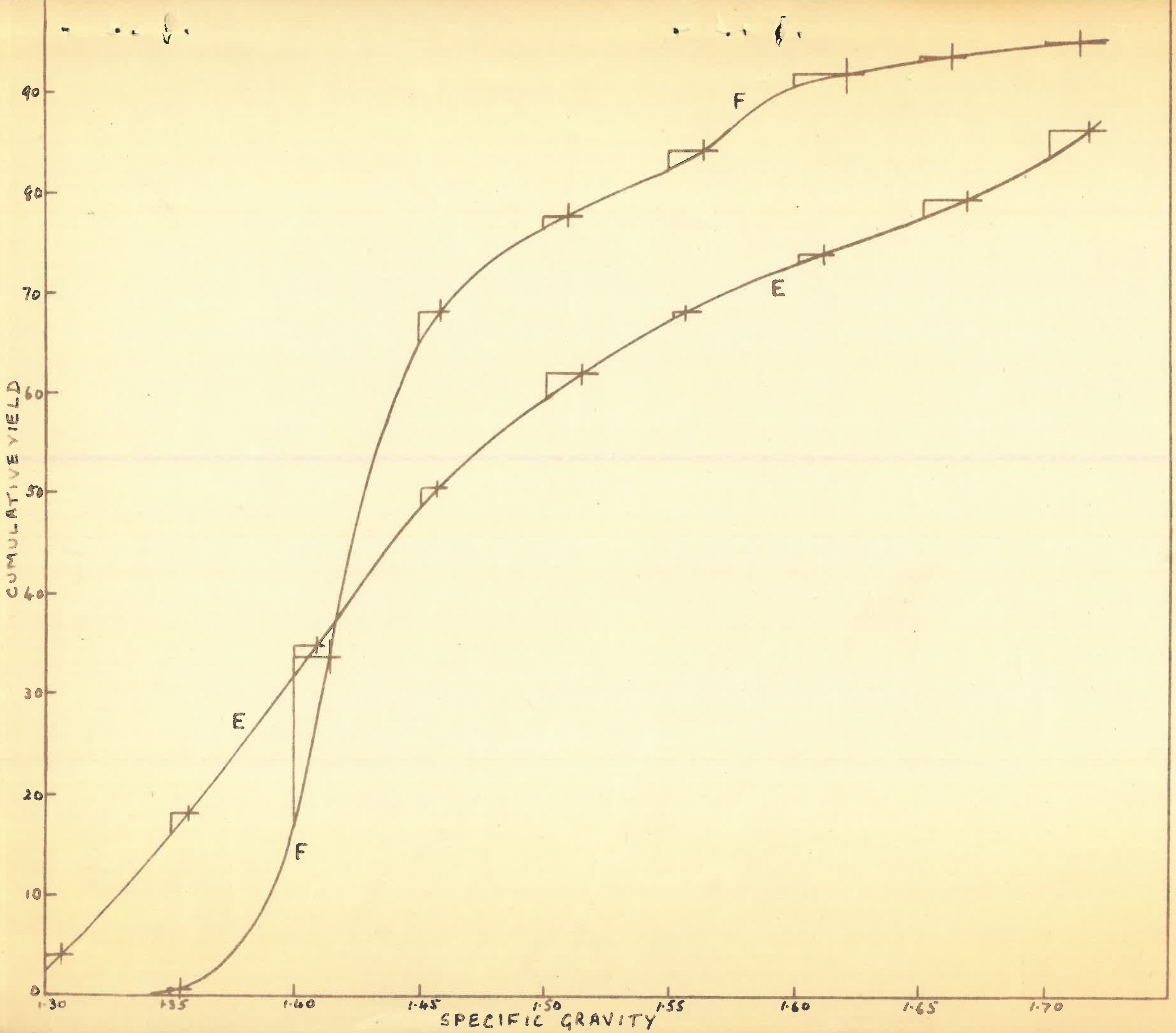

FIGURE 3

E. GREENSIDE No I

F. NATAL ANTHRACITE