Pak. j. sci. ind. res., vol. 34, no. 5, May 1991

STUDY ON WASHABILITY CHARACTERISTICS OF LOW GRADE COALS OF MACH AREA, BALOCHISTAN

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(Received December 31, 1990; revised May 27, 1991)

The low grade coal samples of Mach area fall in four major groups on the basis of proximate analysis, containing 11.4 to 49.0% ash, 14.1 to 29.2% fixed carbon and 29.5 to 49.0% volatile matter. Majority of the samples, having relatively low disintegration in water were found amenable to washing using dense media separation. As a result 21.9 and 27.7% of ash in the coals could be reduced to 13.8 and 15.3 cumulative ash per cent respectively, at 1.60 (S.G), with 50-52% coal yield the sink. Optimum grade recovery conditions were found and discussed in the paper.

Key words: Washability, Coals, Pakistan.

Introduction

The importance of utilizing indigenous coals has recently increased due to the escalation in prices of alternate energy resources. The current per capita energy consumption in Pakistan (250 kw/hr or 0.2 Tonne coal equivalent) is sixty times less than that of USA and four times less than other Asian countries. Although coal is regarded at present as the second most important source of energy, in the developed countries its use in Pakistan is limited. The present production of coal could be boosted considerably if the large tonnage of low grade coals and carbonaceous shale could be upgraded. The present study is undertaken on the mine rejects (essentially consisting of carbonaceous shale associated with coal in the Mach area, Balochistan), to find the washability characteristics.

The coal resources of Pakistan were reported at about one billion tons [1]. The coals beds occur in Paleocene – Eocene rocks in the country. In Quetta-Kalat coal province, coal beds are localized in the middle Ghazij formation of middle Eocene age.

The coals are lignitic to sub-bituminous, friable with high ash and sulphur contents. Substantial tonnage of coal remained unutilized due to the absence of R and D data regarding the washability characteristics of coals.

The washability of coals was first reported by Stutz [2], and later on, a number of reports on U.S. coals were compiled by Vancey and Fraser [3], of U.S. Bur. Mines, and Lowery [4]. Since 1945 mechanized washing has increased many fold in the industrial countries yet it has still not been introduced in this country. The washability studies have shown that float yields were related to the rank of coal [5]. The washability data obtained showed the quality of the coal that could be produced in mechanical washing and the ease or difficulty of operation.

Experimental

Fourteen representative samples of coal weighing 50 to 100 kg each comprising a size fraction with the lumps mostly less than 25 mm size, were received from the mine dumps. The samples were split for mineralogical analysis, chemical studies, proximate analysis and washability studies. The

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TABLE 1. PROXIMATE ANALYSES OF COAL SAMPLES.

S. No.	Moisture (%)	Volatile matter(%)	Fixed carbon (%)	Ash% (%)	L.O.I% (%)	Coal type
1.	06.81	42.27	29.01	21.91	78.09	A
2.	08.82	38.04	24.31	28.83	71.17	B
3.	05.82	29.45	18.81	45.92	54.08	D
4.	07.02	37.42	26.45	29.11	70.89	B
5.	05.01	31.93	14.11	48.95	51.03	D
6.	08.41	37.04	23.91	30.64	69.36	B
7.	05.37	42.76	24.17	27.07	72.31	B
8.	04.51	41.89	16.54	37.06	62.94	C
9.	09.07	43.03	21.45	26.45	73.55	B
10.	05.49	31.42	19.02	44.07	55.93	D
11.	09.08	37.76	17.64	35.52	66.48	C
12.	10.51	48.93	29.21	11.35	88.64	A
13.	07.85	43.05	28.02	21.08	78.92	A
14.	06.01	41.02	15.93	37.04	62.95	C
Average	07.13	39.00	22.04	31.83	68.31	
01.	06.81	42.27	29.01	21.91	78.09	A
12.	10.51	48.93	29.21	11.35	88.64	A
13.	07.85	43.05	28.02	21.08	78.92	A
Mean	08.39	44.75	28.75	18.11	81.88	
02.	08.82	38.04	24.31	28.83	71.17	B
04.	07.02	37.42	26.45	29.11	70.89	B
06.	08.41	37.04	23.91	30.64	69.36	B
07.	05.37	42.76	24.17	27.07	72.31	B
09.	09.07	43.03	21.45	26.45	73.55	B
Mean	7.738	39.658	24.058	28.546	71.456	
08.	04.51	41.89	16.54	37.06	62.94	C
11	09.08	37.76	17.64	35.52	66.48	C
14.	06.01	41.02	15.93	37.04	62.95	C
Mean	06.53	40.22	16.07	36.54	64.12	
3.	05.82	29.45	18.81	45.92	54.08	D
5.	05.01	31.93	14.11	48.95	51.03	D
10.	05.49	31.42	19.02	44.07	55.93	D
Mean	05.44	30.93	17.31	46.31	53.68	

mineralogical studies were conducted in thin and polished sections. For the chemical studies, proximate analysis were conducted using both standard methods and thermo-gravimetric analysis. The results of the proximate analysis are reported in Table 1.

The samples as received were subjected to screening and size analysis. The results are reported in Table 2. In order to find the disintegration of samples on soaking a batch of one kg material was placed in a container and immersed in water. This was gently agitated with a rod for five minutes and allowed to stand for 48 hrs. The material was again agitated and screened through 2.4 mm screen. The results are given in Table 3.

Washability of coals was determined by float and sink method. In this method, the coal to be cleaned was suspended in concentrated solution of inorganic salts with specific gravity intermediate between that of the coal and principal ash forming impurities or shale. The lighter material which has generally more fixed carbon, less ash and low sulphur content will float and heavier gangue material will sink. The floated coal is skimmed off, but the siliceous material settled to the bottom. Six stainless steel boxes of size (8"x8"x12") were used in the washing tests. The most important factor regarding the material of construction of the containers, was the corrosion of vessels, which should be unaffected by the solutions. The vessel consisted of a box with wire basket in it which can be lifted by handles attached to it. It also had wire mesh walls and wire mesh bottom. The wire mesh used was smaller than one half of the size of finest coal in the fraction. Weighed samples were used for the test, where firstly, the sample was placed in the basket which was dipped in the first bath containing zinc chloride solution of specific gravity 1.3. Then the floated coal was recovered using a strainer made of mesh size one half the size of smallest particles. The sinks of 1.3 specific gravity were put in the second container filled with a solution of zinc chloride of higher specific gravity. This process was repeated for the specific gravities between 1.3 and 1.7. Different float and sink products were collected at different specific gravities, washed with tap water, dried and subjected to proximate analysis. The results are Tabulated in Tables 4 to 9.

TABLE 2. WEIGHT PERCENTAGE DISTRIBUTION OF SEIVED SIZES (SEIVE SIZE IN mm.)

Sample No.	a +12.7mm	b 12.7-4.8	c 4.8-2.4	d -2.4mm	Cumulative +4.8	Percentage +2.4
1	10	43	17	30	53	70
2	14	35	18	33	49	67
3	32	38	11	19	70	81
4	30	36	11	23	66	77
5	39	24	10	27	63	73
6	44	31	09	16	75	84
7	21	37	12	30	58	70
8	19	27	12	42	46	58
9	20	32	14	34	52	66
10	26	23	10	41	49	59
11	16	38	12	34	54	66
12	01	14	16	69	15	31
13	26	31	11	32	57	68
14	32	33	12	23	65	77
Mean	23.57	31.57	12.50	32.36	55.14	67.64

TABLE 3. AMOUNT OF FINES OBSERVED ON DRY SCREENING AND SLIME GENERATED ON SOAKING AND WET SEIVING.

Group	Sample No.	Slime%	Fines-2.4mm
A	01	15	30
	12	85	69
	13	25	32
B	02	55	33
	04	15	23
	06	25	16
	07	10	30
	09	35	34
C	08	25	42
	11	50	34
	14	65	23
D	03	45	19
	05	16	27
	10	30	41

Results and Discussion

The results of the proximate analysis showed a wid variation in composition of coal samples. The percentage of ash varied from 11.35 to 48.95 in different samples. The average composition of ash in different coals was 36.18%. The average fixed carbon content (FC) was 22.04% with a range of 14.11 to 29.21, and the average of volatile matter (VM) in the coals was 39.00% with a range of 29.45 to 48.93. On the basis of statistical correlation the coals were divided into four distinct groups representing coals containing low ash, high VM and FC (Groups A); coals containing moderate ash, VM and FC (Group B); coals containing high ash, low FC but moderate VM (Group C) and coals with high ash, low VM and FC. The loss on ignition (L.O.I.%) in these groups were 81.88, 71.46, 64.12 and 53.68% respectively. It is evident from these results that percentage of ash is the major factor causing the compositional variations.

Mineralogy and petrography. The study of the coals in hand specimens and polished/thin section showed the presence of three principal components (a) Jet black colour coal forming the main carbonaceous matter content, (b) carbonate such as calcite in the form of fine grained creamy white bands and (c) grey coloured clayey or carbonaceous clay material. Generally, these three components varied in the form of bands, lenticules and complex structure of variable thicknesses. In the rock specimens the contact between the coals and carbonate was in weak planes. It was observed that during gentle crushing, transportation and handling fine coal content was increased. The mineralogical characteristics of different groups of coals were as follows:-

Group A. In sample 1 and 13 carbonaceous matter was observed to occur in fine bands, ranging in size from 1mm to 3mm. About 10% of the coal was clayey in character whereas the carbonate content was about 30% in sample 1 and 10% in sample 13.

Group B. Sample 2 was grey coloured due to clayey nature with bands of carbonate intercalating with the coal. About 50% carbonate was observed in sample 2 and 20% in sample 7. The later was jet black colour due to the presence of high rank coal with conchoidal fracture, clay content in this sample was about 15%. Sometimes microbands of intercalating coals and carbonate were seen. Most of the samples in this group resembled the features of sample 7.

Group C. In this group coals, sample 8 was massive, tough and of jet black colour whereas samples 11 and 14 were grey coloured due to the presence of clay. More than 50% carbonaceous matter of jet black colour was observed in sample 8 alongwith 25% carbonate and 15% grey clayey portion. Sometimes bands of coals of 2-3mm size intercalating with 1mm size bands of carbonate and clay were also observed. Sample 14 also showed about 25% carbonate, sometimes in the form of bands.

Group D. Sample 5 had only 20% jet black coal with 40% carbonate, the rest of the part was of grey clayey nature showing generally 1mm size (at places 2-5mm) bands of coal, clay and carbonates. The coal sample 3 contained about 30% carbonaceous matter.

The screen analysis of the samples, as revised, showed that sample 12 was fine grained with only 31% particles above 2.4mm, whereas samples 2,8 and 10 were medium grained with 67, 58 and 59% particles above 2.4mm size respectively. The rest of the samples were coarser in nature with over 54% of +4.8mm and about 60 to 84% of +2.4mm particles, and can be treated by heavy media separation.

The amount of fines (Table 3) generated on soaking and agitation with water in most coals were low i.e. between 15 to 25% and the coals could be easily treated in aqueous heavy medium. Only in samples 2 ,3, 9 and 12 high slimes were generated i.e. 55, 45, 60 and 85% respectively. The high clay content in the sample was found to be the cause high slime generation.

The results of sink-float analysis summarized in Table 4, showed the washability characters of low ash coal sample (Group A). The Table 4 shows different sized fractions, their weight percent and the weight percent of float obtained at different specific gravities alongwith their ash content. The calculations of cumulative float weight, percent size and cumulative ash percent as well as, cumulative sink weight percent and cumulative ash percent were carried out using the method of Lowry [4]. It was seen that ash content was reduced in fine sized fractions. The ash percent was found to increased progressively in floats of higher density liquids i.e. from 1.3 to 1.6. The ash content in the floats increased significantly above specific gravity 1.6. The results showed the effect of the variation of specific gravity on the coal ash percent in the float. It was observed that the weight percent float at 1.30 (S.G) was insignificant (Table 4). This was due to the fact that the coal was of low grade, associated with shale and other high density ash forming impurities. Above 1.70 (S.G), the ash contents in the floats were higher than the head grade coals. The sink-float tests for other group coals, accordingly, were restricted to 1.40 to 1.70 (S.G).

In the low ash group (sample 1) the cumulative ash percent in floats 1.7 specific gravity were 17.1, 14.1 and 11.6 respectively in size ranges of +12.5, 12.5 x 4.8mm and 4.8x2.4mm, with a cumulative average of 13.8% ash and coal yield of 52%. Whereas the ash percent in sinks were 27.8, 28.8 and 33.7 at the respective size. It was obvious that in the low ash group coals of Mach area, the ash could be reduced to half in float as compared with sink at specific gravity below and at 1.7.

The low to medium ash group (sample 7) showed 17.3, 15.5 and 11.5 cumulative ash percentages in floats 1.7 specific gravity in the size ranges of +12.5, 12.5x4.8mm and 4.8x2.4mm respectively, with a cumulative average of 15.3% ash and weight recovery of 50.5%. Whereas, the ash percent in the sinks were 33.4, 30.4, 30.8 and 35.8% at the respective size.

The cumulative ash percentages in the medium ash group (sample 8) in floats 1.7 specific gravity were 27.1, 17.7 and 14.1 respectively, in size ranges of +12x5, 12.5x4.8x8mm and 4.8x2.4mm, with a cumulative average of 18.0% ash and coal yielded of 39%. Whereas the ash percent in sinks were 66.3, 61.4 and 55.8 at the respective size.

In high ash group (sample 5) the cumulative ash percentages in floats 1.7 specific gravity were 36.0, 26.4 and 28.3 respectively, in size ranges of +12.5, 12.5x4.8mm and 4.8x2.4mm, with a cumulative average of 28.5% ash and weight recovery of 46%. Whereas, the ash percent in sinks were 80.4, 77.1 and 80.8 at the respective size.

The results in Tables 4 to 7 showed that samples of group A and B were similar in behaviour and about 50-52% coal yield could be obtained in the floats with ash contents below 15.3%. Group C samples gave very low coal yield (39%) with average ash of 18%. The group D samples gave very high ash

TABLE 4. RESULTS OF SINK-FLOAT ANALYSIS OF GROUP A (SAMPLE 1).

Size mm	Size wt.%	Sp.Gr.	Wt.%	Size wt.%	Ash%	Prod. ash	Cumulative size wt.%	Float % ash	Cumulative size wt.%	Sink ash%
12.5	10.0	1.30	00.70	00.70	10.90	00.76	00.07	10.90	10.00	21.10
		1.40	35.60	03.56	15.20	54.11	03.63	15.12	09.93	21.24
		1.50	12.70	01.30	16.40	21.32	04.93	15.45	06.37	24.51
		1.60	06.70	00.67	17.10	11.46	05.60	15.65	05.07	26.59
		+1.70	10.20	01.02	24.50	25.00	06.62	17.02	04.40	28.04
		-1.70	34.10	03.38	28.80	98.35	10.00	21.10	03.38	28.80
12.5-4.8	43.0	1.30	01.20	00.52	06.50	003.38	00.52	06.50	43.00	18.00
		1.40	50.10	21.54	12.75	274.63	22.06	12.60	42.48	18.14
		1.50	10.70	04.60	13.20	060.70	26.70	12.70	20.90	23.80
		1.60	05.70	02.50	16.20	039.70	29.10	13.00	16.30	26.70
		+1.70	07.70	03.30	23.50	077.80	32.40	14.10	13.90	28.60
		-1.70	24.60	10.60	30.20	319.50	43.00	18.00	10.60	30.20
4.8-2.4	17.0	1.30	01.70	00.29	06.10	001.77	00.29	06.10	17.00	17.20
		1.40	58.30	09.91	09.60	095.10	10.20	09.50	16.71	17.39
		1.50	05.00	00.90	09.80	008.30	11.10	09.50	06.80	28.80
		1.60	04.00	00.70	15.20	010.30	11.07	09.90	06.00	31.60
		+1.70	07.70	01.30	27.60	036.10	13.00	11.60	05.30	33.70
		-1.70	24.60	04.20	33.80	141.40	17.20	17.00	04.00	35.70
-2.4	30.0				28.80					
	100	1.30	01.26	01.26	08.73	011.00	01.26	08.73	100.00	21.10
		1.40	34.64	34.64	12.12	419.84	35.90	12.00	98.74	21.26
	Total	1.50	06.70	06.70	13.40	089.80	42.60	12.20	64.10	26.20
		1.60	03.80	03.80	16.20	061.60	46.40	12.50	57.40	27.70
		+1.70	05.60	05.60	24.60	137.80	52.00	13.80	53.60	28.50
		-1.70	48.20	48.20	28.80		100.20	21.00	48.00	28.90

TABLE 5. RESULTS OF SINK-FLOAT ANALYSIS OF GROUP B (SAMPLE 7) LOW TO MEDIUM ASH COAL.

Size mm	Size wt.%	Sp.Gr.	Wt.%	Size wt.%	Ash%	Prod. ash	Cumulative size wt.%	Float % ash	Cumulative size wt.%	Sink ash%
12.5	21.0	1.40	38.50	8.10	14.50	117.20	8.10	14.50	21.00	23.40
		1.50	10.50	2.20	6.80	37.00	10.30	15.00	12.90	28.90
		1.60	6.70	1.40	18.50	26.00	11.70	15.40	10.70	31.40
		+1.70	12.80	2.70	25.60	68.80	14.40	17.30	9.30	33.40
		-1.70	31.50	6.60	36.50	241.40	21.00	23.40	6.60	36.40
12.5-4.8	37.0	1.40	49.40	18.30	13.60	247.70	18.30	13.60	37.00	20.00
		1.50	9.00	3.00	15.60	56.00	21.90	13.90	18.00	26.40
		1.60	5.80	2.00	17.80	38.20	24.10	14.20	15.10	29.00
		+1.70	8.50	3.10	25.50	80.20	27.20	15.50	13.00	30.80
		-1.70	26.50	9.80	32.50	318.07	37.00	20.00	9.80	32.50
-2.4	30.0				35.00					
	100.0	1.40	33.20	33.20	13.00	431.90	33.20	13.00	100.00	24.60
		1.50	6.40	6.40	15.50	99.20	39.60	13.40	66.80	30.40
	Total	1.60	4.10	4.10	17.20	70.50	43.70	13.80	60.40	32.00
		+1.70	6.80	6.80	25.40	172.70	50.50	15.30	56.30	33.00
		-1.70	49.60	48.20	35.00		100.10	24.60	49.50	34.10

TABLE 6. RESULTS OF SINK-FLOAT ANALYSIS OF GROUP C (SAMPLE 8) MEDIUM ASH COAL.

Size mm	Size wt.%	Sp.Gr.	Wt.%	Size wt.%	Ash%	Prod. ash	Cumulative size wt.%	Float % ash	Cumulative size wt.%	Sink ash%
12.5	19.0	1.40	37.50	7.10	15.20	108.30	7.10	15.20	19.00	40.80
		1.50	11.20	2.10	22.80	48.60	9.30	17.00	11.90	56.20
		1.60	5.50	1.00	40.20	42.00	10.30	19.30	9.70	63.50
		+1.70	13.50	2.60	58.30	149.50	12.90	27.10	8.70	66.30
		-1.70	32.30	6.10	69.60	426.90	19.00	40.80	6.10	69.60
12.5-4.8	27.0	1.40	47.80	12.90	13.80	178.10	12.90	13.80	27.00	35.30
		1.50	7.10	1.90	21.50	41.20	14.80	14.80	14.10	34.90
		1.60	1.80	00.50	30.10	14.60	15.30	15.30	12.20	60.20
		+1.70	6.50	1.80	38.50	67.60	17.10	17.70	11.70	61.40
		-1.70	36.80	9.90	65.50	650.80	27.00	35.30	9.90	65.50
4.8-2.4	12.0	1.40	55.10	6.60	11.50	76.00	6.60	11.50	12.00	27.60
		1.50	4.50	00.50	12.30	00.60	7.20	11.60	5.40	47.00
		1.60	4.50	00.50	15.50	8.40	7.70	11.80	4.80	51.30
		+1.70	7.80	00.90	32.50	30.40	8.60	14.10	4.30	55.80
		-1.70	28.10	3.40	62.30	21.10	12.00	27.60	3.40	62.30
-2.4	42.0				37.80					
	100.0	1.40	26.60	26.60	11.50	305.90	26.60	11.50	100.0	40.00
	Total	1.50	4.60	4.60	15.00	69.00	31.20	12.00	73.40	50.40
		1.60	2.50	2.50	31.40	78.50	33.70	13.50	68.80	52.80
		+1.70	5.30	5.30	47.10	249.60	39.00	18.00	66.30	53.60
		-1.70	61.00	48.20	68.50		100.00	40.00	61.00	54.10

TABLE 7. RESULTS OF SINK-FLOAT ANALYSIS OF GROUP D (SAMPLE 5) HIGH ASH COAL.

Size mm	Size wt.%	Sp.Gr.	Wt.%	Size wt.%	Ash%	Prod. ash	Cumulative size wt.%	Float % ash	Cumulative size wt.%	Sink ash%
12.5	39.0	1.40	22.10	8.60	25.20	217.10	8.60	25.20	39.00	63.90
		1.50	5.40	2.10	27.00	57.20	10.70	25.60	30.40	74.80
		1.60	4.30	1.70	45.60	75.80	12.40	28.20	28.30	78.40
		+1.70	6.60	2.60	73.40	188.60	15.00	36.00	26.60	80.40
		-1.70	61.60	24.00	81.20		39.00	63.90	24.00	81.20
12.5-4.8	24.0	1.40	38.80	9.30	22.30	207.40	9.30	22.30	24.00	53.00
		1.50	3.90	00.90	25.00	23.60	10.20	22.50	14.70	72.50
		1.60	2.30	00.50	42.00	22.70	10.80	23.50	13.80	75.70
		+1.70	4.00	00.90	59.30	56.20	11.70	26.40	13.20	77.10
		-1.70	51.10	12.30	78.50	962.90	24.00	53.00	12.30	78.50
4.8-2.4	10.0	1.40	35.50	3.60	19.00	63.90	3.60	18.00	10.00	51.50
		1.50	6.50	00.70	20.50	13.30	4.20	18.40	6.50	70.50
		1.60	5.60	00.60	32.00	17.90	6.80	20.00	5.80	76.10
		+1.70	11.60	1.20	62.50	72.50	5.90	28.30	5.20	80.80
		-1.70	40.80	4.10	86.00	350.90	10.00	51.90	4.10	86.00
-2.4	27.0				30.10					
	100.0	1.40	35.00	35.00	22.50	787.50	35.00	22.50	100.00	54.20
	Total	1.50	3.70	3.70	25.40	94.00	38.70	22.80	65.00	71.20
		1.60	2.80	2.80	42.10	117.90	41.50	24.10	61.300	74.00
		+1.70	4.70	4.70	67.80	318.70	46.20	28.50	58.500	75.50
		-1.70	53.80	48.20	85.00		100.00	54.20	53.800	76.20

TABLE 8. WASHABILITY STUDY OF MACH COMPOSITE COAL (12.5 x 1.56MM FRACTION).

Specific Gravity	Weight%	Ash weight%	Product ash	Cumulative Product ash	Cumulative Float Weight %	Cumulative Float Ash %	Cumulative Sink Weight %	Cumulative Sink Ash %
Float 1.3	2.07	5.02	10.39	10.39	2.07	5.02	97.93	36.84
Float 1.4	27.46	7.25	198.98	209.37	29.53	7.09	70.47	48.37
Float 1.5	17.08	15.52	265.12	474.49	46.61	10.18	53.39	58.88
Float 1.6	13.93	24.04	334.93	809.42	60.54	13.37	39.46	71.18
Float 1.7	6.21	54.54	338.68	1148.10	55.75	17.20	33.25	74.28
Sink 1.7	18.57	77.43	1437.95	2586.05	85.32	30.31	14.68	70.30
Disintegration	14.68	70.30	1031.95	3618.00	100.00	36.18	—	—

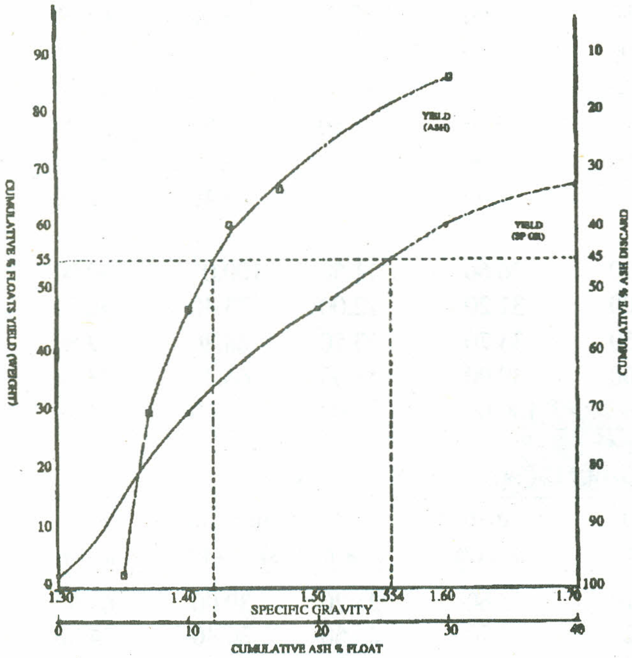

Fig. 1. Washability of composite mach coal.

coals with an average of 28.5%. However, if +12.5mm fraction was omitted the remaining fraction could yield about 27% ash containing coal but the yield would be 17.6% or lower.

In the washability study on the low-grade Mach coal it was observed that in all the groups, the size fractions below 12.5mm size yielded relatively lower ash in the washed coal. A composite sample of coal was prepared using equal weight of all the coal samples. The coarse coal was crushed to pass 12.5mm screen. A sink float test was conducted on the deslimed fraction 12.5mx1.56mm size. The result of the test are shown in Table 8 and Fig. 1.

It may be seen that at 1.60 (S.G) over 62% weight was recovered in the washed fraction having ash content of 13.37%. From Fig. 1, it may be predicted that a product containing around 11% ash may be obtained on washing the coal at 1.56 (S.G). The proximate analysis of the composite coal (12.5x1.56mm size) washed at 1.60 (S.G) is given in Table 9.

TABLE 9. PROXIMATE ANALYSIS OF WASHED COMPOSITE COAL.

Moisture	2.18%
Ash	13.38%
Volatile matter	41.53%
Fixed carbon	45.06%
Sulphur	5.22%
Gross calorific value	10730 Btu/lb

During washing the coal, however, disintegrated to an extent of about 15%. This fraction essentially contained clay and soft shale, having high ash. This fraction after desliming may be beneficiated using techniques such as flotation.

In view of the results obtained on washing of the coarse fraction of Mach coals it is expected that the coals would show good recovery and grade in pilot plant heavy media separation tests, which are recommended. The work would be conducted in a later study. The washability test on composite coal has demonstrated that a marketable grade of coal with com paratively low ash, high fixed carbon and farily high calorific value may be obtained from run of mine Mach coal.

The up-gradation study is extended to fine coal 1.56x0mm size of the coal, so that the economics of an overr all coal preparation on the basis of raw coal may be determined.

References

1. M.N. Khan and A.H. Pelofsky, Coal Development Potential in Pakistan, Proc. 1st Pak. National Coal Con., Feb. 22-26, (1986).
2. S. Stutz, AIME, Trans., **9**, 461077 (1880).
3. H.F. Yancey, and T. Fraser, U.S. Bur. Mines, Bull., 300, (1929), pp. 250.
4. H.H. Lowry, *Chemistry of Coal Utilization* (John Wiley and Sons, Inc. New York, 1962).
5. David J. Brown *et al.*, Washability Data Base of Very Fine Western Coals, Society of Mining Engineers AIME Annual Meeting, New York, Feb. 24-28 (1985).