TULAMEEN THERMAL COAL PROJECT

British Columbia

Canada

PROJECT INTRODUCTION

AND

COAL QUALITY REPORT

T. J. Adamson

January, 1981

(Obsolete Sections Deleted)

May, 1982

CYPRUS ANVIL

TULAMEEN THERMAL COAL PROJECT

British Columbia

Canada

N.T.S. 92-H-7, 10

LATITUDE: $49^{o}30'N$

LONGITUDE: $120^{o}45'W$

By:

T. J. Adamson

CYPRUS ANVIL MINING CORPORATION

January, 1981

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1.0 INTRODUCTION - Obsolete

(see Wright Engineers Report)

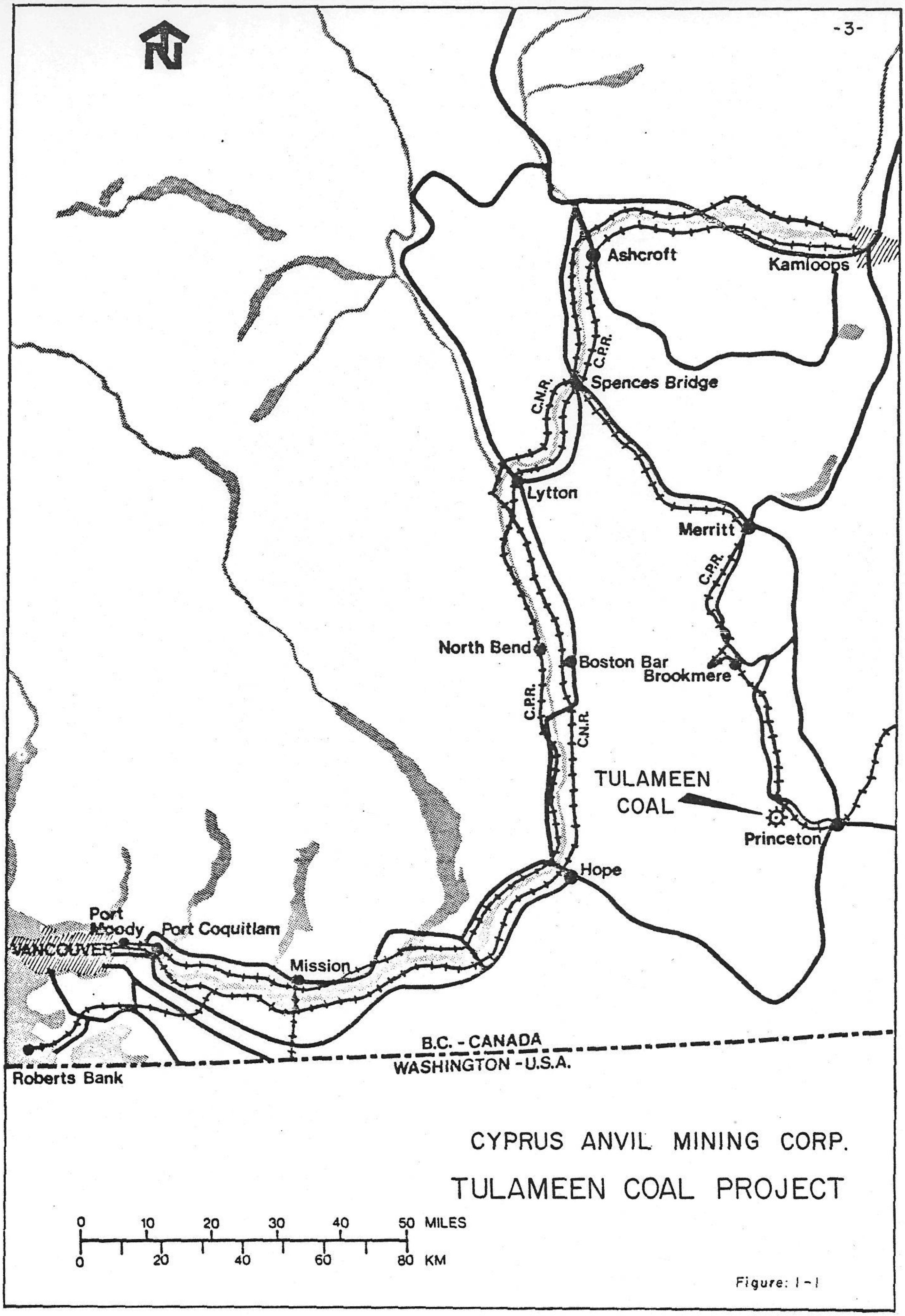
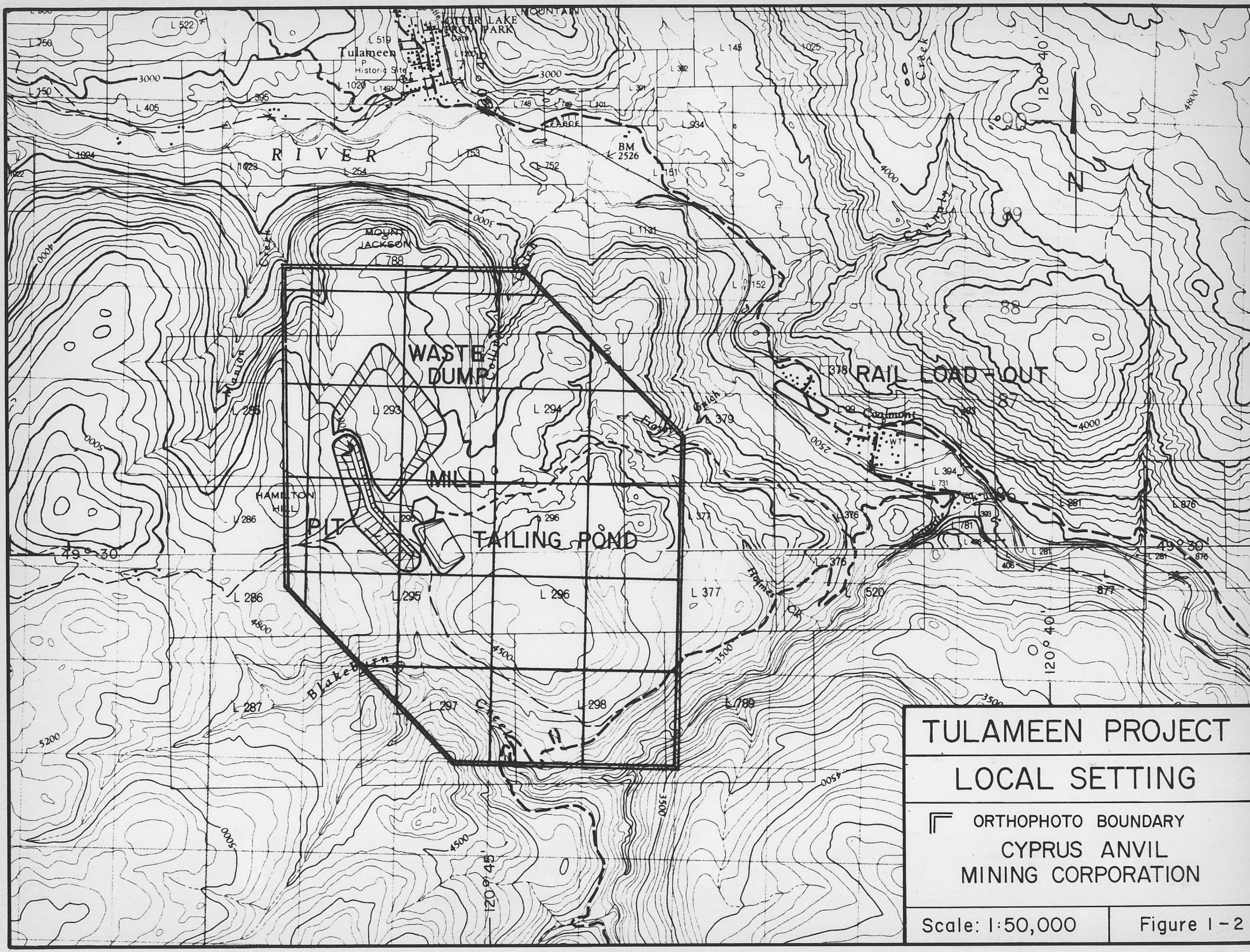

N
Ashcroft
Kamloops
C.P.R.
C.N.R.
Spences Bridge
Lytton
Merritt
C.P.R.
North Bend
Boston Bar
Brookmere
C.P.R.
C.N.R.
TULAMEEN
COAL
Princeton
Hope
Port
Moody
Port Coquitlam
VANCOUVER
Mission
B.C. - CANADA
WASHINGTON - U.S.A.
Roberts Bank
CYPRUS ANVIL MINING CORP.
TULAMEEN COAL PROJECT
0 10 20 30 40 50 MILES
0 20 40 60 80 KM

Figure: I - I



TULAMEEN PROJECT

LOCAL SETTING

Figure 1 - 2

2.0 LOCATION AND ACCESS

The Tulameen coalfield is located in southwestern British Columbia, on the east flank of the Cascade Mountains, about 170 air kilometers east-northeast of Vancouver, and 48 kilometers north of the U. S. border. The proposed development area is centered south of the town of Tulameen and west of the town of Coalmont.

The elevation of the proposed pit and plant sites is approximately 1300 meters and the elevation at the town of Coalmont is 750 meters.

There is good gravel road access to the property from Coalmont, a distance of about 11 kilometers. A paved road connects Coalmont with Princeton, the nearest large community, a distance of about 20 kilometers to the southeast.

A branch line of the Canadian Pacific Railway runs from Princeton, through Coalmont and Tulameen, to join the C. P. Rail main line at Spences Bridge. The rail distance from Coalmont to Vancouver is 420 kilometers.

3.0 LAND STATUS

Cyprus Anvil Mining Corporation holds title to coal licences covering most of the Tulameen coal basin subject to the terms and conditions of an agreement between Imperial Metals and Power Ltd., Mullins Strip Mines Ltd. and Cyprus Anvil Mining Corporation. At such time as Cyprus Anvil makes a production commitment on these licences, Cyprus Anvil shall hold absolute title free of all claims except in respect to a royalty, on production payable to Imperial Metals and Power Ltd. and Mullins Strip Mines Ltd.

Tulameen Coal Project Licences - Operator: Cyprus Anvil Mining Corporation

Coal Licence # 69	259	hectares
70	259	hectares
71	129.5	hectares
125	259	hectares
126	129.5	hectares
145	129.5	hectares
146	129.5	hectares
147	129.5	hectares
154	259	hectares
158	129.5	hectares
159	64.75	hectares
3663	129.5	hectares
3664	259	hectares
3665	129.5	hectares
	2,395.75	hectares

Field work has been carried out on these coal leases under Surface Work Permit #C-115, issued to Cyprus Anvil Mining Corporation on August 9, 1977, pursuant to Section 9 of the Coal Mines Regulation Act.

4.0 EXPLORATION

The Tulameen coal leases were optioned by Cyprus Anvil on December 16, 1976. Exploration commenced on these leases during the summer of 1977 and has continued to the present time (see Map 5-1). Work to date has been oriented towards defining the reserves of low stripping ratio surface minable coal. This exploration program has included the following work:

- topographic control survey
- new aerial photography
- preparation of base maps and orthophotos
- geological mapping (1:5,000 and 1:2,000 scales)
- bulldozer and backhoe trenching
- diamond drilling (12 holes, 1479.1m)
- electrologging of drill holes (gamma, density and neutron logs)
- ground geophysical surveys (resistivity, seismic)
- bulk sampling
- analysis, testing, and washability studies of core samples and bulk samples
- pilot-scale combustion evaluation of a clean coal bulk sample
- preliminary engineering design of proposed open pit mine, preparation plant, and ancillary facilities
- rail transport study

5.0 GEOLOGY AND DESCRIPTION OF COAL RESERVES

5.1 Geology (Map # 5-1, 5-2)

The Tulameen basin consists of an elongate, oval-shaped synclinally folded sequence of Tertiary sediments including coal seams and volcanics which rest unconformably on a basement of Upper Triassic Nicola Group metamorphosed volcanics and sediments.

Underground coal mining was carried out along the southwestern margin of the Tulameen basin from 1919, continuously until 1940 by Coalmont Collieries Ltd. in three adjacent mines (underground mines #3, 4, and 5), as outlined on Map 5-1. A small open pit mine was operated in the same area during the mid 1950's by Mullins Strip Mine Ltd. Approximately 2,150,000 tonnes were extracted from the underground workings and 225,000 tonnes were obtained from the open pit.

The primary object of exploration work carried out since 1977 within the Tulameen basin has been to prove coal reserves that would be minable at a low stripping ratio. For this reason work has been concentrated (all trenching, and drilling, most mapping) along the western margin of the basin. In this area, dips are moderate (25-45^{o} E) and, for a considerable strike distance, the topographic slope tends to fall off the east, resulting in a favourable surface mining situation. Mapping is very sketchy and incomplete along the eastern and southern margins of the basin because of a lack of bedrock exposure. A large number of old bulldozer trenches exist along the eastern margin, but most are extensively slumped. Geological data available suggests that coal seams exist in the sedimentary sequence along the entire eastern margin of the basin but that dips are steep to the west and dip into the topographic slope rather than in the same direction as the topographic slope, as is the case along the western margin. The potential of proving significant surface minable reserves along the eastern margin of the basin is thought to be low.

5.1.1 Stratigraphy

Nicola Group (unit 1) rocks are exposed along the extreme south and eastern sections of the map area. The Nicola Group of Upper Triassic age consists mostly of a varied assemblage of metamorphosed, highly fractured, quartz and carbonate veined volcanic rocks varying from porphyritic and non-porphyritic dacite to basalt. Also present are minor argillite, tuffs, limestone, and chlorite and sericite schist.

Unit 2, the Lower Volcanics, are the oldest Tertiary rocks in the area and they unconformably overlie the Nicola volcanics. This unit consists of a wide variety of generally light coloured, massive to porphyritic and/or fragmental andesite to felsites. This is a very resistant outcrop forming unit. Best exposures are on Hamilton Hill and Jackson Mtn. along the western and northern margin of the basin. Total thickness of this unit, in Collins Gulch, is reported to be about 500 m.

Unit 3 includes the Tertiary sedimentary strata. Unit 3 can be further broken down into a lower sandstone unit (3a); unit 3b, the coal-bearing member consisting of shales, mudstone tuffs, flows, and coal; and an upper sandstone horizon (3c).

Unit 3a is a recessive, poorly exposed, poorly cemented, often arkosic, coarse to fine-grained sandstone, interbedded with minor thin mudstones and shales. The thickness of this unit in the western and northern basin is in the order of 100-150 m.

Unit 3b, the coal member, is about 130 m thick along the western margin of the basin. This unit appears to conformably overlie unit 3a along the western and northern portions of the basin but, to the east and south, it progressively overlaps

TABLE 5-1

TABLE OF GEOLOGIC FORMATIONS

TERTIARY

4 UPPER VOLCANICS

Brown to black, fine-grained basalt.

Unconformity.

3 COAL - BEARING TERTIARY SEDIMENTS

3c UPPER SANDSTONES (600 m)

3c2 Granule conglomerate, coarse sandstone, minor shale, mudstone.

3c1 Transitional unit; interbedded sandstone, mudstone, minor thin coal.

3b COAL MEMBER: Shales, mudstone, tuffs, coal. (130 m)

3b10 Blocky breaking mudstone and shales.

3b9 Finely laminated, fissile shales.

3b8 Interbedded thin dirty coal, bentonite, shales, mudstones.

3b7 Main coal seam

3b6 Light grey, medium-grained sandstone; white muddy matrix.

3b5 Dark grey, massive, blocky breaking mudstone.

3b4 Distinctive color banded, light to dark grey, interbedded shales, mudstones, muddy sandstone.

3b3 Mudstone, medium brownish grey to dary grey, massive to medium laminated.

3b2 Lower coal seam.

3b1 Interbedded fragmental bentonitic tuff, thin coal seams, coaly bentonitic mudstone.

3a LOWER SANDSTONE: Coarse to fine sandstone, interbedded with mudstone and shale (100 - 150 m).

2 LOWER VOLCANIC:

Massive to porphyritic or fragmental; andesitic to felsitic.

Unconformity.

UPPER TRIASSIC

1 NICOLA GROUP:

Highly metamorphosed volcanic and sediments.

unit 3a and unit 2 to lie directly on the Upper Triassic Nicola Group basement. Using drill cores and electrologs, unit 3b has been further broken down into a number of sub-units (3b1-10). These units are readily identifiable in core and electrologs and have been correlated between all holes in the area drilled. Unit 3b is a very recessive weathering unit with very few natural exposures. In weathered surface exposures (outcrop, road cuts, shallow cat and backhoe trenches), it is very difficult to differentiate between the various unit 3b shale and mudstone sub-units.

Main Coal Seam

Unit 3b7 is the Main Coal Seam. This seam was intersected in all twelve diamond drill holes. Drilling was carried out along the western margin of the basin, extending from the northern limit of the old underground workings (Mine No. 5), northwards to the extreme northern limit of the basin. The Main Coal Seam, as a whole, consists of beds, up to 1 m thick, of clean to dirty coal with numerous discrete, thin, waste interbeds. The aggregate thickness of the Main Coal Seam in the area of proposed surface mining range between 15 and 21 meters.

Within the area of exploration drilling, the raw ash content of the Main Coal Seam increases from south to north. The Main Seam, bounded by sections through drill holes T77-1 and T77-5 (Section 1 and Section 5) has an average raw ash content in the order of 38% (adb). From hole T77-6 and continuing through T77-10, there is a rapid progressive increase in ash content, ranging, in this interval, above 50%. The cause of this higher ash content is an increase in the number of discrete waste partings within the coal seam interval.

Individual coal beds are well banded. In hand specimens, bands of vitrain and clarain predominate (approximately 90% of total), with minor durain and fusain. Nodules of bright clear amber are scattered throughout the coal. The coal has well developed bedding and butt cleat.

The 3b coal-bearing sediments are conformably overlain by the Upper Sandstone (unit 3c). This is a thick (600 m) interval of granule conglomerates and coarse sandstones with minor interbeds of shale and mudstone. The conglomerates and sandstones are generally light grey in colour, with a white muddy matrix.

The Upper Volcanic rocks (unit 4) unconformably overlie the unit 3 sediments. Unit 4 is made up of dark brown to black, fine-grained, primarily massive basalt. A few exposures are vesicular and amygdaloidal. Some pillow structure was noted. The basalts form a nearly flat-lying sheet in the order of 100 m thick which occupies most of the southern half of the basin. The limits of this sheet are generally well-defined by cliffs. A small, thin, erosional remnant of this basalt sheet occurs along the northwestern margin of the basin, overlying the unit 3b coal-bearing member between drill holes T-77-6 and T-77-9.

5.1.2 Structure

The Tertiary sediments are folded into an assymetric, northwest trending synclinal structure. In the area of the old underground mines along the southwest margin of the basin, the beds dip between 20 and 25^{0} to the northeast. To the north of this area, between Sections 1 and 5 in the area of proposed surface mining, dips increase from 25^{0} to 45^{0}. The beds tend to flatten to about 20^{0} around the northern nose of the syncline and then steepen to 55 to 80^{0} to the southwest around most of the eastern margin of the basin. The structure around the southeastern margin of the basin, because of the almost total lack of unit 3 rocks exposed, is unclear.

A major northeast trending fault zone exists between the abandoned No. 3 and No. 4 underground mines. This fault zone is noted in descriptions of the old underground workings and can be seen by the surface offset of unit 3b horizons. A similar major northeast fault zone has been described as forming the southeast limit of the No. 3 underground mine. No surface evidence of this zone has been seen. No faulting of significance was seen involving unit 3b between Section 1 and Section 5. To the north of Section 5, numerous small scale faults and drag folds were encountered, although no major displacements are indicated.

5.2 Coal Reserves

Detailed reserve calculations have been made for only the proven coal within the proposed initial open pit. The strike extent of this coal reserve has, as a south limit, the north margin of abandoned No. 5 underground mine just to the south of Section 1 (this also corresponds to the southern limit of topography favourable to surface mining), and runs to the north to just north of Section 5 to where there is an abrupt increase in the raw coal ash content of the seam. The coal seam dip ranges from 28^{0} in the south to 45^{0} to the north, with seam thickness ranging from 15 meters to 21 meters. Measured coal reserves in this zone total 10,500,000 raw tonnes at an overall stripping ratio of 2.80 m^3/raw tonne.

The reserves proposed to be developed in the initial open pit have an economically rather than geologically defined down-dip limit. Additional surface minable reserves are available in this area at progressively higher stripping ratios.

Additional surface minable coal is also available along the surface pillars of abandoned underground Mines Nos. 3, 4 and 5, and above and below the section of the main seam extracted in these mines (only 3-4 meters from a total seam thickness of almost 20 meters was extracted). Again, any significant tonnage of surface minable coal in this area will be available at higher stripping ratios than the ratio in the initial proposed open pit.

The Tulameen coal basin has a large probable, in-situ coal reserve, in excess of 100,000,000 tonnes, which may, at some time in the future, be economically exploitable by underground hydraulic mining or in-situ gasification.

6.0 MINING PLAN - Obsolete

(see Wright Engineers Report)

7.0 COAL QUALITY ASSESSMENT

The following section outlines the quality of the main seam in the area of proven reserves within the limits of the proposed open pit mine. The coal has been assessed as a high quality thermal coal suitable for power generating stations or rotary kiln firing. The coal quality information was developed from drill cores and bulk samples taken from trenches. Outlined in this section are the testing procedures, raw coal characteristics, washability, clean coal specifications, and the burn characteristics of the coal.

7.1 Outline of Testing Program

Cyprus Anvil Mining Corporation initiated a drilling and bulk sampling program in 1977 to evaluate the mining potential and coal quality of the northwest sector of the Tulameen Coal Field. In this regard, 12 holes were drilled and cored in the main seam, and four bulk samples were taken from two trenches (see Map 1 for locations). The testing done to date is sufficiently definitive to support the preliminary preparation plant feasibility study discussed in Section 8.0.

7.1.1 Drillcore Sampling Procedure

The purpose of the drillcore sampling program was to establish the overall quality of the Tulameen coal field, and to confirm that the bulk samples were representative of the coal to be cleaned in the proposed preparation plant. The coal quality information gathered from the drillcores was used to:

(a) Estimate the run-of-mine (ROM) coal ash content of the plant feed.

(b) Develop coal quality variation and trends along the strike and dip within the pit.

Cyprus Anvil Mining Corporation drilled a total of five coreholes within the Tulameen prime mining area. All core was HQ-size and was recovered using a triple-tube core barrel. Within the area of proven reserves, the core recovery from the main coal seam averaged 97%. The handling and testing program for the drillcores is outlined in Figure 7-1. See Appendix A, pp. 1 and 2 for additional details.

Drillcore sampling was carried out in the field on a lithological basis. Coal samples for laboratory analysis and testing were collected in 2 to 4 metre increments over the entire length of the core recovered from the main Tulameen coal seam. As the core was removed from the core barrel, each coal intersection was examined, measured, lithologically described and then photographed. The drillcore samples were sealed in airtight plastic bags and shipped to the Cyclone Engineering Sales Ltd. laboratory in Edmonton for analysis and testing.

Standard geophysical logs were run on Drillholes T-77-1 through T-77-5, which are within the selected mining area. Gamma ray, neutron-neutron and long-spacing bulk density logs were run over the entire length of each drillhole. For each important coal intersection, detailed (slow-speed) gamma ray, long-spacing bulk density and high resolution bulk density logs were also run.

For each hole there is excellent correlation between the electrologs and written core lithologs, and, for each of the holes electrologged, definite correlation can be made, from hole to hole, of coal seams and overlying and underlying strata.

TESTING PROCEDURE FOR TULAMEEN DRILL CORE

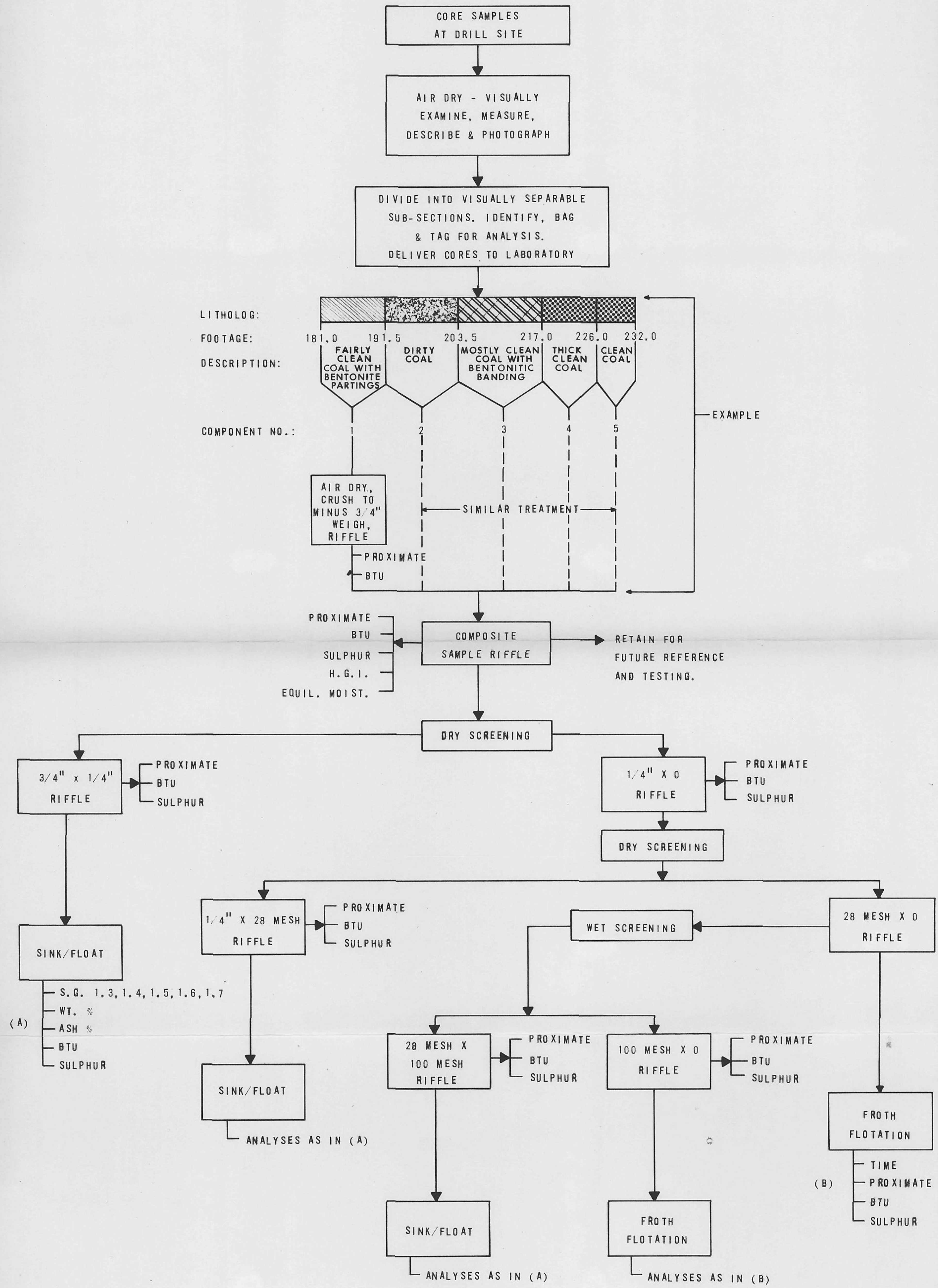


FIGURE 7-1

7.1.2 Bulk Sampling Procedures

The main objective of the bulk sampling program was to provide sufficient coal sample, which was representative of the mineable seam, for washability, pilot plant, and combustion tests. Resulting data were used to assess:

(a) Types of coal cleaning equipment suitable for use in the proposed Tulameen preparation plant.
(b) Coal recovery and the specifications of clean coal which could be produced.
(c) Physical characteristics of the coal such as size distribution, friability, Hardgrove Grindability Index, etc.
(d) Combustion characteristics of Tulameen coal.

Cyprus Anvil Mining Corporation obtained four bulk samples (numbered 1, 2, 3A and 3B) from two separate trenching locations on the outcrop of the main mineable seam. Trenches were cut across the full seam thickness, from footwall to hangingwall, using a CAT D-7E ripper/dozer. The trenches were excavated to a depth where hard, clean coal was reached. Ripped coal along the base of each trench was loaded with a small backhoe into clean 45 gallon metal drums. These drums were sealed and then shipped to the Birtley Coal and Minerals Testing laboratory in Calgary and the Cyclone Engineering Sales Ltd. laboratory in Edmonton for testing and evaluation.

Figure 7-2 shows the testing procedures used on the bulk samples. As will be noted, the testing was quite comprehensive including not only the usual washability tests but also liberation, drop-shatter, crushing, full scale pilot plant washing and pilot scale combustion tests. See Appendix A, pp. 3 - 7 for additional details regarding the bulk samples.

TULAMEEN BULK SAMPLE GENERALIZED TEST PROCEDURE

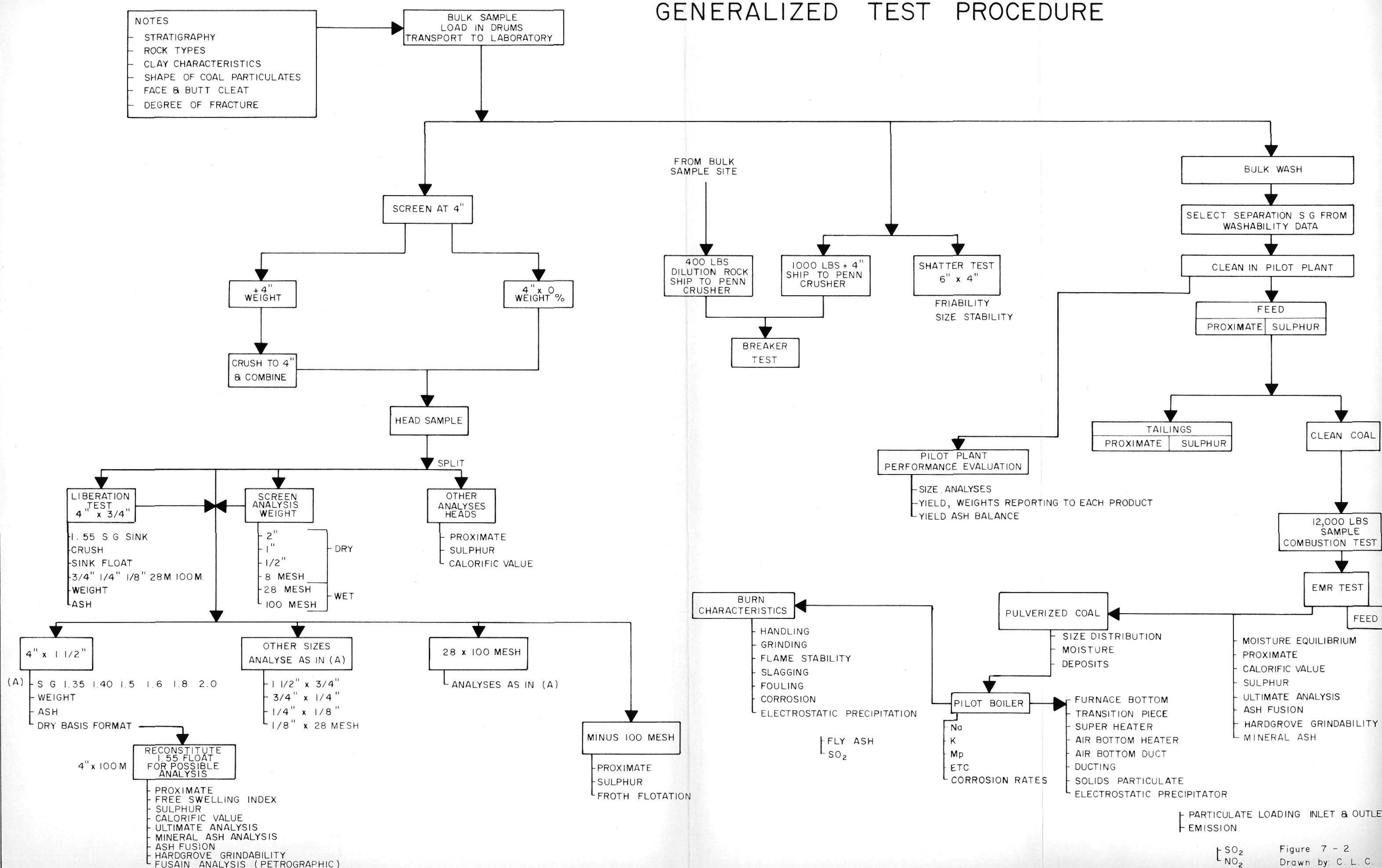


Figure 7 - 2
Drawn by: C. L. C.

7.2 Raw Coal Characteristics

The Tulameen raw coal characteristics have been established in sufficient detail to confirm the general uniformity of the coal along the strike and dip in the pit. Major characteristics are discussed in this section.

7.2.1 In-Situ Ash Content

The raw coal ash content of the cores is important since it provides in-place variability information and may also be used to help confirm the validity of the bulk samples; further, study of the core data assists in determining the need for additional drilling. Figure 7-3 shows coal-bearing horizons intersected by the drillholes within the pit limits. The ash content of the cleaner coal zones varies between about 22% and 30%, while the interbedded zones range up to 55% ash. The average ash is 40.9% on a dry coal basis or 37.6% at the average bed moisture of 8%.

Bulk sample raw coal analyses are as follows (see Appendix A, Table A-1, pp. 5 and 6 for details):

Bulk Sample No.	Ash % (dcb)
1	37.2
2	39.4
3A	35.2
3B	34.1

The bulk sample and drillcore analyses demonstrate that the raw coal ash will range between 35% and 41% (dry basis). As is discussed next, some selective removal of the thicker partings and clay bands is possible.

TULAMEEN COAL MAIN SEAM DRILL HOLES

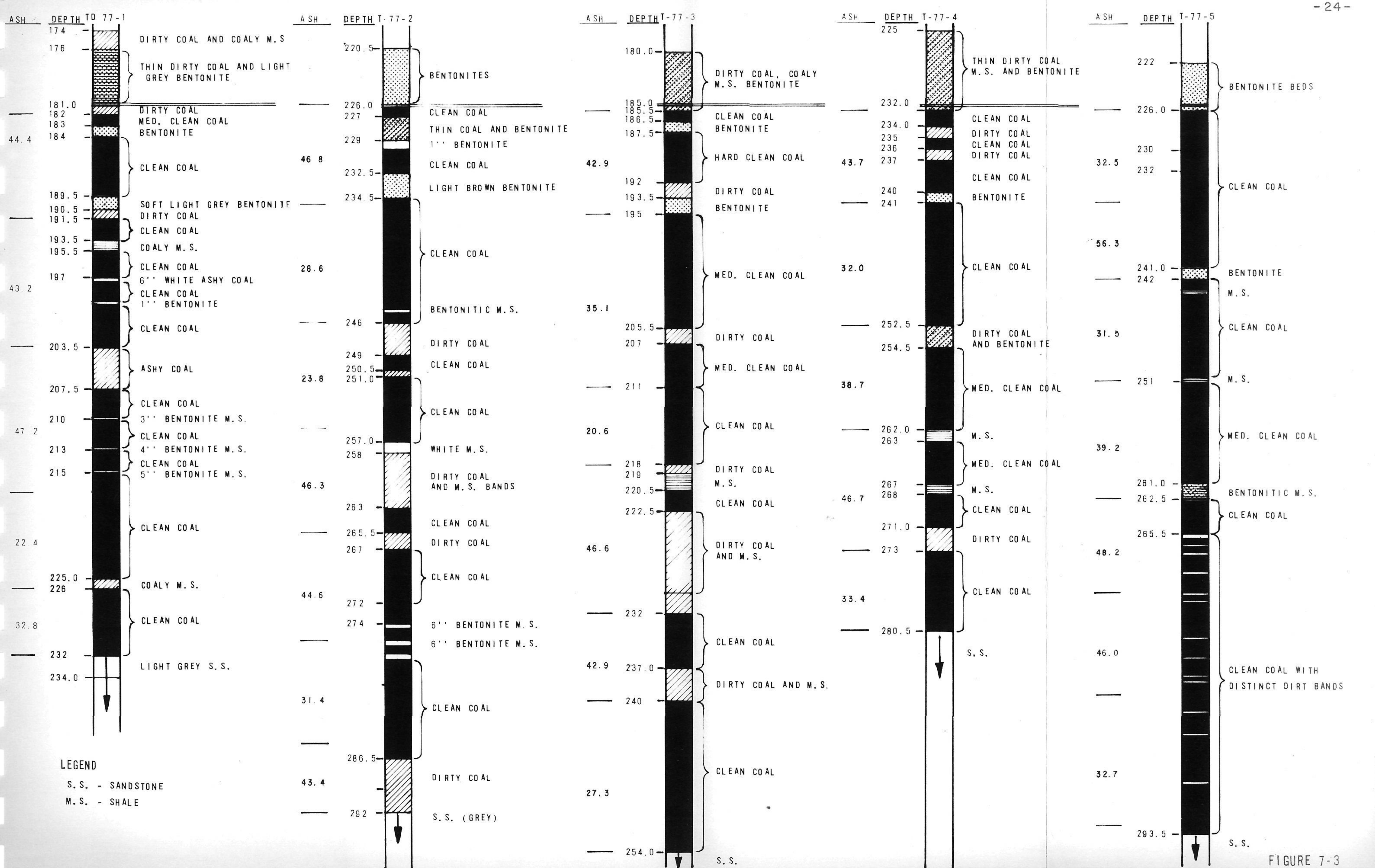


FIGURE 7-3

7.2.2 Run-of-Mine Ash Content

In order to minimize the run-of-mine (plant feed) ash content, careful consideration has been given to selecting a mining method that will eliminate the extraneous rock and clay to the greatest extent possible. The footwall is a very hard, distinct sandstone, so virtually no footwall dilution is expected. The hangingwall consists of bentonitic clay with thin lenses of dirty coal which may be selectively rejected with scrapers or backhoes. A thick in-seam bentonite dirt parting will also be selectively wasted. Finally, a rotary breaker will be incorporated in the raw coal handling system which will result in some additional rock extraction.

Considering selective mining and the breaker rejects, the actual run-of-mine (ROM) plant feed may be roughly calculated as follows:

Raw coal ash content, total seam	40.9% (dcb)
Ash content <u>after</u> selective mining	38.2%
Assume: 18.3m average seam thickness 1.0m parting material rejected parting material 75% ash, 2.2 sg coal material is 1.6 sg	
Ash content <u>after</u> rotary breaker	37.1%
Assume: +4 in. is 15 wt.% of total feed 15% of +4 in. is rejected reject is 85% ash, 2.3 sg	
Thus, ROM (plant feed) at 8% moisture =	34.1%

It will be noted that the ash has been reduced 3.8 percentage points (dcb) or nearly 10% of the total.

7.2.3 Size Distribution, Tests to Determine

One of the most important considerations in wash plant design is the size distribution of the plant feed. Western Canadian coal cleaning experience has shown that the normal methods of determining size distribution are not entirely functional due to coal deposition characteristics, clay bands in the coal seam and mining methods employed. Efforts have been made to simulate, by attrition methods, the degradation which will occur in the mining and cleaning processes, so that exploration samples may be pretreated to give an accurate prediction of size distribution. Unfortunately, no method to date has been 100% successful.

Natural size degradation occurs due to the tectonic folding and faulting which has occurred in the Rocky Mountains, the friable nature of Tertiary coals, and the internal stress relief of coal which has been mined at depth and stockpiled for long periods. Mechanical degradation occurs due to the impact and attrition effects of mining equipment, materials transport and storage, and processing within the preparation plant. Finally, the fines content is also a function of the amount and type of clay and shales contained within the mined coal seam.

Considerable study and testing of the cores, bulk samples and parting materials has been conducted in order to determine the effect of each of the above "fines generating" problem areas on the raw coal size consist. Significant findings are as follows with supporting details included in Appendix A:

(a) Coal Structure - An examination of the Tulameen coal in-place indicates well-developed face and butt cleats and bedding planes. This suggests that the coal material will break to cubicle particle shapes, and fines generation during mining and crushing will be relatively less than with poorly structured material.

(b) Screen Analyses-Bulk Samples - Screen analyses conducted on the bulk samples indicate some divergence from the normal distribution of mined products. This is undoubtedly due to the method of taking the bulk samples which only roughly simulates an actual mining system. The data and plots are shown in Appendix A, Table A-1 and Figure A-2, pp. 5 through 7.

(c) Friability - The friability of the coal is an important factor when determining the size distribution of the plant feed. A "Drop-shatter Test" is used to determine the ability of a coal to resist breakage during handling. The test is conducted by dropping a specific-sized lump of coal (i.e. 4" x 6") on a steel plate from a specified height.

Results of the test are shown in Appendix A, Table A-2 page 8. The size stability is 66% with a friability of 34%. This is slightly softer than the Alberta Foothills sub-bituminous coals, but much harder than bituminous coals in general. Based on this work, it is concluded that Tulameen coal should not degrade during handling to an abnormal extent.

(d) Liberation Tests - This test is primarily conducted to determine the increased coal yield, or Btu recovery, resulting from reduction of the top size of material to be processed in a cleaning plant. Test results, shown and discussed on pages 9-12, Appendix A, indicate an optimum top size of at least 4 inches for the plant; middlings reprocessing appears warranted.

(e) Rotary Breaker Sizing - Having determined the top size of the plant feed should be about 4 inches, additional "Drop-shatter Tests" were conducted to assist in selecting the proper size rotary breaker. The objectives are to determine that size of breaker which will provide the top size of material desired with a minimum production of fines and loss of coal through the reject end.

It was concluded from the testing that a 9' x 16' rotary breaker would be suitable; the test procedure and data are included in Appendix A, pp. 13 and 14.

(f) Clay Parting Mineralogy - The clay partings in the main seam were sampled and analyzed in order to assess the extent of clay contamination which may occur in the plant feed. The parting material was analyzed by Core Laboratories - Canada Ltd. in Calgary, with the following results:

Material less than 5 microns	50.3% (CLAY)
Material greater than 5 microns	49.7% (SILT)

X-RAY DIFFRACTION ANALYSIS (CLAY)

Quartz	3%
Feldspar	4%
Siderite	2%
Kaolinite	35%
Illite	NIL
Chlorite	NIL
Montmorillonite	56%
	100%

It is noted that the parting material is very fine in consist and that the Montmorillonite component is quite high in the clay material. The implications are that much of the parting material will report to the fine coal and water clarification circuits of a cleaning plant; ample desliming and water clarification circuitry will be required.

After consideration of all the above factors, in conjunction with review of actual plant experiences in the general area, the following screen analyses have been developed to provide for materials handling and process plant design:

		PLANT FEED (CUM. %)		
Screen Size	ROM (Cum. %)	Max. Coarse	Average	Max. Fine
+4 in. Rd.	23.6	--	--	--
4 x 1-1/2	45.0	38.0	26.3	21.0
1-1/2 x 3/4	56.8	48.5	40.9	31.0
3/4 x 1/4	70.8	64.0	58.1	48.0
1/4 x 28M	87.6	83.0	78.8	74.0
28 x 100	92.8	90.0	87.7	84.0
100M x 0	100.0	100.0	100.0	100.0

Note that it is estimated the plant may experience up to 26% minus 28M and 16% minus 100M material. These values are judgemental in quality at this time and, as stated, are based on study of the various test data, lithologic logs, and review of area processing plant experiences. Some of the latter experiences have been very poor because of underestimation of the amount of extreme fines (-28M) resulting in the need for costly and time consuming plant modifications. See Appendix A, pp. 15 through 20 for additional rationale and supporting details regarding the design screen analyses.

Some additional test work and further study of operating plants and process unit capabilities will be done in the future for the purpose of refining the fines values. In the meantime, use of these screen analyses should assure ample fine coal circuit and water clarification design in feasibility studies.

7.3 Washability

Float-sink was conducted on cores T-77-1 through T-77-5 and on all four bulk samples. Although the cores were processed somewhat differently, they indicate that the coal quality throughout the proposed mining area is reasonably uniform. This can be seen by comparing yield and ash values at the same specific gravity of separation as shown below:

Core I.D.	Size Processed	1.60 sg Cumulative Float Yield (Wt. %)	1.60 sg Cumulative Float Ash (Wt. %)
T-77-1	3/4" x 100M	54.3	13.1
T-77-2	3/4" x 100M	54.9	13.7
T-77-3	3/4" x 100M	56.7	12.1
T-77-4	3/8" x 100M	47.5	12.2
T-77-5	3/8" x 100M	49.0	11.7

Note the higher yields and ashes for the first three cores as compared to the lower values for the latter two. This is the result of having crushed the latter two cores to -3/8 inch and shows the usual liberation effect expected from smaller size consists. Additional details are shown in Appendix A, pp. 1 and 2.

The bulk samples also indicate a general uniformity across the mining area. Similar values for the bulk samples are listed below:

Bulk Sample I.D.	Size Processed	1.60 sg Cumulative Float Yield (Wt. %)	1.60 sg Cumulative Float Ash (Wt. %)
No. 1	1-1/2" x 100M	57.3	12.2
No. 2	4" x 100M	54.7	13.8
No. 3A	4" x 100M	66.0	18.0
No. 3B	4" x 100M	62.9	17.8

Noting the above ashes, the low ash of 12.2% for Sample No. 1 is expected because of the relatively small size consist processed compared to the other samples. The low ash for the coarser No. 2 Sample seems incorrect. Nevertheless, study of the test data indicate lower ash throughout the sizes.

It is felt that Sample Nos. 3A and 3B offer conservative estimates of the density make-up of the coal. Further, it is felt that the finer size consist actually anticipated in the plant feed (p. 29, Average Screen Analysis) will provide for greater liberation than shown in the bulk sample testing. Because Sample No. 3B was larger than No. 3A (10 tons to 2 tons) and received more extensive testing than 3A, Sample No. 3B washability has been selected as a basis for process design and clean coal quality estimates. The complete float-sink testing of Sample No. 3B is contained in Appendix A, Tables A-3a through 3i, pp. 21 through 29.

7.3.1 Data Interpretation

a. $\pm$ 0.1 Specific Gravity Quantities - In order to obtain both reasonably high plant yields and Btu recoveries, most steam coals are cleaned in the range of 1.60 to 1.80 specific gravity of separation. The amount of $\pm$ 0.1 specific gravity material surrounding the selected gravity of separation provides a measure of the difficulty in making an efficient separation.

Study of the test data indicates considerable "near gravity" material, on the order of 15% to 20%, is present depending on the size fraction and gravity of separation evaluated. Thus, the coal is classed as difficult to clean. It should be noted, however, that this rule-of-thumb regarding the relative difficulty of cleaning a coal was developed long ago for conventional Baum type jigs. Later developed cleaning apparatus such as heavy media systems and/or Batac Jigs can satisfactorily cope with such coals and are usually selected for such tasks. As is discussed later, the Batac Jig has been selected as the principal cleaning unit for this project.

b. Yields - Maximum and Minimum - Yields of clean coal and refuse will vary just as size consist varies. Yield changes are due to a number of factors: changes in mining conditions, weather, top and bottom rock character, parting quantities and character, seam thickness, and the character of the coal.

Yield changes must be taken into account during process design. This variability results in flow rate changes within the plant and, thus, equipment must be sized to accommodate the varying flows. Compounding the problem of determining the magnitude, frequency and duration of flow rate changes within the plant is the sometimes countering and other times additive effects of the feed size consist variability. Fortunately, there is a smoothing effect caused by random multiple variables (they tend to balance each other); additional smoothing is provided by multiple coal extraction points in the pit and by the natural blending which takes place in raw coal handling and storage systems.

Study of the core and bulk sample washability data indicates the main influence on yield change will be due to varying amounts of parting and extraneous rock included in the plant feed. Changes within the density make-up of the coal itself are not great.

Considering the above, it is felt that clean coal yields may vary as much as 10 percentage points on either side of the average yield determined for each size fraction from Sample No. 3B washability. As is discussed in the process design section, four major size consists will be used for design. Thus, as an example, the 1.60 sg clean coal yield from the 3/4" x 1/4" size consist may vary from 57.4% to 77.4% around the average of 67.4%. See Appendix A, Table A-3c, p. 23.

c. Froth Flotation - Froth flotation tests were conducted on 28M x 0 and 100M x 0 fractions of the core and bulk samples. Flotation response was very poor, with little coal floating, and the coal that did float was very high in ash. These results, coupled with the high clay content of the main Tulameen coal seam, indicate that froth flotation would not be practical.

d. Flocculation Tests - Floc tests were conducted on -100M material from Bulk Sample Nos. 2 and 3A; other tests were conducted on a -65M sample from the Birtley Bulk Wash test. Several brands of material were tested with a range of results. The tests indicate that the slimes from the cleaning plant can likely be thickened. More testing will be done in the future to better define optimum brands, dosages, etc. Final determinations will be made after plant start-up when the various circuits have stabilized.

7.4 Pilot Plant Performance

A combination of Bulk Samples No. 2 and 3B was washed in the pilot plant facilities of Birtley Coal and Minerals Testing Ltd. in Calgary. The purpose of the pilot washing was to produce a clean coal bulk sample for a test burn, and to measure the adverse effects that the clay may have on desliming, cyclone performance, and the plant water circuit in general. The results of this test should not be interpreted as an equipment performance evaluation, although some of the results may be used as guidelines for plant design. See Appendix B for details. Significant findings are as follows:

a. Water-only cyclones were effective in making a separation on fine rejects.

b. Conventional sieve bends were ineffective due to the high clay slimes component; it was felt that two-stage vibrating sieve bends would be much more effective.

c. Magnetic separator products contained large amounts of clay indicating that heavy media circuitry would be a poor choice for cleaning this coal.

d. Clean coal products from the test, especially the +28M sizes, compared favorably to predicted quality based on washability.

7.5 Process and Product Description

Since a coal preparation plant must be installed at the Tulameen site, a variety of products may be produced. The heating value, ash content and moisture content may be adjusted to suit the needs of potential buyers.

7.5.1 Preparation Plant Process Selection

Because Tulameen coal will be difficult to wash, Cyprus Anvil Mining Corporation has chosen a highly efficient Batac jig combined with hydrocyclones for the cleaning process. The plant itself is described in detail in Section 8.0. The presence of interbedded clay bands and partings, and the density make-up of the coal dictate that the coarse coal washing unit must be flexible regarding washing gravities and it must have the ability to make efficient separations. Less efficient jigs would not have the flexibility necessary to produce a uniform product.

The fine coal cleaning accompanying the Batac jig will incorporate a two-stage hydrocyclone circuit. Selection of this system versus tables is also based on experience gained from the Birtley bulk wash test. In that test, it was determined that hydrocyclones performed well; this is probably because hydrocyclone circuits require large volumes of water which ostensibly minimized viscosity effects due to the clay materials. It is felt that the cleaning efficiency of a table circuit may be diminished due to the fact that much less water is required for tables and hence clay induced viscosity problems may become significant.

During the Birtley bulk wash test, it was found that heavy media cleaning would be impractical for the +28M fraction of the Tulameen coal because the clay would increase the viscosity of the media beyond functional washing ranges. Heavy media vessels were considered for plus 1/4 inch coal where the clay would not be so severe a problem; minus 1/4 inch coal would then be cleaned in a fine coal circuit. This scheme was rejected because of high capital and operating cost, and the added problems of handling and storing magnetite media.

No froth flotation is included in the process due to poor test results. Hence, minus 100M materials will be wasted. The process will incorporate mechanical dewatering through the use of vibrating screens and centrifuges. Process water clarification and recovery will be accomplished through the use of settling ponds.

7.5.2 Clean Coal Yield and Quality Estimates - Technique

A clean coal yield and ash quality estimate has been made using partition curves for the Batac jig and Hydrocyclones. These curves have been developed through performance tests; they describe the performance of commercial scale units and thus allow the theoretically perfect laboratory developed washability to be appropriately altered. The curves are shown in Appendix A, Figures A-4 and A-5, pp. 30 and 31.

Clean coal quality may be varied according to the operation of the preparation plant circuitry. In general, hydrocyclone circuits are operated at a fixed gravity of separation resulting in a relatively uniform product quality. Jigs on the other hand, can be easily adjusted to change the gravity of separation. Thus, product quality changes are accomplished in this manner.

Gravity concentrating devices such as cyclones and jigs, when processing a range of sizes, normally affect higher separating gravities on the smaller sized materials. This is shown in the legends of the partition curves; the range of gravities shown are for illustrative purposes only.

Estimated yields and product ash for three different average gravities of plant operation are as follows:

Average Separating Gravity (SG)	Yield (Wt%, dry)	Ash (Wt%, dry)
1.55	45.5	17.8
1.60	52.0	19.1
1.65	57.1	20.3

These values are based on:

- o The "Average" plant feed screen analysis, discussed p.29.
- o Bulk Sample No. 3B washability, p.31.
- o Partition curves, p. 36.
- o Middlings re-processing (contributes 2.5% yield) p. 27, item d.
- o Minus 100M material wasted (12.3% of plant feed), p. 29, screen analysis.
- o Reasonably effective selective mining (most of thick bentonite parting removed) and some further slight amount of rock extraction at the rotary breaker, p. 25.

7.5.3 Plant Clean Coal Products

As shown, the plant can be operated to provide various yields and ash levels. The Btu content of the final product will be dependent on the ash level and the total moisture of the plant product.

Btu projections are based on a moisture and ash free (MAF) value of 15,525 Btu per pound. Study of the various test data show the following:

- o The bulk sample simulated clean coal composites (1.55-1.65 sg. float) have an average MAF Btu of 13365.

TULAMEEN CLEAN COAL SPECIFICATIONS

Company CYPRUS ANVIL MINING CORPORATION Date December 22, 1980

Mine Tulameen Type Coal Simulated Plant Clean Coal (Washed or ROM)

Mine Location (County) Size 4" x 100M

Description of Sample 1.60 sg average plant operating gravity

PROXIMATE

	As Rec.	A.D.B.	Dry
% Moisture	13.2	4.5	----
% Ash	16.6	18.2	19.1
% Volatile	27.0	29.7	31.1
% F.C.	43.2	47.6	49.8
Btu/lb.	9500	10457	10945
Kcal/Kg.	5278	5809	6080
% Sulfur	0.56	0.62	0.65

ULTIMATE

	As Rec.	Dry
% Moisture	13.2	----
% Carbon	54.4	62.6
% Hydrogen	3.7	4.3
% Nitrogen	1.0	1.2
% Chlorine	----	----
% Sulfur	0.5	0.6
% Ash	16.6	19.1
% Oxygen	10.6	12.2

FUSION TEMPERATURE OF ASH (°C)

	Red.	Oxid.
In. Def.	1288	1354
Softening (H=W)	1399	1438
Softening (H=1/2 W)	1435	1460
Fluid Temp.	1482	1482

SULFUR FORMS

	As Rec.	Dry
Pyritic	0.09	0.10
Sulfate	<0.01	<0.01
Organic	0.46	0.54
Total	0.56	0.65

ANALYSIS OF ASH

	Ign. Basis
Phos Pentoxide P_2O_5	0.2
Silica SiO_2	70.5
Ferric Oxide Fe_2O_3	5.1
Alumina Al_2O_3	16.2
Titanium TiO_2	0.7
Lime CaO	0.7
Magnesia MgO	0.5
Sulfur Trioxide SO_3	0.4
Potassium Oxide K_2O	1.4
Sodium Oxide Na_2O	0.6
Undetermined	3.7

Equilibrium Moisture: 9.8%

Hardgrove Grindability Index: 59

Base/Acid Ratio: 0.095; R_s=0.06; R_f=0.06

Classification: High Volatile Bituminous "C"

Fuel Ratio FC/VOL: 1.6

- A similar value for the 1.60 sg float of five cores, taken at greater depth, shows an MAF value of 13558.

The implication is that the bulk samples are slightly oxidized. The ultimate analysis, when plotted on Seyler's Coal Chart (Appendix A, Figure A-6, p. 32) also indicates a partially oxidized condition. This is quite probable since the bulk samples were taken in trenches relatively close to the ground surface. The mined product will be from greater depths, hence oxidation of the ROM coal should be minimal and thus a higher MAF has been selected.

The total moisture of the clean coal product from the preparation plant is estimated at 13.2%. This estimate is based on a review of equilibrium, as-received, and total moistures resulting from the Birtley bulk wash test and CANMET analyses of the clean coal product from that test. In addition, account has been taken of the anticipated screen analysis and proposed plant dewatering circuitry. Total moisture of the plant feed is estimated at 8.0%. Thus, a possible range of plant clean coal products follows:

Average Separating	At 13.2% Total Moisture		
Gravity (sg)	Yield (Wt%)	Ash (Wt%)	Btu (lb.)
1.55	48.2	15.5	9650
1.60	55.1	16.6	9500
1.65	60.5	17.6	9350

Total description of the 9500 Btu product is shown on Table 7-1, p. 39. Characteristics of the other products should be much similar.

A petrographic analysis of the Tulameen Coal shows that it is predominantly vitrain and clarain composed of greater than 90 percent vitrinite.

7.6 Burn Characteristics of the Product

A combination of Bulk Sample No. 2 and 3B was washed in the Birtley pilot plant to produce a clean coal similar to that expected from a commercial operation. This coal was burned in the pilot-scale boiler of the Canadian Combustion Research Laboratory in Ottawa. The boiler operates under conditions representative of those existing in large pulverized coal-fired thermal power boilers. The details of that test (observed by Techman Ltd. staff) are attached as Appendix C. Major conclusions are:

- Tulameen coal exhibits very good properties as a power plant fuel. It has low slagging and fouling tendencies and SO_2 emission levels will be approximately 1.1 lbs per million Btu.

- The coal will also be an excellent fuel for firing cement kilns. Most sulfur will be retained in the cement and existing pollution control equipment should be adequate without modification.

8.0 COAL PREPARATION FACILITIES - Obsolete

(see Wright Engineers Report)

Pages 42 - 47 (Obsolete)

9.0 CLEAN COAL TRANSPORT

9.1 Trucking from Preparation Plant to Rail Car Load-Out

Clean coal will be trucked from the preparation plant to a rail car loading facility to be built immediately west of the town of Coalmont. This haul will utilize 20 to 30 ton trucks. Trucks will load from a 100 ton clean coal bin at the preparation plant. This bin will be equipped with an undercut gate which may be operated by the individual truck drivers during load-out operations.

The existing road from the plant site to the proposed rail load-out is approximately 11 kilometers in length. A number of alternate possible road routes are being investigated. These routes could be substantially shorter than the existing road and could be developed with more moderate grades.

Trucks will dump in a stockpile area adjacent to the rail loading facility. This stockpile site consists of a level base, drainage ditches for run-off water, and a settling pond.

9.2 Rail Car Loading System

Rail car loading will utilize a large front end loader, reclaiming from the truck-dumped stock pile and loading directly into the rail cars, assisted by a built up camp.

9.3 Rail System

The rail system that will be used to transport the coal is comprised of C.P. Rail's branch line from Coalmont to Spences Bridge and their mainline from Spences Bridge to Port Coquitlam Yards, near Vancouver. This routing is shown on Figure 1-1. Routes from Port Coquitlam will depend on eventual markets. For overseas markets, the coal will be delivered to deep-sea bulkcommodity terminals in the Vancouver area.

The C.P. Rail branch line from Coalmont to Spences Bridge, in its present condition, is capable of handling the proposed volume of coal using cars of 80 ton capacity. One hundred ton cars and their resulting heavier axle loadings would necessitate upgrading of this section of track.

Rolling stock would consist of two trainsets of 46 triple cross hoppers which would be capable of handling 78 short tons per car. Loaded trains would be lifted by an arriving empty train and the empty cars would then be available for loading until return of the previously loaded train, approximately 65 hours later. An allowance of 16 hours is made for unloading at a Vancouver area bulk terminal.

APPENDIX A

DRILLING, CORING, AND CORE TESTING

Twelve diamond drillholes, totaling 1,479.1m, were drilled during the period July through September, 1977. The following lists some of the more pertinent details of the program.

- All 12 holes penetrated the "Main Seam" which is of primary interest.
- The five holes T-77-1 through T-77-5 are of most interest in this study since they are within the area of intended mining.
- Core recovery on these five holes was very good ranging from 94% to 98%.
- Core testing, as shown on Figure 7-1 (page 20 of the report text), was conducted by Cyclone Engineering Sales, Ltd.
- Raw coal analyses:

Hole I.D.	Equil. Moisture %	Ash %	Sul. %	Btu/lb.	Specific Gravity
T-77-1	7.3	37.3	0.40	7077	1.63
T-77-2	7.4	36.2	0.43	7302	1.61
T-77-3	8.0	35.7	0.41	7364	--
T-77-4	7.8	40.4	0.40	6750	--
T-77-5	8.3	40.3	0.41	6506	1.77 (T-77-6)
Average	7.8	38.0	0.41	7000	1.64[a]

[a] Determined from ash vs. specific gravity curve; used for reserves determination.

o Representative Washability Data:

Hole I.D.	Size Material	1.60 Cum. Float (Dry Values) Wt. %	Ash %	Btu
T-77-1	3/4" x 100M	54.3	13.1	11070
T-77-2	3/4" x 100M	54.9	13.7	10970
T-77-3	3/4" x 100M	56.7	12.1	11140
T-77-4	3/8" x 100M	47.5	12.2	11130
T-77-5	3/8" x 100M	49.0	11.7	10930

The latter two cores were crushed to -3/8 inch by mistake. However, the lower yields and generally higher quality point out the problem of making clean coal quality projections from cores.

BULK SAMPLES

Four large bulk samples were taken during the 1977 field work. Pertinent details are as follows:

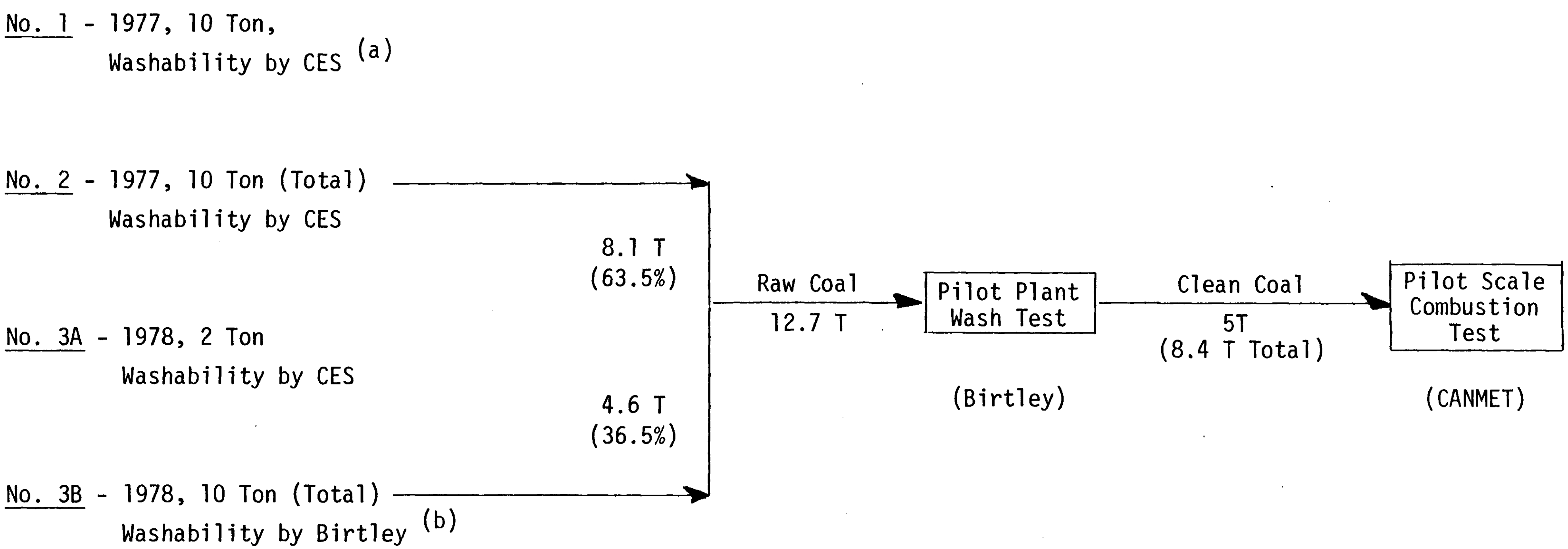
- o Sample Nos. 1 and 2, 10 tons each, were collected from Trench No. 5; Sample Nos. 3A and 3B, 2 tons and 10 tons respectively, were collected from Trench No. 3. See Map 5-1 for locations.

- o Sample Nos. 1 and 2 included all interbeds; Sample Nos. 3A and 3B excluded the approximate 1m bentonite bed.

- o As shown on Figure A-1, next page, washability and pilot plant washing and combustion tests were run on these samples. Additional processing details are shown on Figure 7-2, p. 22 of the text.

- o Results of the pilot plant washing test conducted by Birtley are contained in Appendix B; results of the combustion tests conducted by CANMET are contained in Appendix C.

BULK SAMPLE PROCESSING



(a) Cyclone Engineering Sales, Ltd.

(b) Birtley Coal and Minerals Testing

Figure A-1

TABLE A-1

BULK SAMPLES - SCREEN ANALYSES AND QUALITY

SIZE FRACTION	WT. %	ASH % (dcb)
Bulk Sample No. 1 (Crushed to 1-1/2" top size)		
1-1/2" x 3/4"	34.70	41.9
3/4" x 1/4"	31.62	36.8
1/4" x 28M	23.26	30.6
28M x 100M	6.62	32.3
100M x 0	3.80	46.9
	100.00	37.2
Bulk Sample No. 2		
+4"	22.96	40.7
4" x 1-1/2"	23.06	38.8
1-1/2" x 3/4"	15.82	40.1
3/4" x 1/4"	9.87	38.5
1/4" x 8M	7.71	22.6
8M x 28M	8.64	26.5
28M x 100M	5.67	45.8
100M x 0	6.27	68.8
	100.00	39.4
Bulk Sample No. 3A		
+4"	24.36	36.0
4" x 1-1/2"	19.65	36.7
1-1/2" x 3/4"	7.75	35.3
3/4" x 1/4"	18.22	33.2
1/4" x 8M	8.42	19.9
8M x 28M	8.81	20.9
28M x 100M	4.74	31.5
100M x 0	8.05	67.1
	100.00	35.2

TABLE A-1 (Continued)

SIZE FRACTION	WT. %	ASH % (dcb)
Bulk Sample No. 3B		
4" x 1-1/2"	26.1	35.7
1-1/2" x 3/4"	14.3	36.0
3/4" x 1/4"	17.4	33.0
1/4" x 1/8"	10.4	30.1
1/8" x 28M	23.6	30.7
28M x 100M	6.0	40.4
100M x 0	2.2	49.0
	100.0	34.1

DEC. 17, 1980

SIZE CHARACTERISTICS OF: CYPRUS ANVIL / TULAMEEN COAL

BULK SAMPLES - MAIN SEAM (Eb7)

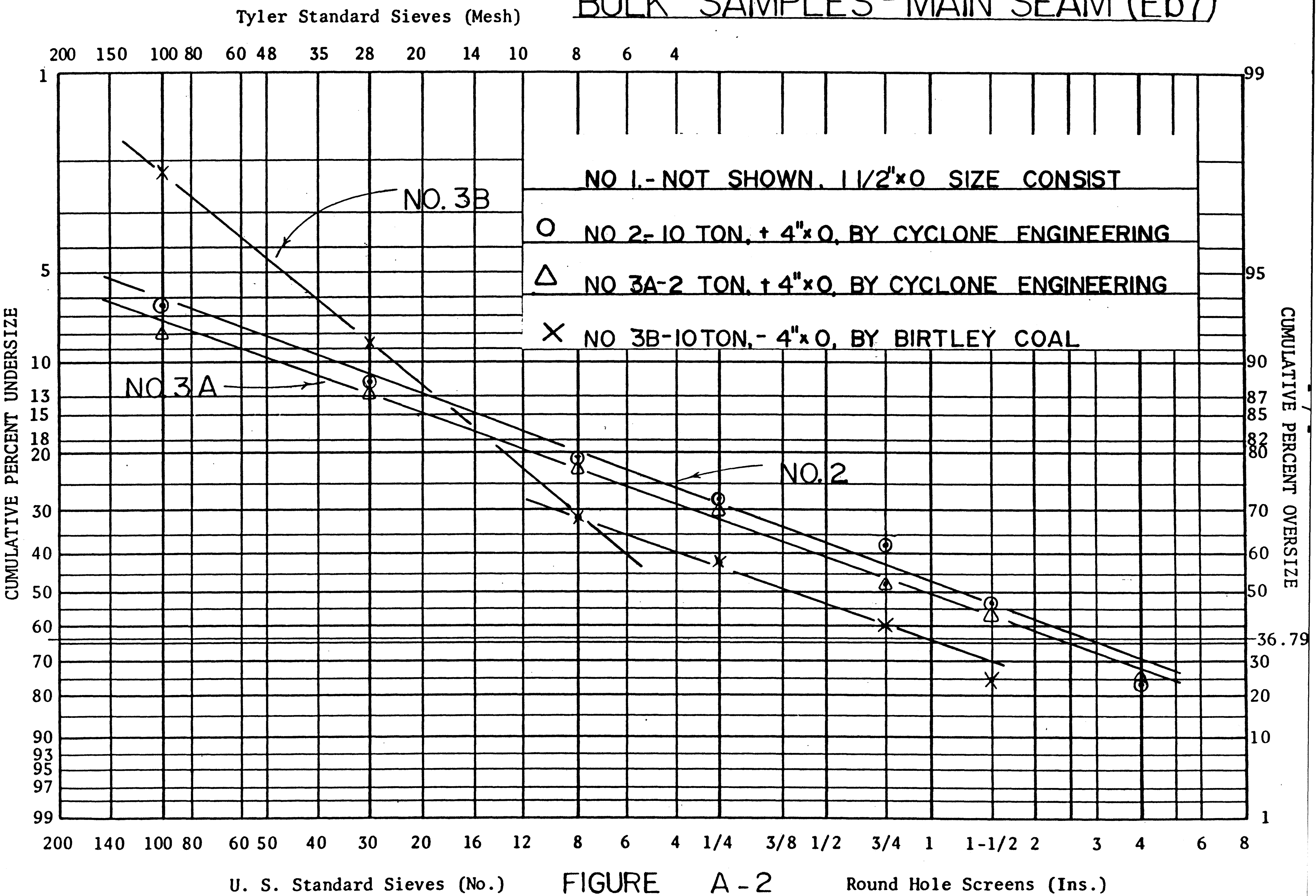


FIGURE A-2

TABLE A-2

DROP-SHATTER TEST

(6" x 4" Raw Size Fraction) - Bulk Sample 3B

SCREEN SIZE INCH (MM.)		WEIGHT %	AVERAGE OF SCREEN OPENINGS		PRODUCT OF WT. % x FACTOR
RETAINED ON %	PASSING %		INCHES	FACTOR	
SAMPLE					
4" (101.6)	6" (-----)	100.0	5.000	1	100.0 = S
4" (101.6)	6" (-----)	43.3	5.000	1	43.3000
3" (76.2)	4" (101.6)	19.0	3.500	0.7	13.3000
2" (50.8)	3" (76.2)	10.3	2.500	0.5	5.1500
1-1/2" (38.1)	2" (50.8)	5.9	1.750	0.35	2.0650
1" (25.4)	1-1/2" (38.1)	5.1	1.250	0.25	1.2750
3/4" (19.1)	1" (25.4)	2.3	0.875	0.175	0.4025
1/2" (12.7)	3/4" (19.1)	2.6	0.625	0.125	0.3250
1/4" (6.4)	1/2" (12.7)	3.5	0.375	0.075	0.2625
1/8" (3.2)	1/4" (6.4)	2.4	0.1875	0.0375	0.0900
	1/8" (3.2)	5.6	0.0625	0.0125	0.0700
TOTAL (Sum of Products (WT. % x FACTOR) for dropped coal) =					66.2400 = S
SIZE STABILITY, % = (100 x S)/S = 66.2 rounded off as 66 FRIABILITY, % = 34					

LIBERATION TESTS

Liberation tests were conducted on Bulk Sample No. 3B for two purposes, viz. 1) to determine the optimum top size of plant feed and 2) to determine the potential for improved yields through crushing and reprocessing of the coarse middlings. Results and conclusions are as follows:

A. Top Size Determination

Tests were run on the 4 in. x 3/4 in. fraction of Bulk Sample No. 3B that enabled a determination regarding the feasibility of reducing the plant feed top size to 3/4 inch. In this type of study, the objective is to determine whether the increased yield from the plant will more than off-set the added costs. These are additional crushing, more fine coal processing apparatus, additional dewatering costs due to the finer size of materials processed, and the loss of additional extreme fines (-100M) to waste. Calculations are as follows:

		FEED WT. %
Original Coal (4" x 3/4" fraction only)		40.2
1.55 sg float	21.2	
1.55 sg sink	19.0	
Total	40.2	
1.55 Sink Crushed to 3/4" Top Size		
3/4" x 1/4", 19.5% Ash, Yield		0.5
1/4" x 1/8", 19.5% Ash, Yield		0.6
1/8" x 28M, 19.5% Ash, Yield		2.9
28 x 100M, 19.5% Ash, Yield		1.2
Increased Yield =		5.2%
Additional -100M Material Generation		
Total 4" x 3/4" crushed to 3/4" x 0 =		2.1%
Net Gain (-100M Wasted) =		3.1%

The above is interpreted as follows:

- o Assume the total natural size fraction of 4" x 3/4" is reduced to 3/4" x 0 prior to processing. Thus, the plant feed is 3/4" x 0 instead of 4" x 0.

- o In reducing the top size to 3/4", 2.1% additional -100M material is generated.

- o For convenience in determining yields, assume all crushed sizes are processed to provide 19.5% ash. In actual fact, the ash levels of the smaller sizes (-1/4" sizes) may be somewhat higher resulting in higher yields than shown.

- o The net gain of 3.1% yield must offset the additional costs as listed before. Detailed studies would be required to evaluate this problem; however, similar studies conducted by consultants on other projects indicate the feasibility as marginal.

B. Middlings Crushing and Reprocessing

Another possible means of accomplishing a yield improvement is to reprocess the coarse coal (4" x 3/4") middlings stream produced by a primary cleaning unit such as a jig. The major differences in this scheme, as compared to the preceding discussion, are as follows:

- o The top size of feed to the plant is kept as coarse as possible (4" to 6").

- o Only the coarse middlings are crushed to -3/4" and reprocessed.

- o "Middlings" are considered to be intermediate gravity materials. In the following calculation, middlings are the 1.55 sg x 1.80 sg material.

o This scheme can greatly minimize the small and fine coal circuitry required in the plant. This is important because, in general, it costs three or more times as much in capital and operating costs to process a ton of -1/4" material as compared to a ton of +1/4" material.

		FEED WT. %
Original Coal (4" x 3/4")		40.2
1.55 sg float	21.2	
1.55 x 1.80 sg (Middlings)	12.3	
1.80 sg sink	6.7	
Total	40.2	

Middlings Crushed to 3/4" Top Size	
3/4" x 1/4", 19.5% Ash, Yield	0.3
1/4" x 1/8", 19.5% Ash, Yield	0.4
1/8" x 28M, 19.5% Ash, Yield	1.9
28 x 100M, 19.5% Ash, Yield	0.8
Increased Yield =	3.4%

Additional -100M Generation	
4" x 3/4" middlings crushed to 3/4" x 0 =	0.7%
Net Gain (-100M Wasted) =	2.7%

Interpretation of this scheme is as follows:

o The net gain is similar to that calculated in A.

o Considerably less material is being crushed and reprocessed.

o Fines generation (-100M) is much less.

- Small and fine coal circuitry requirements will be significantly less.

- This scheme appears economically feasible and warrants further study.

Conclusions

- Testing to date indicates no economic benefit in reducing the plant feed top size from 4 in. to 3/4 in.

- It does appear feasible to reprocess the coarse middlings.

ROTARY BREAKER SIZING TESTS

Birtley Coal and Minerals Testing provided the Pennsylvania Crusher Corporation with approximately 600 lbs. of plus 4 inch coal and rock material for sizing tests. The material was obtained from bulk sample No. 3B after a 2 ton portion was extracted for float-sink and size analyses.

The test is conducted in a manner to simulate the action of a rotary breaker. It consists of dropping oversize material repeatedly until the remaining oversize material is primarily rock only. Two tests were conducted as follows:

Test No. 1

The material was dropped from a height which simulated a 9' diameter Bradford Breaker. The starting weight of plus 4" round hole material was 150.50 Kg. Drop test results were as follows:

Drop Number	Oversize (Plus 4")	Undersize (Minus 4")	Cum. % of Oversize	Cum. % of Undersize
1	127.25 Kg.	23.25 Kg.	84.55	15.45
2	93.75 Kg.	33.50 Kg.	62.29	37.71
3	74.00 Kg.	19.75 Kg.	49.17	50.83
4	60.50 Kg.	13.50 Kg.	40.20	59.80
5	52.50 Kg.	8.00 Kg.	34.88	65.12
6	41.25 Kg.	11.25 Kg.	27.41	72.59

Test No. 2

The material was dropped from a height which simulated a 12' diameter Bradford Breaker. The starting weight of plus 4" round hole material was 127.25 Kg. Drop test results were as follows:

Drop Number	Oversize (Plus 4")	Undersize (Minus 4")	Cum. % of Oversize	Cum. % of Undersize
1	94.75 Kg.	31.50 Kg.	75.25	24.75
2	65.75 Kg.	30.00 Kg.	51.67	48.33
3	44.50 Kg.	21.25 Kg.	34.97	65.03
4	25.50 Kg.	19.00 Kg.	20.04	79.96
5	11.25 Kg.	14.25 Kg.	8.84	91.16

Note:

1. The material tested was dry.
2. The oversize material after the last drop from both tests was rock with some tightly bonded coal layers.
3. Hardgrove Grindability Indices for Test 1 and 2 were 52 and 54 respectively.

Conclusions

The test results indicated that a 9' x 16' Bradford Breaker would reject more than 25% of the coarse feed and this could be increased by removing lifters from the breaker once in operation. The shatter tests showed that only a very small amount of coal would be rejected from the rotary breaker.

DESIGN SCREEN ANALYSES - RATIONALE

Several screen analyses are required for the preparation plant process design. These analyses are an average in-process, and maximum coarse and fine size consists. The nominal flow rates within the plant circuitry are based on the average screen analysis but equipment is sized based on the maximum coarse or fine size consist expected.

I. Average Screen Analysis (In-process)

This screen analysis should reflect the average size consist being processed by the plant. The raw coal degrades or breaks down throughout the raw coal handling and plant processing circuits.

It is usual for coal to be handled six to ten or more times prior to being fed to the plant. This includes truck loading, dumping, belt transfers, top size preparation, in and out of storage, etc.

Once in the plant, continual degradation takes place due to the action of the process units; also, dependent on the circuitry employed, the fines resulting from degradation along with the natural fines may be reprocessed with the in-coming plant feed. Because small and fine coal process units are sensitive to deviations from optimum process rates, it is important to estimate the expected flow rates accurately.

Review of the bulk sample taking and processing points out the following:

- Sample Nos. 1 and 2 included the approximate one metre bentonite parting whereas Nos. 3A and 3B did not. It is anticipated that elimination of this parting, and others to some extent, will be part of the normal mining practice. It is also expected that periods of bad weather will make 'cleaning' in the pits ineffective at times.

- o Review of the bulk sample screen analyses, Table A-1, pp.5-6, this Appendix, point out that Sample No. 1 was crushed to 1-1/2 inch for processing. This is inconsistent with the proposed 4 inch feed to the preparation plant; thus this screen analysis cannot be used.

- o Sample Nos. 2 and 3A have a top size of +4 inch; again, this is inconsistent with the feed proposed for the plant.

- o Sample Nos. 2 and 3A have expected amounts of minus 28M and 100M materials considering the character of the coal, included parting materials, etc. Rosin-Rammler plots (see Figure A-2, p. 7) show reasonably good adherence to the normal distribution expected of mined coal; however, the large 3/4 x 1/4 inch fraction of No. 3A appears to be abnormal. This is likely due to the sampling technique which only roughly simulates the proposed mining system. Also, the samples have not been handled to the extent that actual ROM will experience; this handling tends to smooth out plots of actual ROM.

- o Sample No. 3B appears to have too little minus 28M and especially minus 100M considering that the thick bentonite parting was included in the sample. Also, a plot of this curve indicates abnormal distribution (see Figure A-2, p. 7). Thus, this screen analysis should not be used for plant design purposes.

- o Study of the laboratory processing of these samples, especially Nos. 2 and 3A, show that the crushed +4 inch (crushed to minus 4 inch and recombined with the natural minus 4 inch) is unusually coarse in size consist. This is due to manual crushing with a hammer instead of using a crusher. Thus, the resulting 4 inch x 0 size consist likely has a coarse bias. Crushing tests usually show that the coarse particles, when crushed, will have a relatively normal size distribution similar to the same natural size consist.

Considering the above, the "average" design screen analysis has been developed as follows:

1. Combine Sample Nos. 2 and 3A to best represent the "as-mined-in-pit" material (one sample includes the bentonite parting; also, the samples represent both trenches).

Size Fraction	Wt.% Direct	Wt.% Cumulative
+4"	23.6	23.6
4 x 1-1/2"	21.4	45.0
1-1/2 x 3/4	11.8	56.8
3/4 x 1/4	14.0	70.8
1/4" x 8M	8.1	78.9
8M x 28M	8.7	87.6
28M x 100M	5.2	92.8
100M x 0	7.2	100.0

This size consist should approximate the feed to the rotary breaker in the preparation system described in Section 8.

2. Reduce the size consist from +4 inch x 0 to -4 inch x 0. It is expected that the +4 inch material will crush to approximately the same size consist as the natural 4 inch x 0.

Size Fraction	Wt. % Direct	Wt. % Cumulative
4 x 1-1/2"	28.0	28.0
1-1/2 x 3/4	15.5	43.5
3/4 x 1/4	18.3	61.8
1/4" x 8M	10.6	72.4
8M x 28M	11.4	83.8
28M x 100M	6.8	90.6
100M x 0	9.4	100.0

This size consist should approximate the feed to the preparation plant.

3. Finally, to estimate the "in-process" size consist, the above has been altered to reflect a 5.0 percentage point increase in the 28M x 0 fraction. This additional material results from in-plant degradation and is based on performance studies conducted on similar plants processing similar coals.

	Wt. %	
Size Fraction	Direct	Cumulative
4 x 1-1/2"	26.3	26.3
1-1/2 x 3/4	14.6	40.9
3/4 x 1/4	17.2	58.1
1/4" x 8M	10.0	68.1
8M x 28M	10.7	78.8
28M x 100M	8.9	87.7
100M x 0	12.3	100.0

Flowrates, quality, and yield projections are based on this screen analysis which is denoted as the "Average" curve on Figure A-3, p. 20 , this Appendix.

II. Maximum Coarse and Fine Screen Analyses

A plant will experience large swings or changes in size consist from time to time. These occurrences normally take place when the first or last coal is withdrawn from open storage piles. Process units must be sized to accept the resulting flow rate changes.

Selection of these screen analyses is arbitrary to a large extent and primarily depends on past experiences with similar coals, materials handling systems and plants. For this study, the average weight percent of the coarse and fine halves of the average size consist has been increased by 25%. Resulting screen analyses, shown on Figure A-3, p. 20 , are as follows:

Size Fraction	Max. Coarse (Wt. %) Direct	Max. Coarse (Wt. %) Cumulative	Max. Fine (Wt. %) Direct	Max. Fine (Wt. %) Cumulative
4 x 1-1/2"	38.0	38.0	21.0	21.0
1-1/2 x 3/4"	10.5	48.5	10.0	31.0
3/4 x 1/4"	15.5	64.0	17.0	48.0
1/4 x 8M	8.0	72.0	10.0	58.0
8 x 28M	11.0	83.0	16.0	74.0
28 x 100M	7.0	90.0	10.0	84.0
100M x 0	10.0	100.0	16.0	100.0

DEC. 17, 1980

SIZE CHARACTERISTICS OF: CYPRUS ANVIL / TULAMEEN COAL

PROCESS DESIGN SCREEN ANALYSES

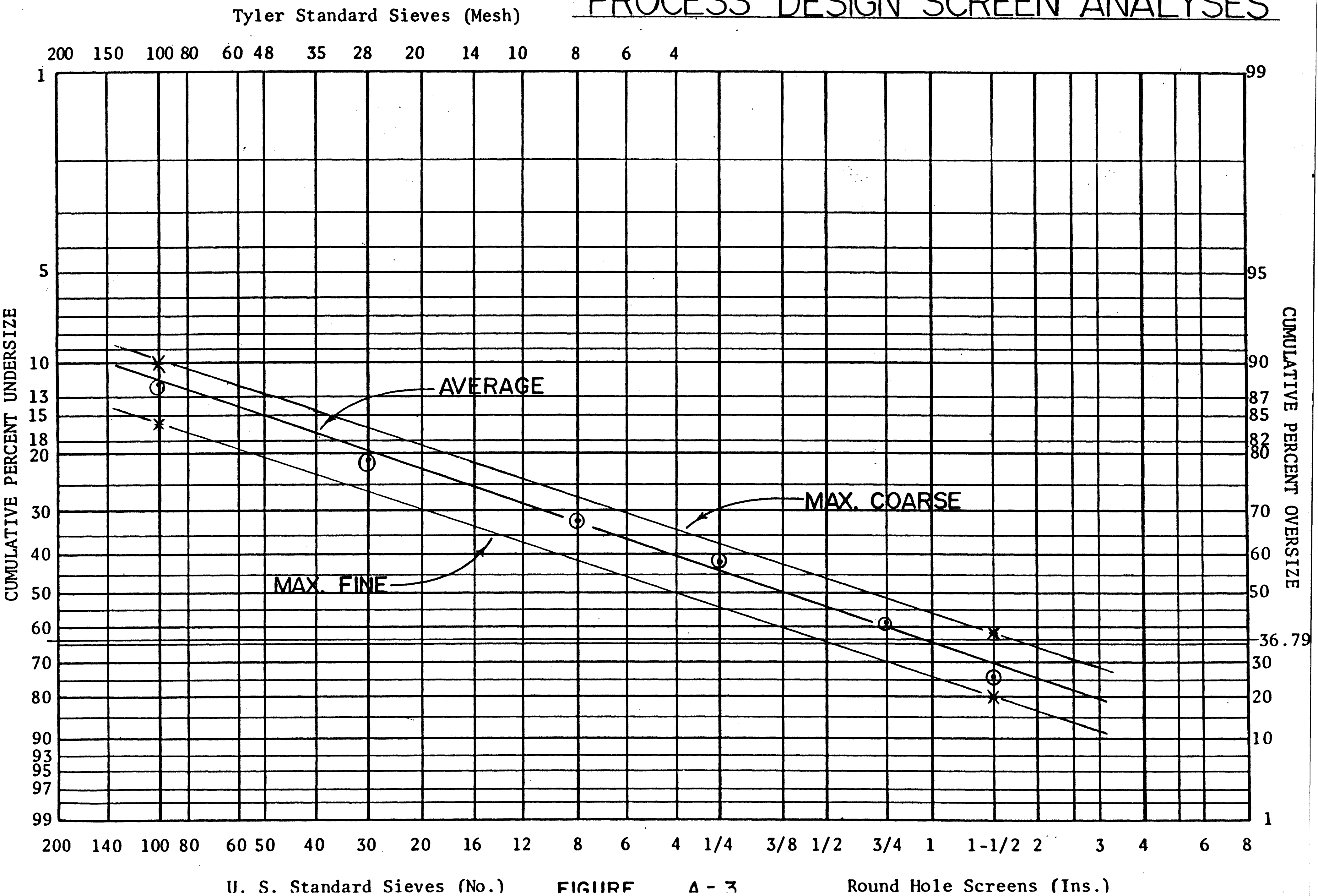


FIGURE A - 3

FLOAT AND SINK TABLES

TABLE A-3a

PLANT/SEAM – Cyprus Anvil/Tulameen Coal Field

Reported Dec. 15, 19 77

Test on : Main Coal Seam (Unit 3b7); Bulk Sample No. 3B; 10 Tons

Purpose : Washability

Sampling Procedure : Dozer trench and backhoe; Trench No. 3

Remarks : Processed by Birtley Coal and Minerals Testing

SIZE : 4" x 1-1/2"

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	--	--			--	--			--	--		
1.30	1.40	18.1	11.5			18.1	11.5			100.0	35.7		
1.40	1.50	25.0	22.6			43.1	17.9			81.9	41.0		
1.50	1.55	6.5	31.5			49.6	19.7			56.9	49.1		
1.55	1.60	11.1	36.6			60.7	22.8			50.4	51.4		
1.60	1.65	10.2	42.4			70.9	25.6			39.3	55.5		
1.65	1.70	4.4	45.7			75.3	26.8			29.1	60.1		
1.70	1.75	3.3	51.3			78.6	27.8			24.7	62.7		
1.75	1.80	5.8	56.0			84.4	29.8			21.4	64.4		
1.80	2.00	7.9	62.9			92.3	32.6			15.6	67.6		
2.00		7.7	72.4			100.0	35.7			7.7	72.4		

FLOAT AND SINK TABLES

TABLE A-3b

PLANT/SEAM - ____________________ Reported Dec. 15 , **19** 77

Test on : Bulk Sample No. 3B, Continued

Purpose : ____________________

Sampling Procedure : ____________________

Remarks : ____________________

SIZE : 1-1/2" x 3/4"

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	--	--			--	--			--	--		
1.30	1.40	24.4	10.6			24.4	10.6			100.0	36.0		
1.40	1.50	25.4	23.4			49.8	17.1			75.6	44.3		
1.50	1.55	6.5	32.1			56.3	18.9			50.2	54.8		
1.55	1.60	6.2	37.3			62.5	20.7			43.7	58.2		
1.60	1.65	4.6	42.5			67.1	22.2			37.5	61.6		
1.65	1.70	5.5	47.6			72.6	24.1			32.9	64.3		
1.70	1.75	3.3	50.8			75.9	25.3			27.4	67.7		
1.75	1.80	3.8	59.4			79.7	26.9			24.1	70.0		
1.80	2.00	9.1	68.2			88.8	31.1			20.3	72.0		
2.00		11.2	75.0			100.0	36.0			11.2	75.0		

FLOAT AND SINK TABLES

TABLE A-3c

PLANT/SEAM - ____________ Reported Dec. 15, **19** 77

Test on : Bulk Sample No. 3B, Continued

Purpose : ____________

Sampling Procedure : ____________

Remarks : ____________

SIZE : 3/4" x 1/4"

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	13.9	5.3			13.9	5.3			100.0	33.5		
1.30	1.40	19.1	11.5			33.0	8.9			86.1	38.0		
1.40	1.50	21.7	22.5			54.7	14.3			67.0	45.6		
1.50	1.55	5.7	32.1			60.4	16.0			45.3	56.7		
1.55	1.60	7.0	38.9			67.4	18.4			39.6	60.2		
1.60	1.65	5.7	42.1			73.1	20.2			32.6	64.8		
1.65	1.70	1.1	46.2			74.2	20.6			26.9	69.6		
1.70	1.75	2.4	53.3			76.6	21.6			25.8	70.6		
1.75	1.80	2.8	59.8			79.4	23.0			23.4	72.3		
1.80	2.00	8.9	70.0			88.3	27.7			20.6	74.0		
2.00		11.7	77.1			100.0	33.5			11.7	77.1		

FLOAT AND SINK TABLES

TABLE A-3d

PLANT/SEAM - ________________ Reported Dec. 15, 19 77

Test on : Bulk Sample No. 3B, Continued

Purpose :

Sampling Procedure :

Remarks :

SIZE : 1/4" x 1/8"

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	4.0	4.6			4.0	4.6			100.0	30.2		
1.30	1.40	38.4	8.3			42.4	8.0			96.0	31.3		
1.40	1.50	14.6	20.6			57.0	11.2			57.6	46.6		
1.50	1.55	7.1	28.4			64.1	13.1			43.0	55.5		
1.55	1.60	4.5	35.9			68.6	14.6			35.9	60.8		
1.60	1.65	3.6	40.8			72.2	15.9			31.4	64.4		
1.65	1.70	2.9	45.2			75.1	17.0			27.8	67.5		
1.70	1.75	1.9	49.5			77.0	17.8			24.9	70.1		
1.75	1.80	2.4	52.9			79.4	18.9			23.0	71.8		
1.80	2.00	6.9	63.4			86.3	22.5			20.6	74.0		
2.00		13.7	79.3			100.0	30.2			13.7	79.3		

FLOAT AND SINK TABLES

TABLE A-3e

PLANT/SEAM - ________ Reported Dec. 15 **, 19** 77

Test on : Bulk Sample No. 3B, Continued

Purpose :

Sampling Procedure :

Remarks :

SIZE : 1/8" x 28M

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	6.4	5.1			6.4	5.1			100.0	30.3		
1.30	1.40	30.1	7.0			36.5	6.7			93.6	32.0		
1.40	1.50	17.7	17.7			54.2	10.3			63.5	43.9		
1.50	1.55	6.3	25.0			60.5	11.8			45.8	54.0		
1.55	1.60	3.5	31.6			64.0	12.9			39.5	58.6		
1.60	1.65	3.6	36.4			67.6	14.1			36.0	61.2		
1.65	1.70	3.0	42.0			70.6	15.3			32.4	64.0		
1.70	1.75	3.0	45.1			73.6	16.5			29.4	66.2		
1.75	1.80	3.0	49.0			76.6	17.8			26.4	68.6		
1.80	2.00	8.8	59.3			85.4	22.1			23.4	71.2		
2.00		14.6	78.3			100.0	30.3			14.6	78.3		

FLOAT AND SINK TABLES

TABLE A-3f

PLANT/SEAM - ________________ Reported Dec. 15, **19** 77

Test on : Bulk Sample No. 3B, Continued

Purpose :

Sampling Procedure :

Remarks :

SIZE : 28M x 100M

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	0.4	5.7			0.4	5.7			100.0	39.9		
1.30	1.40	12.1	7.9			12.5	7.8			99.6	40.0		
1.40	1.50	18.9	13.6			31.4	11.3			87.5	44.5		
1.50	1.55	6.6	19.8			38.0	12.8			68.6	53.0		
1.55	1.60	6.5	26.5			44.5	14.8			62.0	56.5		
1.60	1.65	4.5	31.4			49.0	16.3			55.5	60.0		
1.65	1.70	3.8	34.6			52.8	17.6			51.0	62.6		
1.70	1.75	3.6	40.1			56.4	19.1			47.2	64.8		
1.75	1.80	3.8	44.7			60.2	20.7			43.6	66.9		
1.80	2.00	15.4	57.2			75.6	28.1			39.8	69.0		
2.00		24.4	76.4			100.0	39.9			24.4	76.4		

FLOAT AND SINK TABLES

TABLE A-3g

PLANT/SEAM - ____________ Reported Dec. 15 , **19** 77

Test on : Bulk Sample No. 3B, Continued

Purpose :

Sampling Procedure :

Remarks :

SIZE : 4" x 28M Composite

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	4.7	2.8			4.7	2.8			100.0	33.0		
1.30	1.40	24.7	9.8			29.4	8.7			95.3	34.5		
1.40	1.50	21.4	21.2			50.8	14.0			70.6	43.1		
1.50	1.55	6.4	29.7			57.2	15.7			49.2	52.6		
1.55	1.60	6.9	35.8			64.1	17.9			42.8	56.0		
1.60	1.65	6.0	40.6			70.1	19.8			35.9	59.9		
1.65	1.70	3.4	45.1			73.5	21.0			29.9	63.8		
1.70	1.75	2.9	48.2			76.4	22.0			26.5	66.2		
1.75	1.80	3.8	55.1			80.2	23.6			23.6	68.4		
1.80	2.00	8.4	64.2			88.6	27.4			19.8	71.0		
2.00		11.4	76.0			100.0	33.0			11.4	76.0		

FLOAT AND SINK TABLES

TABLE A-3h

PLANT/SEAM -

Reported Dec. 15, 19 77

Test on : Bulk Sample No. 3B, Continued

Purpose :

Sampling Procedure :

Remarks :

SIZE : 4" x 3/4" Composite

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	--	--			--	--			--	--		
1.30	1.40	20.3	11.2			20.3	11.2			100.0	35.8		
1.40	1.50	25.2	22.9			45.5	17.7			79.7	42.0		
1.50	1.55	6.5	31.7			52.0	19.4			54.5	50.9		
1.55	1.60	9.4	36.8			61.4	22.1			48.0	53.5		
1.60	1.65	8.2	42.4			69.6	24.5			38.6	57.5		
1.65	1.70	4.8	46.4			74.4	25.9			30.4	61.6		
1.70	1.75	3.3	51.1			77.7	27.0			25.6	64.5		
1.75	1.80	5.1	57.2			82.8	28.8			22.3	66.5		
1.80	2.00	8.3	64.8			91.1	32.1			17.2	69.2		
2.00		8.9	73.3			100.0	35.8			8.9	73.3		

FLOAT AND SINK TABLES

TABLE A-3i

PLANT/SEAM - ____________

Reported Dec. 15 , **19** 77

Test on : Bulk Sample No. 3B, Continued

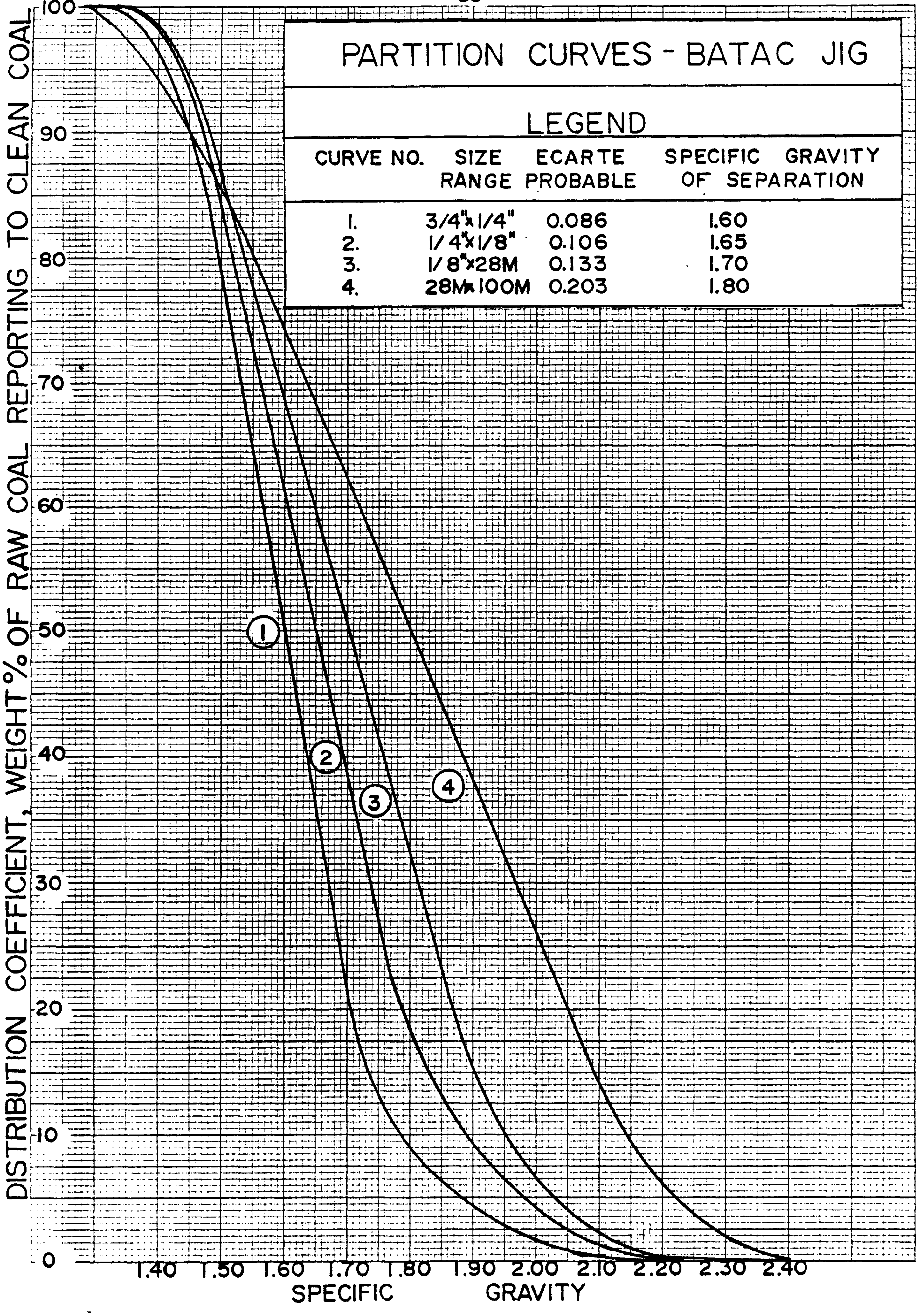
Purpose : ____________

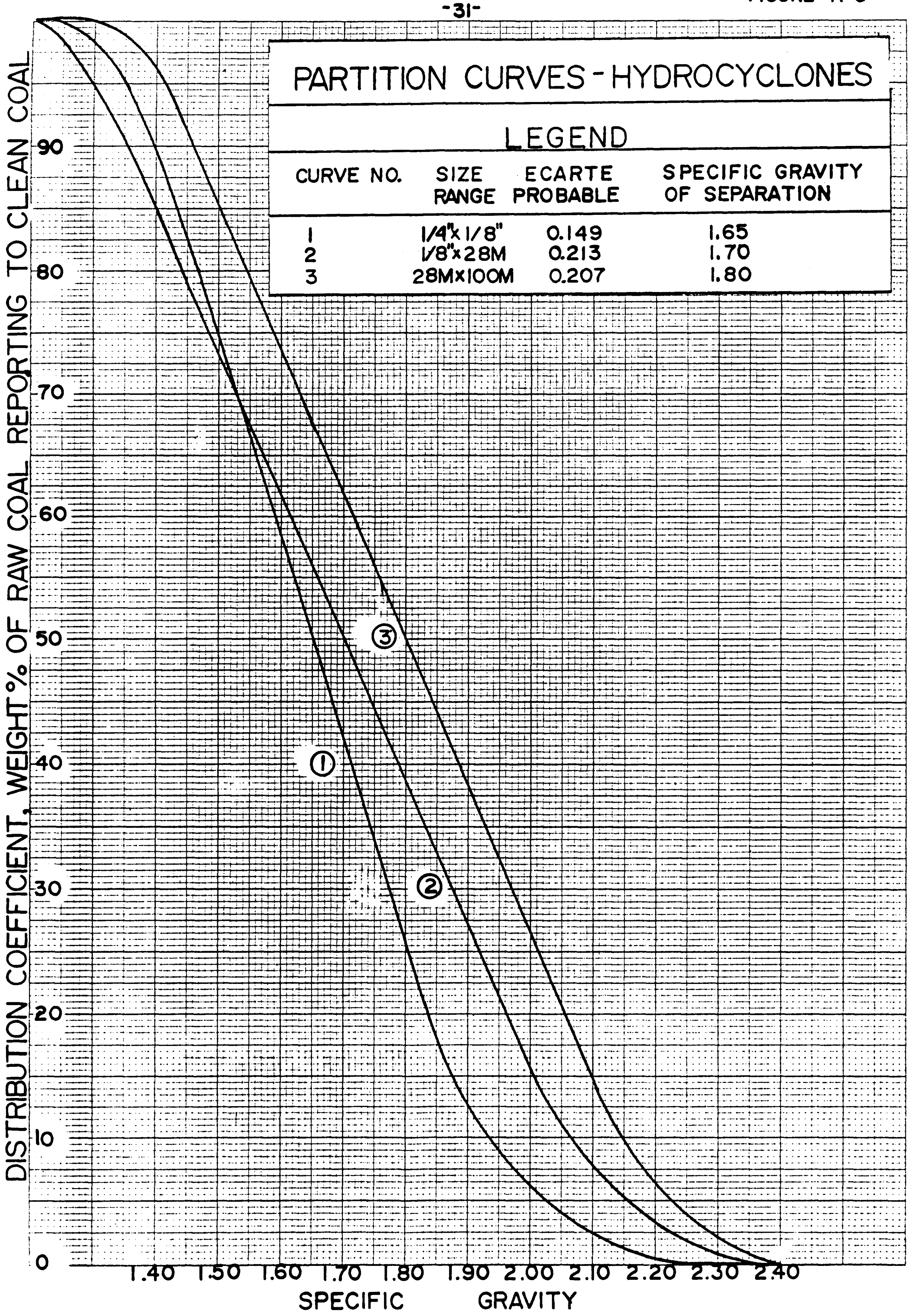
Sampling Procedure : ____________

Remarks : ____________

SIZE : 3/4" x 28M Composite

SP. GR.		DIRECT				CUMULATIVE FLOAT				CUMULATIVE SINK			
Sink	Float	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU	% Wt.	% Ash	% Sul.	BTU
	1.30	8.5	5.1			8.5	5.1			100.0	31.3		
1.30	1.40	28.1	8.8			36.6	7.9			91.5	33.8		
1.40	1.50	18.4	19.9			55.0	11.9			63.4	44.8		
1.50	1.55	6.3	28.1			61.3	13.6			45.0	55.0		
1.55	1.60	4.9	34.9			66.2	15.2			38.7	59.4		
1.60	1.65	4.3	39.2			70.5	16.6			33.8	63.0		
1.65	1.70	2.3	44.1			72.8	17.5			29.5	66.5		
1.70	1.75	2.6	48.8			75.4	18.6			27.2	68.3		
1.75	1.80	2.8	53.4			78.2	19.8			24.6	70.4		
1.80	2.00	8.4	63.8			86.6	24.1			21.8	72.6		
2.00		13.4	78.1			100.0	31.3			13.4	78.1		


PARTITION CURVES - BATAC JIG
LEGEND
CURVE NO. SIZE RANGE ECARTE PROBABLE SPECIFIC GRAVITY OF SEPARATION
1. 3/4"x1/4" 0.086 1.60
2. 1/4"x1/8" 0.106 1.65
3. 1/8"x28M 0.133 1.70
4. 28Mx100M 0.203 1.80
DISTRIBUTION COEFFICIENT, WEIGHT % OF RAW COAL REPORTING TO CLEAN COAL
100
90
80
70
60
50
40
30
20
10
0
1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10 2.20 2.30 2.40
SPECIFIC GRAVITY
1
2
3
4


PARTITION CURVES - HYDROCYCLONES
LEGEND
CURVE NO. | SIZE RANGE | ECARTE PROBABLE | SPECIFIC GRAVITY OF SEPARATION
1 | 1/4" x 1/8" | 0.149 | 1.65
2 | 1/8" x 28M | 0.213 | 1.70
3 | 28M x 100M | 0.207 | 1.80
DISTRIBUTION COEFFICIENT, WEIGHT % OF RAW COAL REPORTING TO CLEAN COAL
0
10
20
30
40
50
60
70
80
90
1.40 1.50 1.60 1.70 1.80 1.90 2.00 2.10 2.20 2.30 2.40
SPECIFIC GRAVITY
①
②
③

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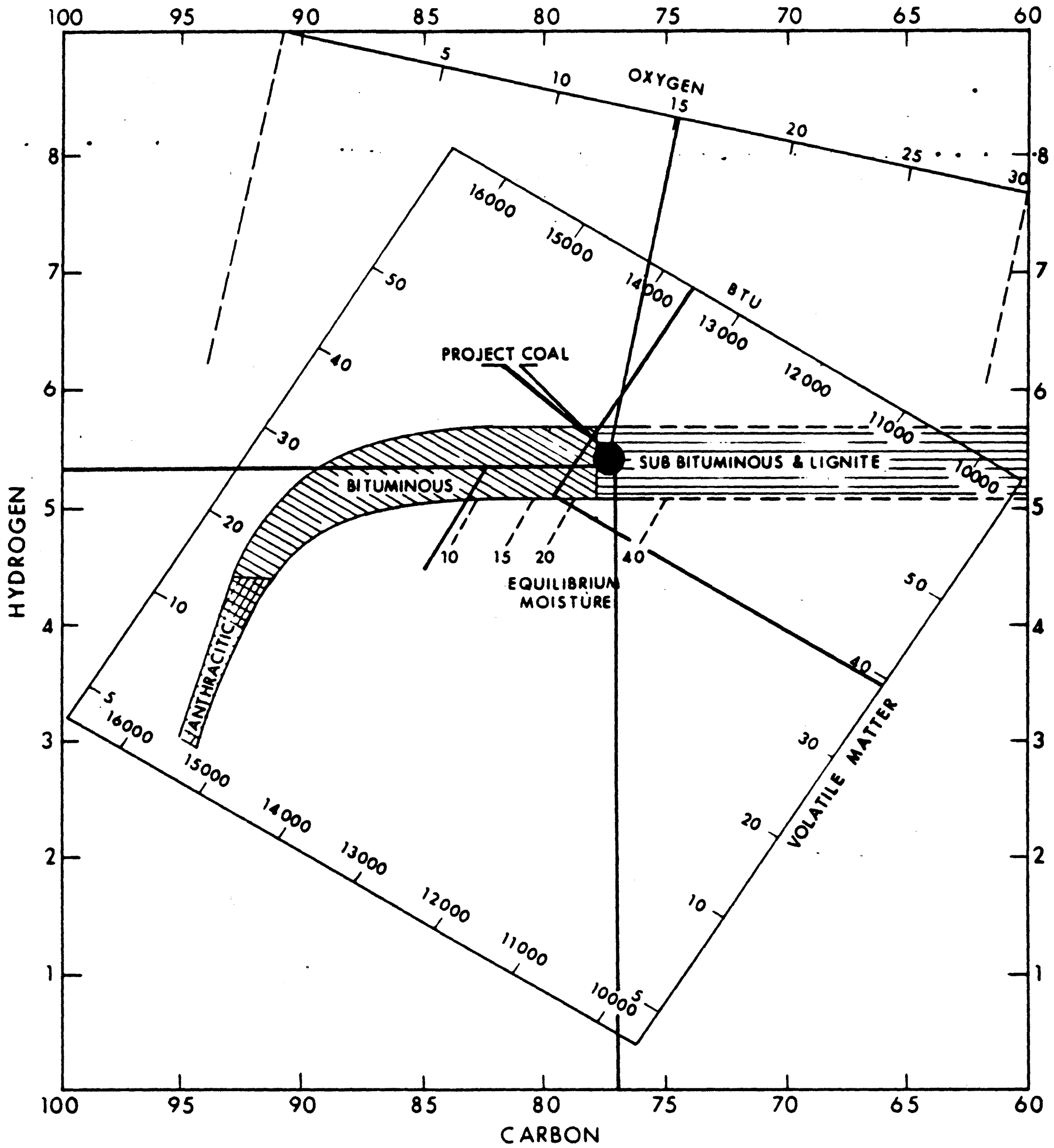
CLASSIFICATION of AVERAGE CLEAN COAL PRODUCT ACCORDING to SEYLER'S COAL CHART



Note: Equilibrium moisture on ash free basis.
All other values on dry, mineral - matter free basis.

FIGURE A-6

APPENDIX B

BULK WASH TEST

The following is a description of the Birtley Coal & Minerals Testing pilot plant. Raw coal is dumped by a front end loader into a hopper at ground level, which has a heavy two inch square screen installed to ensure that the bucket elevator receiving the feed does not handle oversize material. The two inch oversize coal is crushed manually to pass the two inch screen, but "rock" is collected in barrels and reported as shale of the heavy media circuit. A bucket elevator discharges the minus two inch feed at a rate of 5 to 7 metric tons per hour into a rotary 3/4 inch screen of the third deck. The 3/4 inch oversize falls via a chute into a 5" x 8" jaw crusher where it is crushed to minus 3/4 inch and is recycled through the feed system. The 3/4" x 0 screen underflow is washed with water onto a 28M sieve bend and low head vibrating screen for desliming.

The 3/4" x 28M coal is fed to a 14 inch DSM Heavy Media cyclone. The slurry of coal and correct medium is pumped to a cyclone from the mixing tube at a pressure of 9 to 10 psi. The overflow and underflow products are discharged onto a common, but split, 28M low head vibrating screen preceded by 28M sieve bend where the magnetite is washed off into the correct and dilute medium tanks directly below. Additional clean spray water and baffles across the clean coal stream ensure that a minimum of magnetite is retained on the clean coal product. The clean coal and shale are collected in barrels by means of individual chutes for weighing.

The dilute medium is pumped to a thickening cyclone and fed to a 30 inch magnetic separator. The recovered magnetite is sluiced back to the correct medium tank. The specific gravity of the medium is monitored manually, using a density meter, and adjusted for loss by adding cyclone grade magnetite directly to the correct medium tank.

The 28M x 0 coal collected in the slimes tank at ground level is pumped to the thickening cyclone. From this point, it is fed to a two-stage water-only cyclone system.

Coal to the six inch DSM water-only primary cyclone is pumped at a pulp density of 10% to 20% from the cyclone feed tank at a pressure of 20 psi, and a flow rate of 85 Imperial gallons per minute. A mechanically adjustable vortex finder facilitates settings for a desired ash content. The primary cyclone underflow with make-up water is fed to a similarly adjustable secondary four inch unit. The overflow is directed back to the primary cyclone feed tank with the underflow being the waste product.

The waste product is routed to the static thickener while the primary underflow is fed by gravity to a rapped 0.25mm sieve bend. The sieve bend overflow + 65M is the water-only cyclone product, and is directed to an Eimco disc filter for dewatering.

The sieve bend underflow which is not clean, passes by gravity to a static thickener.

The sieve bend overflow filter cake and the heavy media clean coal are combined to form the clean coal product or clean mix.

Each circuit is sampled for feed, product and waste in addition to the 0.25mm sieve bend overflow and underflow, filter cake, thickening cyclone overflow and underflow and analyzed for ash content. The primary water-only cyclone overflow product is screened at 65M as the plus 65M figure is used to calculate the yield of the water-only cyclone circuit.

The heavy media clean coal is "drained" of extraneous moisture before being combined and homogenized with the partially dried filter cake. This partial drying is accomplished by spreading the fines product on a pad, heated electrically at 20° C, which reduces the moisture content of 22% to 28%, to less than 12%.

Test Results

The results of the pilot plant wash reflected a smooth run with no problems during testing. Techman Ltd. provided personnel to observe the wash and to comment. Observations were as follows:

a. The raw coal deslimed very well. The clay did not extrude into the screen openings, but instead either reported directly to the fines circuit or remained in lump form and reported to the heavy media cyclone circuit.

b. The coarse coal drain and rinse screens effectively removed the clay from the coarse clean coal but not from the coarse rejects. The "rain box" on the coarse rejects side of the screen was plugged and the product was very wet and contained a great deal of gummy clay. This observation resulted in a slight change in the original plant flowsheet in that additional sprays were added to the clean coal and rejects D & R screens. This could present similar problems for the Batac jig rejects screen in the commercial plant.

c. The compound water cyclone circuit was very effective in removing the fine rejects, but the sieve bend made a poor 65M separation in the primary compound water cyclone product. Two-stage vibrating sieves would be considerably more effective.

d. The pieces of clay which were present in the raw coal were surprisingly hard and competent, and were plus 1.80 sg. Techman Ltd. have anticipated a more severe clay problem in the plant design since the clay will be much more plastic when freshly mined.

e. The product from the magnetic separators contained a large amount of clay impurities even over the short period of time necessary to process the bulk sample. It was apparent that a heavy media system operating on +28M material would be impossible to operate continually. Details of the test follow.

Birtley Coal
& Minerals Testing

A DIVISION OF GREAT WEST STEEL INDUSTRIES LTD.

March 9, 1978

Mr. B. Raymond
Techman Ltd.
320 - 7 Avenue SW
Calgary, Alberta
T2P 2M7

Dear Brian:

The enclosed are the plant wash results for the Tulameen bulk sample which was a combination of raw coals from our reserved portion and a lot delivered from Cyclone Engineering in Edmonton.

Yours truly,

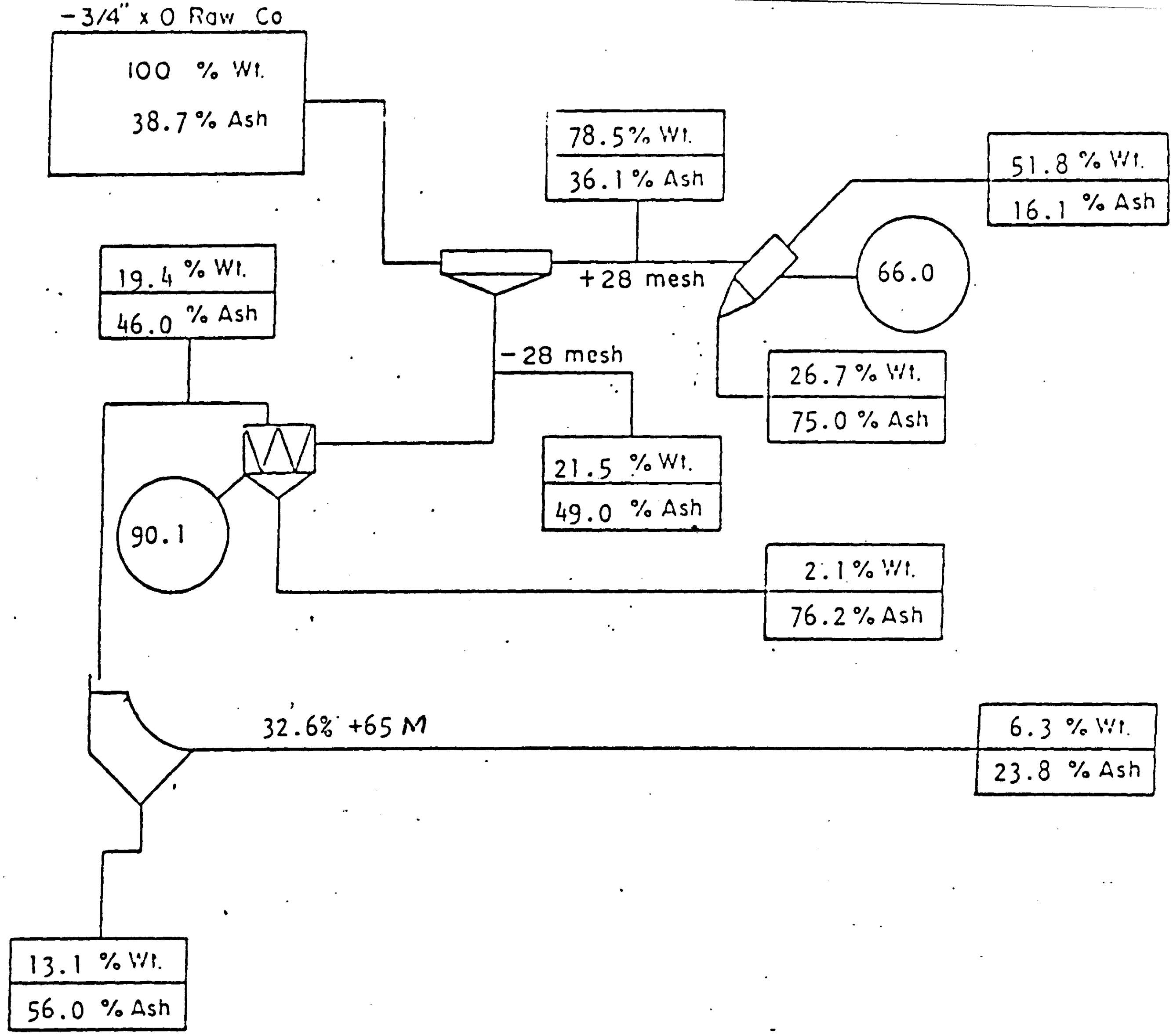
BIRTLEY COAL & MINERALS TESTING

Frank J. Horvat

Frank J. Horvat
General Manager

cas
Encl.
cc: Mr. T. Adamson, Cyprus Anvil

505 - 50th Avenue S.E., P.O. Box 5488, Station "A", Calgary, Alberta T2H 1X9 Telephone (403) 253-8273



OVERALL YIELD = (Dry Basis) 58.1% @ 16.9 Ash (Calc.)

LEGEND:

○ *CIRCUIT YIELD %*

Wt. *WEIGHT %*

Ash *ASH CONTENT* (Dry Basis)

BIRTLEY ENGINEERING (CANADA) LTD.

Title: PLANT BALANCE FLOWSHEET CYPRUS ANVIL TULAMEEN BULK WASH LAB. NO. 238	Date: March 6, 1978
	Drawn

BIRTLEY ENGINEERING (CANADA) LTD.

Coal Science & Minerals Testing Div.

CYPRUS ANVIL MINING CORPORATION

BULK WASHING DATA*

ADIT TULAMEEN SEAM ______ LAB. NO. 238

DELIVERY DATE Nov. 16/77 & Feb. 24/78 DATE OF WASH March 2 & 3, 1978

Raw Coal Analysis: ADM ______ ASH% 38.7 FSX ______ HGX ______

Delivered Bulk Weight 12.715 Metric Tons

Washed Weight 8.378 Metric Tons

* All weight and analyses are on Dry Basis
unless otherwise indicated.
Raw Feed

RAW ASH & PROPORTION OF PLANT FEED (dry basis)			
BULK SAMPLE FROM	WT.%	ASH%	
BC & MT	36.5	35.0	Bulk Sample 3B
C.E.S.	63.5	40.8	Bulk Sample 2

CYPRUS ANVIL MINING CORPORATION

BULK WASHING DATA

HEAVY MEDIUM CIRCUIT

ADIT/SEAM NO. TULAMEEN LAB. NO. 238

1. S. G. of Separation 1.66
2. Feed Ash Content 36.1 % RXSXX. ________
3. Clean Coal Estimated Weight 4.302 M.T.
4. Clean Coal Analysis - Ash 16.1 % RXSXXX ________
5. Reject Estimated Weight 2.276 M.T.
6. Reject Analysis - Ash 75.0 % RXSXX. ________
7. Estimated 3/4" x 28M in Circuit 6578 M.T. 78.5 Wt.%
8. Yield Clean Coal (Weighed): ____

   65.4 %
9. Yield Clean Coal
   (Calculated Ash Balance) - ____

   66.0 %

Birtley Engineering
Subsidiary of Great West Steel Industries

CYPRUS ANVIL MINING CORPORATION

BULK WASHING DATA

WATER-ONLY CYCLONE CIRCUIT

ADIT/SEAM NO. TULAMEEN LAB. NO. 238

1. Vortex Finder Clearance (VCF) #2 = 6.35 / #1 - 2.54 CM 2.50 / 1.00 INCHES

2. Feed Pressure #2 = 0.4 / #1 = 1.4 KG/CM^2 5 / 20 P.S.I.

3. Feed Rate #2 = 5.8 / #1 - 23.2 $M^3/HR.$ 21.2 / 85.0 I.G./Min.

4. Feed Pulp Density 90 - 130 g/l. 9 - 13 Solids W/V

5. Sample Analysis

	SCREEN SIZE	WT.%	ASH%	XXXXX.	CUM. WT.%	CUM. ASH%	HEAD ASH%	XXXX XXX
FEED							49.0	
O'FLOW	+65 Mesh	32.6	31.8		32.6	31.8	46.0	
	65M x100 Mesh	15.0	39.6		47.6	34.3		
	100M x 0	52.4	56.3		100.0	45.8		
U'FLOW							76.2	
S.B.O.							22.9	
S.B.U.							56.0	

6. Yield - Total W.O. Cyclone Circuit = 90.1

7. Estimated Yield of 28 x 65 Mesh Coal = 29.4
(as % of 28 Mesh x 0 Feed)

8. Estimated 28M x 0 in circuit
(Plant Feed - HM Products) 1.800 MT 21.5 %

9. Weight S.B.O. recovered = 0.361 M.T.

CYPRUS ANVIL MINING CORPORATION

BULK WASHING DATA

ADIT/SEAM TULAMEEN LAB. NO. 238 DATE OF WASH March 2 & 3, 1978

a) Raw Coal

Delivered Weight	= 12.715	M.T.
Ash %	= 38.7	
KXSXX.	=	
Estimated Washed Wt.	= 8.378	M.T.

b) Heavy Media Circuit

Estimated Proportion of +28 Mesh in Feed 78.5

Effective S.G. =	1.66		
Raw Feed	36.1	% Ash	KXSXI.
Clean Coal	16.1	% Ash	KXSXI.
Reject	75.0	% Ash	KXSXI.
Calculated Yield	66.0	%	
Weighed Yield	65.4	%	

c) Water-Only Cyclone Circuit

Raw Feed	49.0	% Ash	KXSXI.
Overflow	46.0	% Ash	KXSXI.
Underflow	76.2	% Ash	KXSXI.
Calculated Yield	90.1	%	
% of +65M in O/F	32.6	%	
Sieve Bend Overflow	22.9	% Ash	KXSXI.
Sieve Bend Underflow	56.0	% Ash	

CYPRUS ANVIL MINING CORPORATION

BULK WASHING DATA

BULK WASHING SUMMARY (Cont.)

ADIT/SEAM NO. TULAMEEN LAB. NO. 238

d) Clean Coal Mix Analyses

(i) Proximate

ADM% 9.7 RM.% 3.3 ASH% 16.1 VM.% 32.1 FC.% 48.5

S% 0.57 BTU/LB. 10764 H.G.I. 50

e) Clean Coal Mix Make-Up

H.M. CLEAN COAL	FINES FILTER CAKE	CLEAN COAL MIX		SHIPPED		IN STOCK	
M.T. (DRY)	M.T. (DRY)	BBLS.	M.T.*	BBLS.	M.T.*	BBLS.	M.T.*
4.302	0.361	30	5341	27	4.807	3	0.534

* as received

Birtley Engineering

Subsidiary of Great West Steel Industries

CLIENT: CYPRUS ANVIL MINING CORPORATION March 7, 1978

SAMPLE: TULAMEEN BULK SAMPLE
ANALYSIS OF PLANT WASH SAMPLES

PLANT SAMPLE	RM.% % TOTAL MOISTURE	ASH%	VM.%	FC.%	S%	BTU/LB	CALC. FACTORS
HEAVY MEDIA FEED	1.9	35.4	27.4	35.3	--	---	a.d.b.
		36.1	27.9	36.0			d.b.
HEAVY MEDIA CLEAN COAL	8.6	14.7	31.8	44.9	0.55	10290	a.d.b.
		16.1	34.8	49.1	0.60	11258	d.b.
HEAVY MEDIA REJECT	9.3	68.0	--	--	--	---	a.d.b.
		75.0					d.b.
WATER-ONLY CYCLONE FEED	6.3	45.9	20.5	27.3	--	---	a.d.b.
		49.0	21.9	29.1			d.b.
W.O.C. O'FLOW	5.7	43.4	--	--	--	---	a.d.b.
		46.0					d.b.
W.O.C. U'FLOW	2.0	74.7	--	--	--	---	a.d.b.
		76.2					d.b.
SIEVE BEND O'F	3.9	22.9	28.2	45.0	0.51	9649	a.d.b.
		23.8	29.3	46.9	0.53	10041	a.d.b.
SIEVE BEND U'F	3.9	53.8	--	--	--	---	a.d.b.
		56.0					d.b.

PLANT SAMPLE	ADM%	RM% % TOTAL MOISTURE	ASH%	VM.%	FC.%	S%	BTU/LB	H.G.I.	CALC. FACTORS
TOTAL	9.7	3.3	16.1	32.1	48.5	0.57	10764	50	a.d.b.
CLEAN		12.7	14.5	29.0	43.8	0.51	9720	--	a.r.b.
COAL			16.6	33.2	50.2	0.59	11131	--	d.b.

a.d.b. = air dried basis

a.r.b. = as received basis

d.b. = dry basis

Birtley Coal
& Minerals Testing

APP. C

Energy, Mines and Resources Canada | Énergie, Mines et Ressources Canada

CANMET
Canada Centre for Mineral and Energy Technology | Centre canadien de la technologie des minéraux et de l'énergie

A PILOT-SCALE COMBUSTION EVALUATION OF TULAMEEN COAL

T.D. Brown and G.K. Lee
Canadian Combustion Research Laboratory

NOVEMBER 1978

ENERGY RESEARCH PROGRAM
ENERGY RESEARCH LABORATORIES
ERP/ERL 79-7 (CF)

Revised April 1979

CONFIDENTIAL

Declassification Date: 1 April 1980

A PILOT SCALE COMBUSTION EVALUATION OF TULAMEEN COAL

by

T.B.Brown * and G.K.Lee**

ABSTRACT

A pilot scale combustion evaluation of pulverized Tulameen coal has been carried out to identify the combustion performance and emission characteristics of the fuel under conditions representative of utility boiler operating practice.

The coal was found to be generally suitable for utility boiler operation; the coal handling and flame stability were excellent throughout the six combustion trials. The coal could be used in a dry-bottom pulverized fired system; under these conditions special attention must be given to the size distribution of the coal and the performance of the electrostatic precipitator.

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* Research Scientist, **Manager, Canadian Combustion Research Laboratory, Energy Research Laboratories, CANMET, Department of Energy,Mines and Resources, Ottawa, Canada.

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1. INTRODUCTION

The Canadian Combustion Research Laboratory (CCRL), in collaboration with Cyprus-Anvil Mining Corporation, carried out an evaluation of the combustion characteristics of washed Tulameen coal. This coal, which is ranked as high volatile bituminous "C" by ASTM classification procedures, is from a newly developed deposit in British Columbia and has not previously been burned in large-scale equipment.

The joint project formed part of the CANMET Energy Research Program and included an analytical investigation of the coal properties as well as combustion studies in the CCRL pilot-scale research boiler under conditions representative of those in large pulverized-fired thermal power boilers.

This report describes the objectives of the project, the analyses of the test coal, the facilities and operational procedures used and an evaluation of the combustion trials. A comparison is also given of the combustion performance of Tulameen coal with that of Sundance, a coal currently being burned in a large thermal power plant.

2. RESEARCH OBJECTIVES

The objectives of the combustion trials and the related analytical studies were:

(a) To determine the comminution and handling characteristics of the coal.

(b) To evaluate the combustion performance of the pulverized coal at two fineness levels (90% and 70% less than 200 mesh) and with two burner configurations.

(c) To characterize the particulate and gaseous pollutants generated during combustion.

(d) To assess the slagging and fouling potential of ash constituents on radiant heat transfer surfaces and superheater tubes respectively.

(e) To assess the corrosion potential of condensed sulphuric acid on cold-end boiler surfaces.

(f) To determine the fly-ash resistivity characteristics and the ease of fly-ash collection by electrostatic precipitator.

3. COAL CHARACTERISTICS

A five-ton sample of the washed coal was delivered to CCRL in sealed 45-gallon drums. The coal, when drained of surface moisture, yielded an "as received" moisture content of 12%. At this condition it appeared to be uniform and moved through the CCRL coal handling system without difficulty. Analysis of the coal, which has been washed to a target specification of 10,000 Btu/lb at 14% ash and 12% moisture, is presented in Table 1, together with an analyses of Sundance, a sub-bituminous coal being burned near Edmonton by the Calgary Power Company.

As shown in Table 1 the volatile-matter content of the Tulameen coal is relatively high, but this does not necessarily indicate that pulverized coal flames from this fuel will be stable. One comparative index of coal reactivity, which can be calculated from the proximate and ultimate analyses, is the volatile-matter combustion temperature achieved by a stoichiometric mixture of coal and air.

In this calculation, the coal is considered to be in a dry condition, the combustion air is considered to carry all of the moisture in the coal as fed to the pulverizer, and the combustion of volatile-matter is considered to be complete prior to combustion of the fixed carbon. The volatile-matter combustion temperatures for the Tulameen coal are shown in Table 2. The calculated temperatures for the Tulameen coal used in the project lie in the range 450-460°C; this suggests that the coal may not ignite easily.

4. PILOT-SCALE RESEARCH BOILER

The CCRL research boiler, illustrated schematically in Figure 1, is a pulverized-coal-fired boiler incorporating two opposed in-shot burners that tilt downward over a refractory chamber. The furnace is of membrane-wall construction and operates at pressures of up to 25 cm W.C. At the full-load firing rate of 2500 Mj/h (0.7 MW) the boiler generates 730 kg/h steam at 6.8 atm. The heat is dissipated in an air cooled condenser. During the tests with Tulameen coal the firing rate was held at approximately 1750 Mj/h (70 kg/h).

Crushed coal is supplied from a 4500-kg hopper mounted on an electronic weigh scale through a variable-speed worm feeder to a ring-and-roller type of pulverizer, which is normally swept and pressurized by air at any temperature up to 230°C. If necessary, the pulverizer can be swept and pressurized with a mixture of air and flue gas at any temperature up to 490°C. The pulverizer contains a motor-driven classifier for controlling coal fineness; a riffle at the pulverizer outlet proportions the coal to each burner. Secondary air can be supplied to the burner at any temperature up to 260°C.

Combustion gases leave the furnace at between 760°C and 860°C and then pass through a transition section, a test-air heater and a conventional three-pass air heater before entering a long horizontal sampling duct. At the end of the sampling duct, the gas flow can either be passed entirely into the stack or, if necessary, a portion of the gas flow to the stack can be diverted isokinetically into a small two-stage electrostatic precipitator. A by-pass from the air heater to the stack breeching and additional heat exchanger surface in the sampling duct permit the gas temperature in the sampling duct to be varied between 150°C and 300°C.

A forced-draft fan supplies air to the air heater at 0.07 atm. The air, on leaving the heater,is divided into three streams: primary air to the pulverizer, secondary air to the burners and cooling air to the test-air heater. The last stream, after leaving the test-air heater, either can be exhausted to the atmosphere or can be blended with the primary-air supply to the pulverizer.

The research boiler is manually controlled, except for electrical interlocks to ensure that safe start-up and shut-down procedures are followed. When burning high-grade coals, it has been possible to operate with as little as 1.0% O_2 and no more than 0.1% CO in the flue gases, with a smoke density of less than No.1 Ringelmann. When severe fouling of the convective heat-transfer surfaces occurs, firing-rate or excess-air level must be reduced to control furnace pressure.

5. EXPERIMENTAL PROCEDURES

5.1 Operating Procedure

The operating procedure given below was used for all tests, with some minor variations in timing as necessary.

1. Before each test, all boiler and air-heater fireside surfaces were cleaned by air lancing. Ash deposits sintered to refractory surfaces were manually removed. Sufficient coal was bunkered to provide approximately 10 h of operation at the desired feed rate.
2. At 0600 h, the cold boiler was fired up on No.2 fuel oil at 16 gph. Excess-air was adjusted to provide 3% O_2 in the flue gas and the boiler was allowed to stabilize at full steaming rate and pressure. All continuous monitoring instruments were put into service.
3. At 0730 h, feed of pulverized coal to the boiler was started with the specified classifier speed, mill temperature and excess oxygen in the flue gas. One oil torch was left in operation.
4. At 0745 h, the oil torch was removed, leaving the boiler operating on pulverized coal only.
5. At 0900 h, scheduled testing was begun. Boiler panel readings were recorded hourly. The specified coal feed rate and excess oxygen level were maintained as closely as possible.
6. By 1500 h, scheduled tests were usually nearing completion. If repeat measurements were required, these were begun.
7. When all measurements were completed, an oil torch was inserted and coal feed to the pulverizer was shut off. When the pulverizer was empty, the boiler was shut down.
8. The furnace was allowed to cool overnight. Then the furnace bottom was removed and the ash remaining in the furnace bottom and boiler hoppers was collected and weighed.

5.2 Parameters of Combustion Performance

The following parameters of combustion performance were measured in each test at appropriate measuring stations.

1. Proximate, ultimate and ash analyses and ash fusion determinations of samples taken from a bulk sample of crushed coal obtained by hourly grab samples at the pulverizer inlet.
2. Moisture and sieve analyses of samples of pulverized coal taken every two hours at the pulverizer outlet.
3. CO_2 and CO content of the flue gas, measured continuously by infra-red monitors.
4. O_2 content of the flue gas, measured continuously by a paramagnetic monitor.
5. NO content of the flue gas, measured continuously by a chemiluminescent monitor.
6. SO_2 content of the flue gas, measured continuously by a chemifluorescent monitor.
7. SO_2 and SO_3 content of the flue gas, measured by the API and the Shell-Thornton methods, respectively, two or three times per test.
8. Low-temperature corrosion potential, measured by three mild-steel probes inserted simultaneously into the flue-gas stream and maintained at three different temperatures for the duration of the combustion test.
9. Fly-ash loading, measured isokinetically by an automated sampling system (two to four samples per test). These samples were analyzed for carbon content, chemical composition and size distribution.
10. Ash fouling of heat-transfer surfaces, evaluated by examination of deposits on a simulated superheater, installed immediately down-stream of the screen tubes to accommodate studies of fly-ash build-up on high-temperature boiler tube surfaces.

11. Electrostatic precipitator efficiency, measured by passing part of the flue gas through a small electrostatic precipitator for a period of 45 minutes (three samples per test). The efficiency was calculated from the measured inlet and outlet dust loadings.
12. Fly-ash resistivity, measured by an in-situ, point-plane resistivity apparatus at flue gas temperatures of 200°C and 400°C (two measurements at each location per test). A series of static isothermal measurements on selected samples of fly ash extracted from the gas stream at the precipitator inlet were also made.

In addition, qualitative observations on flame appearance and length were logged. When the furnace was sufficiently cooled after a test, the superheater and furnace walls were photographed.

5.3 Burner arrangement

The test coal was burnt using two burner configurations shown in Figures 1 and 2 respectively to illustrate the effects of extended furnace temperature and residence time in addition to the basic parameter of coal fineness. Table 3 summarizes these variables and identifies the combination of test conditions used in each numbered combustion trial. The trial number is used subsequently throughout the report.

6. COMBUSTION PERFORMANCE

6.1 Coal Comminution

The "as received" coal was crushed, metered and pulverized to the selected degree of fineness. It was then transported directly to the burner without moisture separation from the carrying air; no blockage or segregation occurred in either of the coal pipes to the boiler. The size distribution of the pulverized coal used in each combustion test is shown in Table 4.

6.2 Flame Characteristics

The combustion performance data remained essentially constant throughout each combustion test and confirmed that the handling characteristics of the coal were excellent. The flame was bright, clean and extremely stable under all experimental conditions and an oil support flame was required for only about five minutes after the start of each trial.

6.3 Flue-gas Analyses

The combustion parameters measured during each test are presented in Table 5 where it can be seen that the ease of handling of the fuel produced essentially constant fuel feed rates with only small deviations in the overall combustion conditions.

The concentration of nitric oxide increased significantly between combustion tests 2 and 3. This was because the increased fuel fineness produced a significant increase in combustion intensity with an associated rise in flame temperature. A further increase in nitric oxide was recorded during combustion test 4 which was carried out using the refractory lined adiabatic furnace bottom.

In the tests with both burner configurations, the nitric oxide yield was a direct funtion of coal particle size. The results presented in Figure 3 indicate that the mixing intensity between fuel and air is reflected in the nitric oxide concentration. As expected the best mixing and combustion condition occurred when the burners were located in the adiabatic furnace bottom and the finest coal was used. The nitric oxide emission as a function of the carbon in fly-ash is shown in Figure 4 for this experimental condition.

The gas-phase sulphur dioxide measurement accounts for nearly 70% of the fuel sulphur and as shown in Table 5, the extent of sulphur neutralization by the cations in the ash, does not normally vary as a function of fuel particle size.

Fixation of SO_2 by alkali and alkaline earth elements in the coal ash is known to depend on both excess-air level and local combustion gas temperatures. Previous work at CCRL with lignitic coals has shown that sulphur retention is enhanced by higher excess-air levels which tend to increase furnace exit temperatures, reduce residence times in the furnace, and increase the oxidation of fuel sulphur to sulphur oxides.

6.4 Fly-Ash Characteristics and Coal Burn-Out

The fly-ash (particulate) concentrations in the flue gas stream entering the electrostatic precipitator and the effect of coal fineness on the fly-ash carbon are shown in Table 6.

It is apparent that the rate of heat transfer from the flame plays a dominant role in the burn-out of this coal. When the rate of quenching was high - as in those experiments when the sidewall burners were used - the burn-out of the coal was only marginally acceptable. This occurred despite the relative fineness of the pulverized fuel input. When the rate of quenching was low - as when the "adiabatic" furnace bottom was used - the burn-out of the coal was significantly improved. This occurred even with a less finely pulverized coal.

When using the "adiabatic" furnace bottom the thermal penalty due to unburnt carbon was not only dependent on fuel particle size (Figures 5 & 6), but was higher than utility operating standards except at the finest pulverized coal condition (90% below 200 mesh).

In large furnaces where overall residence times are greater than 1.5 s the burn-out of coal is usually superior to that recorded in the pilot-scale boiler. In the smaller system, burn-out is inhibited by a high surface to volume ratio, rapid flame quenching and maximum residence times of 0.35 s.

6.5 Fly-Ash Resistivity and Electrostatic Precipitator Performance

The fly-ash resistivity and collection efficiency of the pilot-scale electrostatic precipitator are shown in Table 7.

Fly-ash resistivity is known to be affected by the presence of conductors such as carbon, and the existence of a "critical carbon content" has been identified. At carbon contents above this level the measured resistivity is that of carbon; at carbon contents below this level a true ash resistivity is measured. Figure 7 indicates that, for this coal, the critical carbon content occurs at approximately 4%. Any results measured when the carbon content is above this level are therefore suspect.

The resistivity of fly ash containing about 2% carbon when measured "in-situ" was above 1×10^{11} ohm cm at 200°C and decreased by one order of magnitude to 1×10^{10} as the temperature increased to 280°C. This high ash resistivity will be an important factor when assessing the suitability of Tulameen coal as a substitute fuel in boilers equipped with precipitators designed for fly ash with a lower resistivity.

A high electrical resistivity ($>10^{10}$ ohm cm) indicates that a precipitated fly ash will retain a strong electrical charge and generate a back corona within the deposit which can repel incoming charged particles. Conversely, a low-resistivity ($<10^7$ ohm cm) fly-ash will readily precipitate but will not adhere strongly to the collecting plates and will easily be re-entrained in the flue gas. Intermediate resistivity values of approximately $10^8 - 10^9$ ohm cm are considered to yield the best precipitator efficiencies.

Extrapolation of the resistivity data as shown in Figure 8 indicates that a high temperature precipitator would be required to operate well above 400°C to accommodate an "in-situ" ash resistivity of 5×10^9 ohm cm.

Alternatives to hot precipitators are available for use with high-resistivity fly-ash. One common strategy is to inject chemical conditioning agents into the combustion products to reduce the fly-ash resistivity to optimum levels for electrostatic precipitation. Previous research at CCRL has demonstrated the effectiveness of this technique with western Canadian coals.

Table 7 shows that the electrostatic precipitation characteristics of the Tulameen coal were poor. The precipitator efficiency was consistently low and, although the pilot-scale precipitator is small, it gives a clear indication that precipitation of the fly-ash from this coal may not be efficient when used as a substitute fuel.

7. HIGH TEMPERATURE ASH DEPOSITS

Two general types of high temperature ash deposition can occur on the gas-side furnaces of coal-fired boilers:

1. Slagging - fused deposits that form on surfaces exposed predominantly to radiant heat transfer;
2. Fouling - high temperature bonded deposits that form on surfaces exposed predominantly to convective heat transfer. Particularly troublesome areas are superheaters and reheaters.

An assessment of the slagging and fouling potential of the Tulameen coal used in these pilot-scale experiments has been done using accepted empirical indices based on the ash analyses of the raw coal, the analyses of the fireside deposits and the visual assessment of the deposits produced within the boiler. The analytical data for selected deposits in the boiler are presented in Tables 8, 9 and 10.

7.1 Ash Fusion Temperatures

The deposits produced in the furnace bottom and on the refractory quarls surrounding the burners were bulky and showed surface fusion due to flame exposure. The ash fusion temperatures of both the deposits and the parent coal are shown in Table 10 for tests 2 and 6.

Ash fusion characteristics determined according to procedures described in ASTM D1857 define four temperatures at which physical changes in a standard specimen become apparent. The test can be carried out in either a reducing or an oxidizing atmosphere, but normal reference is to the reducing atmosphere which usually generates lower temperatures and is therefore a more restrictive condition.

The results show that initial deformation can occur, for both the coal ash and the furnace bottom ash, in the range 1190-1270^{o}C. The fusion temperatures of the furnace bottom ash are consistently higher than those from the parent coal and indicate a slight preferential volatilisation of fluxing components.

7.2 Slagging Indicators

The assessment of slagging potential in pulverized or crushed coal-fired boilers has been attempted by several workers who have produced indices or composite parameters to describe the nature and severity of the slag deposits. These indices are frequently described as "specific" in the sense that they reflect the type of combustion equipment used in a particular unit.

Many ash slagging indices are described as being applicable only to coals with "Eastern type" ash or to coals with "Western type" ash. The term "Western type" ash is defined as an ash having more CaO + MgO than Fe_2O_3 when all are measured as a weight per cent of the coal ash.

The application of this parameter to the coal and deposit analyses presented in Tables 8 and 9 shows that this coal falls well within the classification for an Eastern ash. It must be remembered that the criterion is dependent on ash analyses and does not have any rank or geographic connotation. The importance of this will become apparent in the following discussion of three common indices for determining slagging potential.

7.2.1 Base to Acid Ratio

The base to acid ratio is defined as:

$$\frac{Fe_2O_3 + CaO + MgO + Na_2O + K_2O}{SiO_2 + Al_2O_3 + TiO_2}$$

where each oxide is expressed as a % of the total ash.

A maximum value of 0.5 for the base to acid ratio has sometimes been specified for dry bottom-pulverized-fired units although this is not a necessary restriction.

Values below 0.27 indicate that the coal is not generally suitable for use in wet-bottom units since slag viscosity will not be adequately low. The values for both the Tulameen coal-ash and the furnace bottom deposit lie in the range 0.11 - 0.15. Wet-bottom operation is therefore precluded and the upper limit for dry-bottom firing is not exceeded.

7.2.2 Ash Viscosity and Slagging

To further evaluate the potential of the bottom ash to slag, the analytical data has been used to calculate the viscosity/temperature relationship for both the coal and the bottom ash deposits using the method outlined below:

$$T = \frac{10^7 M}{\log V - C} + 150,$$

where

T = Temperature, ^oC.

V = Ash viscosity, poise.

M = $0.00835 (SiO_2) + 0.00601 (Al_2O_3) - 0.109$

C = $0.0415 (SiO_2) + 0.0192 (Al_2O_3) + 0.0276 (Fe_2O_3) + 0.016 (CaO) - 3.92$

T_{250} = Temperature in ^oC when the viscosity of a potential slag is 250 poise. 20% of the iron is considered to be in the ferrous form.

and

$$SiO_2 + Al_2O_3 + Fe_2O_3 + CaO + MgO = 100$$

For wet bottom furnaces the preferred slag viscosity for easy tapping is below 100 poise and the T_{250} temperature should not normally exceed 1425°C.

For dry bottom furnaces the T_{250} temperature can be one factor used to rate the coal ash in relation to furnace slagging. A suggested rating scheme is:-

Slagging Category	T_{250}, oC
Low	> 1275
Medium	1400 - 1150
High	1250 - 1120
Severe	> 1205

It should be noted that there is considerable overlap between the categories.

The results of this viscosity calculation, shown in Figure 9, confirm that coal ash reactions during combustion and after deposition have produced an increase in slag viscosity. The T_{250} value of over 1600°C indicates that the coal has a low slagging potential.

The temperature of critical viscosity (T_{cv}), which is also shown in Figure 9, is the temperature limit above which viscosity can be confidently predicted from the ash analyses. It can be seen that for the Tulameen coal, extrapolation of viscosity to temperatures below 1575°C is unreliable.

T_{cv} can also be defined as the temperature above which molten ash can be expected to run freely down the furnace walls, and can be calculated from the following relationship:

$$T_{cv}\ (^{o}C) = 2990 - 1470\ \frac{(SiO_2)}{Al_2O_3} + 360\ \left(\frac{SiO_2}{Al_2O_3}\right)^2$$

$$- 14.7\ (Fe_2O_3 + CaO + MgO)$$

$$+ 0.15\ (Fe_2O_3 + CaO + MgO)^2$$

T_{cv} has also been defined as the Ash Fusion Temperature of Hemispherical Deformation + 100°C.

7.2.3 Slagging Factor

$$R_s = \left(\frac{\text{Base}}{\text{Acid}}\right) \times \%S ,$$

where

$\%S$ = Sulphur content of dry coal.

Slagging Category	Slagging Factor R_s
Low	Less than 0.6
Medium	0.6 - 2.0
High	2.0 - 2.6
Severe	above 2.6

The Slagging Factor for Tulameen coal is 0.10 which confirms the other indications that it has a low slagging potential.

7.3 Fouling Indicators

Visual inspection of the deposits collected on the simulated superheater (controlled at 560°C) showed that the deposits, although bulky, were light and friable. This suggests that the coal will have a relatively low fouling tendency and that superheater deposits should be easily controlled with conventional sootblowing equipment and schedules.

7.3.1 Sodium Content of the Coal Ash

There has been general agreement between research and operating practice that the dominant factor correlating with superheater fouling is the sodium content of the coal ash.

The following classification has been proposed:

Fouling Category	% Na_2O in Ash	
	"Eastern" coals	"Western" coals
Low	< 0.5	< 2.0
Medium	0.5 - 1	2.0 - 6.0
High	1.0 - 2.5	6.0 - 8.0
Severe	> 2.5	> 8.0

Under this classification, the coal ash analyses given in Table 8 indicate that Tulameen coal can be considered to have a low fouling potential. Although Na_2O occurred in the fireside deposits on one of the low temperature surfaces, no enrichment was detected on the simulated superheater. Therefore, the low superheater fouling potential predicted from the coal ash analyses appear to be valid.

8. LOW-TEMPERATURE CORROSION

Low-temperature corrosion problems are due to the condensation of gas-phase sulphur trioxide on metal surfaces below the acid dewpoint. The condensed acid (H_2SO_4) can then react with air heater and/or economizer tubes to produce an $FeSO_4$ corrosion product.

Table II shows the analyses of the deposits collected on cylindrical corrosion probes which were controlled at temperatures of 104°C, 120°C and 138°C during exposure to flue gas at 270°C.

The data shows that no free acid was detected on any of the corrosion probes during the course of the combustion trials. The amount of calcium in the coal ash was capable of neutralizing any free acid either after deposition or in the gas stream. It can be expected therefore, that no significant low-temperature corrosion will occur on surfaces maintained at temperatures above 120°C with up to 5% excess oxygen in the flue gas.

9. COMPARISON BETWEEN SUNDANCE AND TULAMEEN COALS

Previous experiments with Sundance coal at CCRL were performed using the sidewall burner configuration shown in Figure 1 and a coal size distribution of 78% below 200 mesh. A comparison of combustion performance can therefore be made between Sundance coal and Tulameen coal test No.2.

Relative to Sundance coal at the same thermal input Table I shows that use of the Tulameen coal presents a 1% increase in ash burden to the system and that a two and one-half fold increase in sulphur input will occur. At the low sulphur neutralization levels observed in the Tulameen trials, SO_2 emissions were close to 1.2 lb. per million Btu input. Table 12 shows that the calculated volatile-matter adiabatic flame temperatures for the Tulameen coal was low and it should not be expected to offer the same degree of flame stability and turn-down as Sundance in units of similar design. The NO levels, which are temperature, excess-oxygen and fuel nitrogen dependent, were very similar, indicating that the higher nitrogen content of the Tulameen coal had not undergone a major conversion to nitric oxide.

The fly-ash characteristics from the two coals were remarkably different. The low - rank Sundance coal produced a low-carbon, low-resistivity fly-ash, whereas the higher rank Tulameen coal produced a high-resistivity fly-ash but with a higher carbon content. This high-resistivity (10^{11} ohm cm.)is consistent with the 0.6% sulphur content of the Tulameen coal. Normally, coals with less than 0.7% sulphur are associated with fly-ash resistivities above 10^{10} ohm cm.

It is clear from the carbon carry-over in the fly-ash that the Tulameen coal is not as reactive as the Sundance coal although this decreased reactivity was not reflected in the steaming rates recorded in the two trials.

When the slagging and fouling characteristics of the two coals are compared as in Figure 10, it is clear that Tulameen coal is less likely to produce molten slag problems within a combustion chamber than Sundance coal. Moreover, the low-temperature corrosion potential of both coals is low, indicating that air heater corrosion rates when burning Tulameen coal should be as low as with Sundance coal.

10. CONCLUSIONS

Tulameen coal performed satisfactorily in pilot-scale combustion experiments representative of full scale practice. It handled and flowed readily at 12% moisture and produced easily ignited stable flames throughout the course of the experimental program.

The carbon content of the fly-ash was high when the usual pulverized coal specification of 70% through 200 mesh was used. However, the coal burn-out increased at a finer fuel particle size. In large units with their increase in residence time over that available in the pilot-scale boiler, a fuel specification of 80% through 200 mesh can be expected to produce a fly-ash with less than 3% carbon.

The gaseous SO_2 emissions from the system showed evidence of neutralization. It can be anticipated that 70% of the input sulphur will appear as sulphur dioxide when this fuel is used in a pulverized form. The nitric oxide emissions were not excessive and will be amenable to control (where required) using the familiar staged-combustion or flue-gas recirculation techniques.

The fly-ash from the pulverized coal has a high electrical resistivity about 10^{11} ohm cm. It must be expected that substitution of this coal for a coal with low-resistivity ash in existing equipment will lead to a reduction in electrostatic precipitator performance. The use of a hot precipitator will demand flue-gas inlet temperatures above 400°C to reduce the resistivity to 5×10^{9} ohm cm. Higher efficiencies will be obtained at low temperature by using flue-gas conditioning agents to reduce resistivity.

The coal ash and furnace bottom ash analyses all indicate that the fuel is suitable for dry-bottom operation and will not produce fouling or slagging problems that cannot be handled by normal sootblowing equipment.

There is no evidence to suggest that the coal will produce any corrosion on metal surfaces operating at temperatures down to 121°C.

Comparison of the Tulameen coal with Sundance coal currently in use by Calgary Power suggests that it will make a good boiler fuel when used in the pulverized form. The areas requiring special attention will be the size distribution of the fuel and the performance of the electrostatic precipitators.

11. ACKNOWLEDGEMENTS

The authors wish to acknowledge the efforts of the staff of the Canadian Combustion Research Laboratory during the coal evaluation experiments described in this report. In addition, Mr. W.J.Montgomery of the Energy Research Laboratories provided invaluable analytical support services.

TABLE 1

Analyses of the Experimental Coals

(as fed to the pulverizer)

		TULAMEEN	SUNDANCE
Proximate Analysis			
Moisture	%	11.76	13.61
Ash	%	15.08	13.84
Volatile Matter	%	29.17	29.12
Fixed Carbon	%	43.99	43.43
Ultimate Analysis			
Carbon	%	57.54	54.89
Hydrogen	%	2.99	2.19
Sulphur	%	0.57	0.21
Nitrogen	%	0.99	0.67
Oxygen	%	11.07	14.60
Ash	%	15.08	13.84
Calorific Value			
Cal/g		5427	5020
Btu/lb		9768	9036
Equilibrium Moisture		10.82	
Classification		High-Volatile Bituminous "C"	Sub-bituminous "B"

TABLE 2

Volatile-Matter Adiabatic Flame Temperatures

for Sundance and Tulameen Coals

Coal	Volatile-matter adiabatic flame temperature,
Sundance	868°C
Tulameen	454°C

TABLE 3

Burner Configuration and Pulverized Coal Size

for the Combustion Tests

Combustion Test 1 :	Condition setting
Combustion Test 2 :	Sidewall burners Coal: 70% below 200 mesh
Combustion Test 3 :	Sidewall burners Coal: 90% below 200 mesh
Combustion Test 4 :	Adiabatic furnace bottom Coal: 90% below 200 mesh
Combustion Test 5 :	Adiabatic furnace bottom Coal: 60% below 200 mesh
Combustion Test 6 :	Adiabatic furnace bottom Coal: 70% below 200 mesh

TABLE 4

Coal Size Distribution throughout the Combustion Trials

	Combustion trial number				
Coal Size Fraction Mesh Size	2	3	4	5	6
>100 %	0.5	0.4	0.6	2.9	0.7
100 - 140 %	5.1	0.9	1.2	25.2	13.4
140 - 200 %	16.4	5.9	6.9	15.8	18.0
200 - 325 %	46.0	58.5	36.9	28.1	36.8
325 - 400 %	4.7	3.9	6.5	4.7	5.8
<400 %	27.3	30.4	47.9	23.3	25.3
% below 200 mesh	78.0	92.8	91.3	56.1	67.9

TABLE 5

Combustion Conditions throughout the Combustion Trials

Combustion Trial No.	Fuel, % below 200 mesh	Feed rate kg/h	Steaming rate kg/h	Combustion product analysis				
				O_2 %	CO_2 %	CO %	N O p p m	SO_2 p p m
1 *		72.8 ±5.5	495 ±9.0	4.3 ±0.5	16.4 ±0.5	NIL	680 ± 34	401
2	78.1	71.3 ±1.6	483 ±15.7	4.9 ±0.2	16.5 ±0.7	NIL	654 ±32	390 ±10
3	92.8	70.9 ±1.5	478 ±6.5	4.9 ±0.2	------	NIL	753 ±28	393 ±5
4	91.8	70.6 ±3.4	467 ±11.2	5.0 ±0.1	------	-----	798 ±45	-----
5	56.1	70.3 ±1.5	468 ±11	5.0 ±0.1	------	TRACE	693 ±35	-----
6	67.9	69.1 ±1.4	479 ±8.5	5.0 ±0.1	------	TRACE	767 ±19	399 ±3

* Trial 1 was used chiefly to establish experimental conditions for subsequent experiments.

TABLE 6

Effect of Coal Fineness on Fly-Ash Characteristics

	Combustion Trial				
	2	3	4	5	6
Coal feed % below 200 mesh	78.1	92.8	91.8	56.1	67.9
Fly-ash Concentration mg/m^3	1245	2220	2199	2192	2207
Carbon in fly-ash %	7.8	8.0	2.1	7.3	4.0
Thermal Penalty due to unburnt carbon % of input	1.9	2.0	0.5	1.8	1.0

TABLE 7

Fly-Ash Resistivity and Electrostatic Precipitator Performance

Combustion trial no.	Fly-ash characteristics: Flue gas Temperature °C	Carbon content* %	Electrical resistivity ohm.cm	Mean daily electrostatic precipitator efficiency %
2	205	7.8	1.2×10^4	
	270	7.8	2.4×10^4	59
3	195	8.0		
	260	8.0		58
4	199	2.1	7.9×10^{11}	
	220	2.1	4.8×10^{11}	
	220	2.1	4.16×10^{11}	66
	280	2.1	1.3×10^{10}	
	280	2.1	1.07×10^{10}	
5.	200	7.3	1.9×10^6	
	210	7.3	2.5×10^7	73
	250	7.3	9.6×10^4	
	260	7.3	6.8×10^4	
6	210	4.0	9.5×10^{10}	
	270	4.0	6.3×10^5	77

TABLE 8

Chemical Analysis of the Furnace Deposits Produced during Combustion Trial No. 3

Ash component	Coal ash composition %	Deposit Composition %			
		Furnace bottom deposit	Furnace wall deposit	Superheater deposit	Air heater deposit
SiO_2	71.7	71.09	62.05	64.22	70.93
Al_2O_3	14.3	16.46	14.90	14.65	15.58
Fe_2O_3	9.07	8.23	11.07	9.73	7.27
TiO_2	0.84	0.81	0.90	0.77	0.56
P_2O_5	0.15	0.06	0.18	0.13	0.10
CaO	1.03	1.24	2.67	1.66	1.56
MgO	0.46	0.72	1.02	0.32	0.88
Na_2O	0.11	0.17	0.28	0.15	0.17
K_2O	2.80	2.34	2.11	2.07	2.39
SO_3	0.32	0.08	1.27	0.67	0.49

TABLE 9

Chemical Analysis of the Furnace Deposits Produced during Combustion Trial No. 6

Ash Component	Deposit composition; %			
	Furnace bottom deposit	Furnace wall deposit	Super-heater deposit	Air heater deposit
SiO_2	69.30	64.22	65.92	62.84
Al_2O_3	14.63	14.96	16.11	14.31
Fe_2O_3	5.74	11.37	13.29	12.60
TiO_2	0.79	1.02	1.45	1.01
P_2O_5	0.37	0.37	0.22	0.26
CaO	0.72	1.19	1.53	1.15
MgO	0.81	1.52	0.98	0.78
Na_2O	0.14	----	0.05	0.08
K_2O	1.98	1.84	2.04	1.99
SO_3	0.09	0.12	0.24	0.10

TABLE 10

Ash Fusion Temperatures of the Coal Ash and Deposits Exposed to Flame Radiation

Test No.	Fusion characteristic	Coal ash		Furnace bottom ash		Furnace wall ash	
		Oxidising	Reducing	Oxidising	Reducing	Oxidising	Reducing
2	Initial deformation, °C	1280	1194	1330	1270	1210	1150
	Spherical deformation, °C	1400	1349	1400	1350	1327	1230
	Hemispherical deformation, °C	> 1480	1480	> 1480	1400	1466	1320
	Fluid deformation, °C	> 1480	>1480	> 1480	>1480	>1480	1380
6	Initial deformation, °C	1280	1190	1330	1340		
	Spherical deformation, °C	1400	1340	1380	1400		
	Hemispherical deformation, °C	> 1480	>1480	> 1480	1450		
	Fluid deformation, °C	> 1480	>1480	> 1480	>1480		

TABLE 11

Analysis of the Water-Soluble Material in the Low-Temperature Deposits

Combustion trial no.	Water soluble ion	Water Soluble Component, mg		
		Corrosion Probe temperature		
		104°C	120°C	138°C
3	SO_4	6.9	5.4	2.1
	Fe	0.2	0.2	0.0
	Mg	0.0	0.0	0.0
	Ca	5.2	5.8	6.1
	Na	0.1	0.1	0.1
	K	0.0	0.0	0.0
	Free H_2SO_4	---	----	----
4	SO_4	13.5	8.1	3.7
	Fe	2.9	1.4	0.8
	Mg	0.0	0.0	0.0
	Ca	9.8	8.0	6.7
	Na	0.1	0.0	0.1
	K	0.0	0.0	0.0
	Free H_2SO_4	---	----	----
6	SO_4	12.0	15.3	4.1
	Fe	2.9	2.6	0.0
	Mg	0.0	0.0	0.0
	Ca	7.5	7.7	8.4
	Na	0.1	0.0	0.1
	K	0.0	0.0	0.0
	Free H_2SO_4	---	---	---

TABLE 12

Comparison between Tulameen and Sundance Coals in Pilot-Scale Boiler Experiments

Parameter	Tulameen coal	Sundance coal
Volatile-matter adiabatic flame temperature, ^{o}C	454 @ 12% moisture	868 @ 13.6% moisture
Fly-ash		
carbon content, %	2	less than 2
Resistivity, ohm cm	5×10^{11}	5×10^{7}
Precipitator efficiency,%	77	93
Ash characteristics		
$\frac{\text{Base}}{\text{Acid}}$ Ratio	0.15	0.25
T_{250}, ^{o}C	1690	1425
NO emmissions at O_2 = 5% ppm	650	640

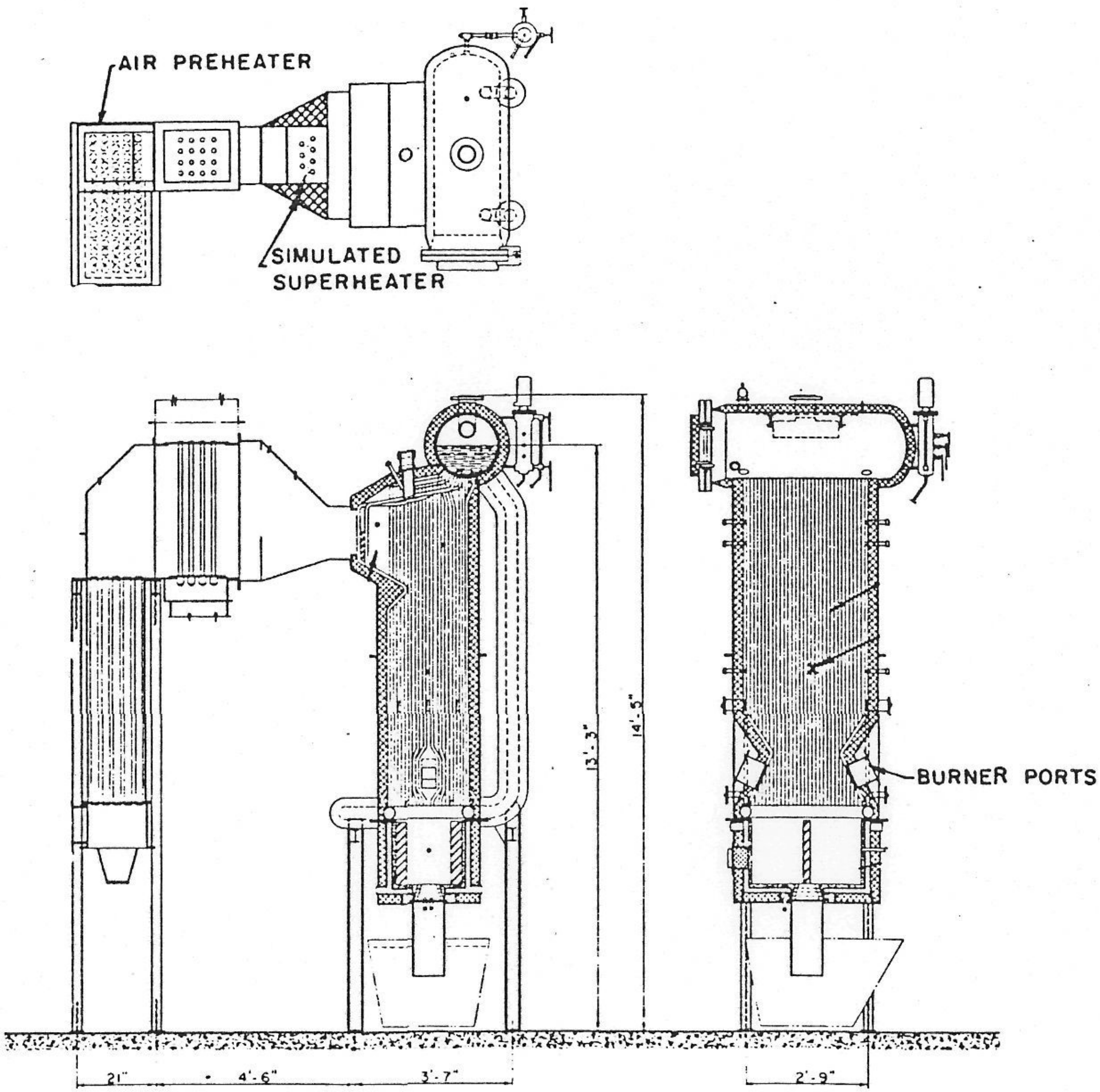


Figure 1. Pilot-Scale research boiler.

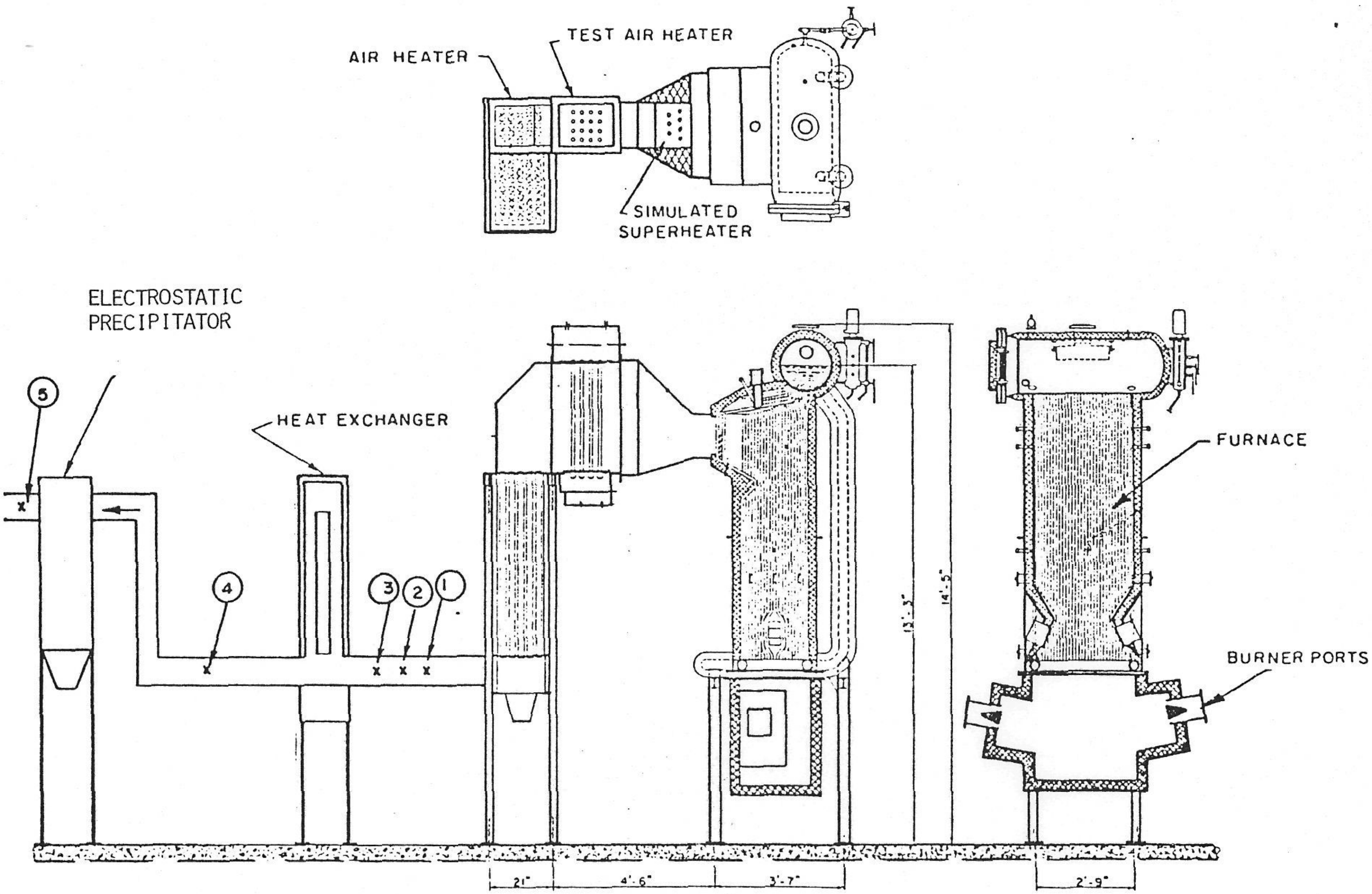


FIGURE 2. Pilot-Scale Research Boiler showing the Adiabatic Furnace Bottom

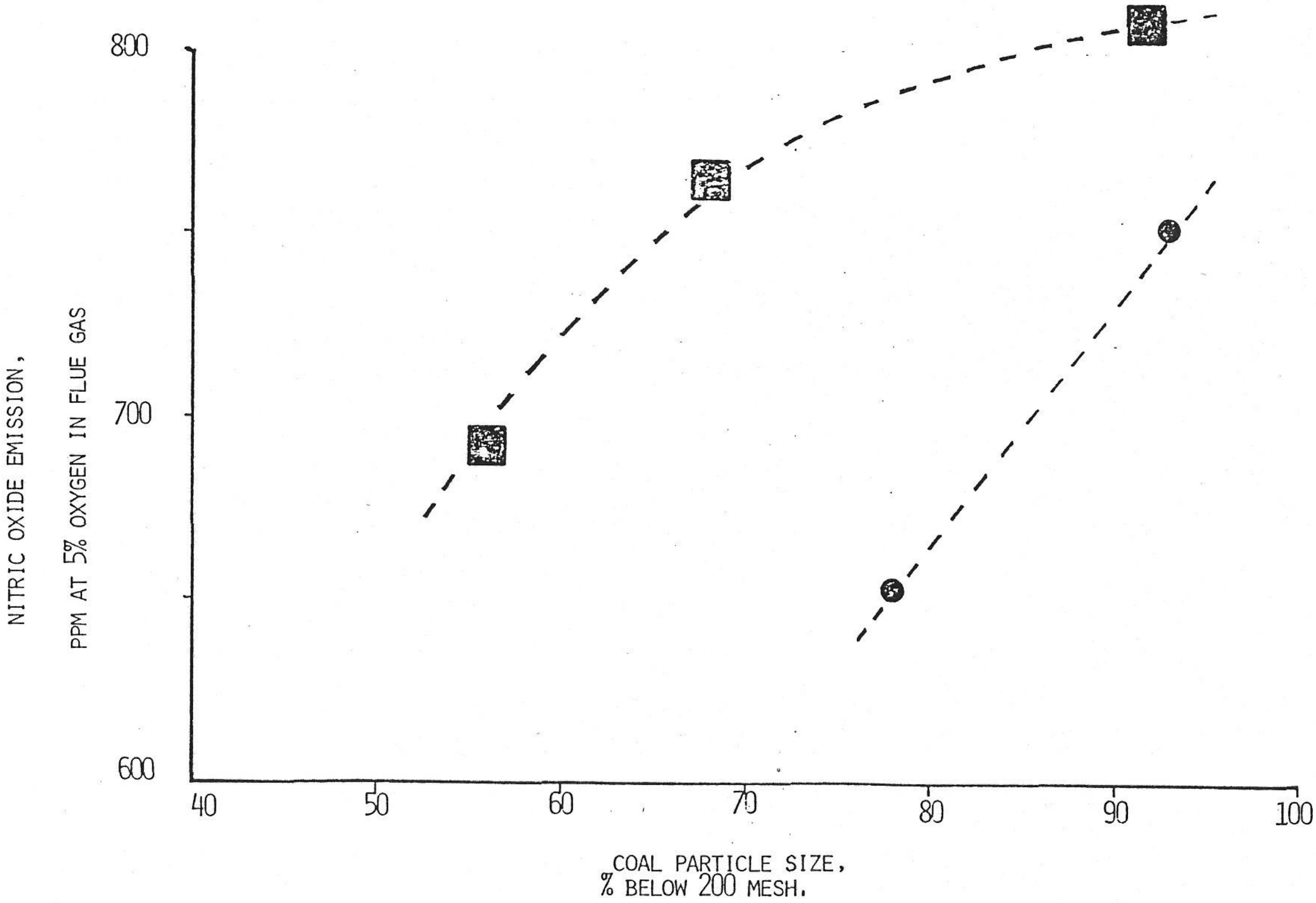


FIGURE 3 Effect of Coal Particle Size on Nitric Oxide Emissions

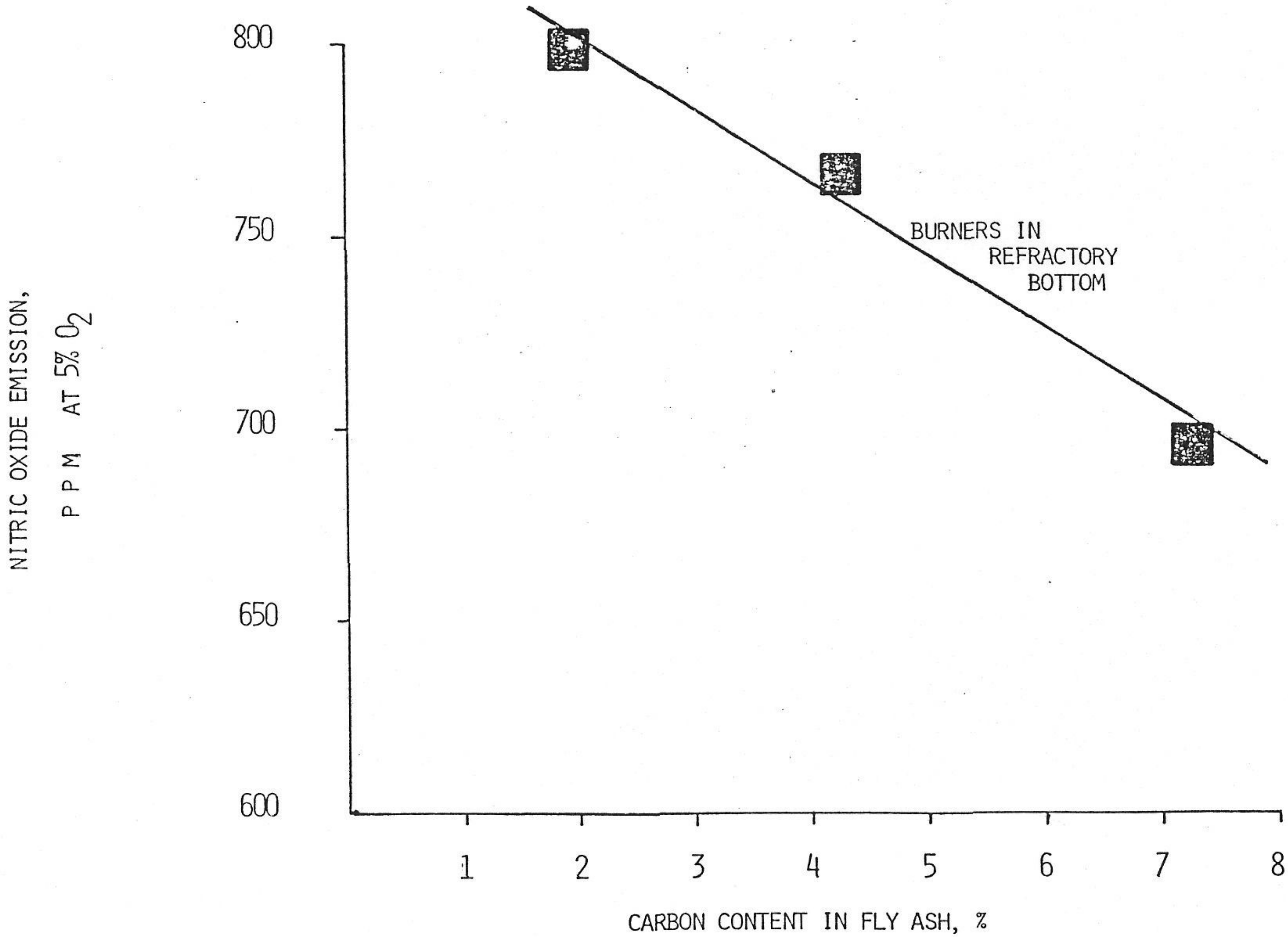


Figure 4 The Relationship between Carbon Content in the Fly Ash and Nitric Oxide Emissions

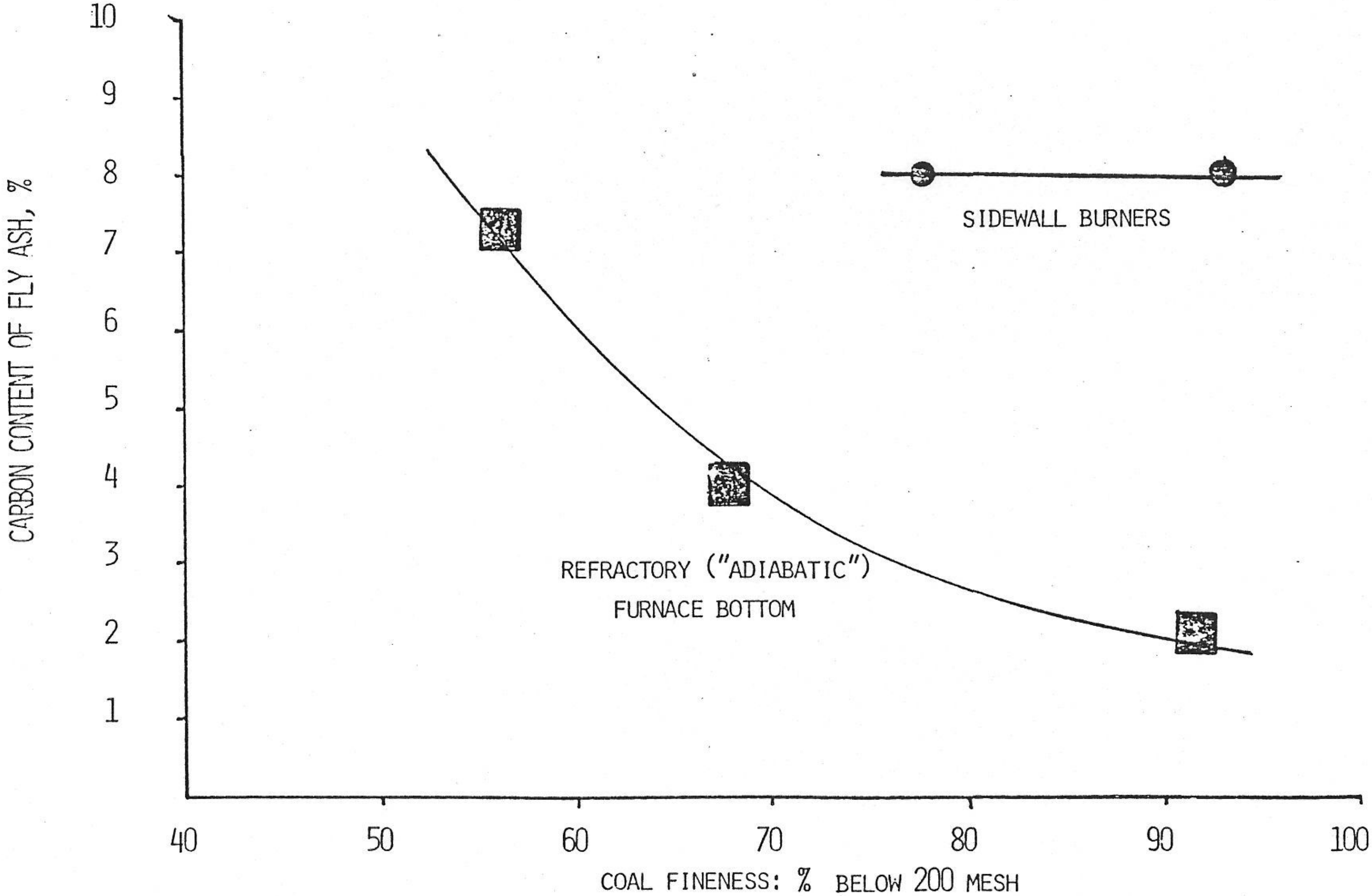


Figure 5 Effect of Coal Particle Size on Carbon Content in the Fly Ash

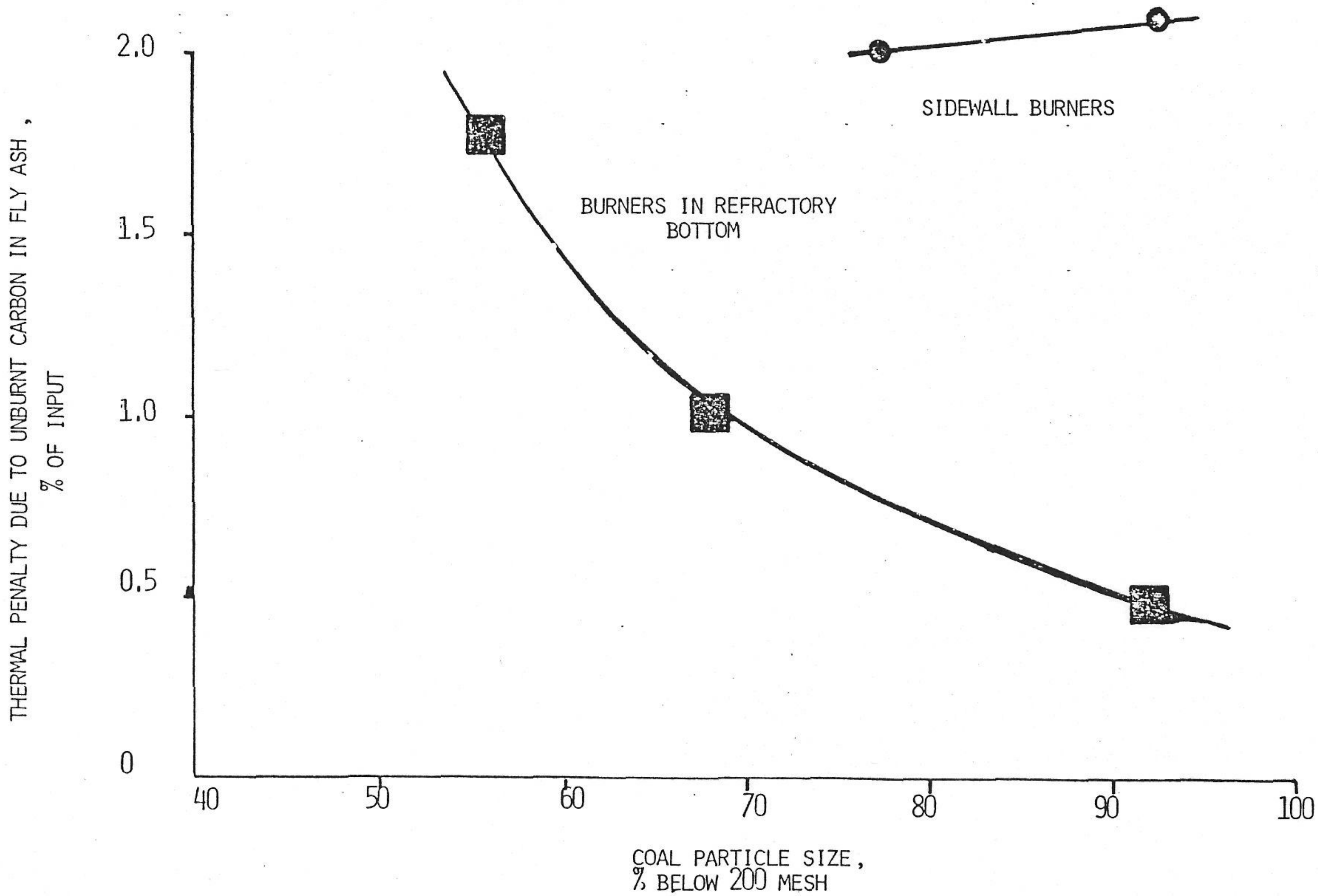


Figure 6 Effect of Coal Particle Size on the Thermal Penalty due to Unburnt Carbon in the Fly-Ash

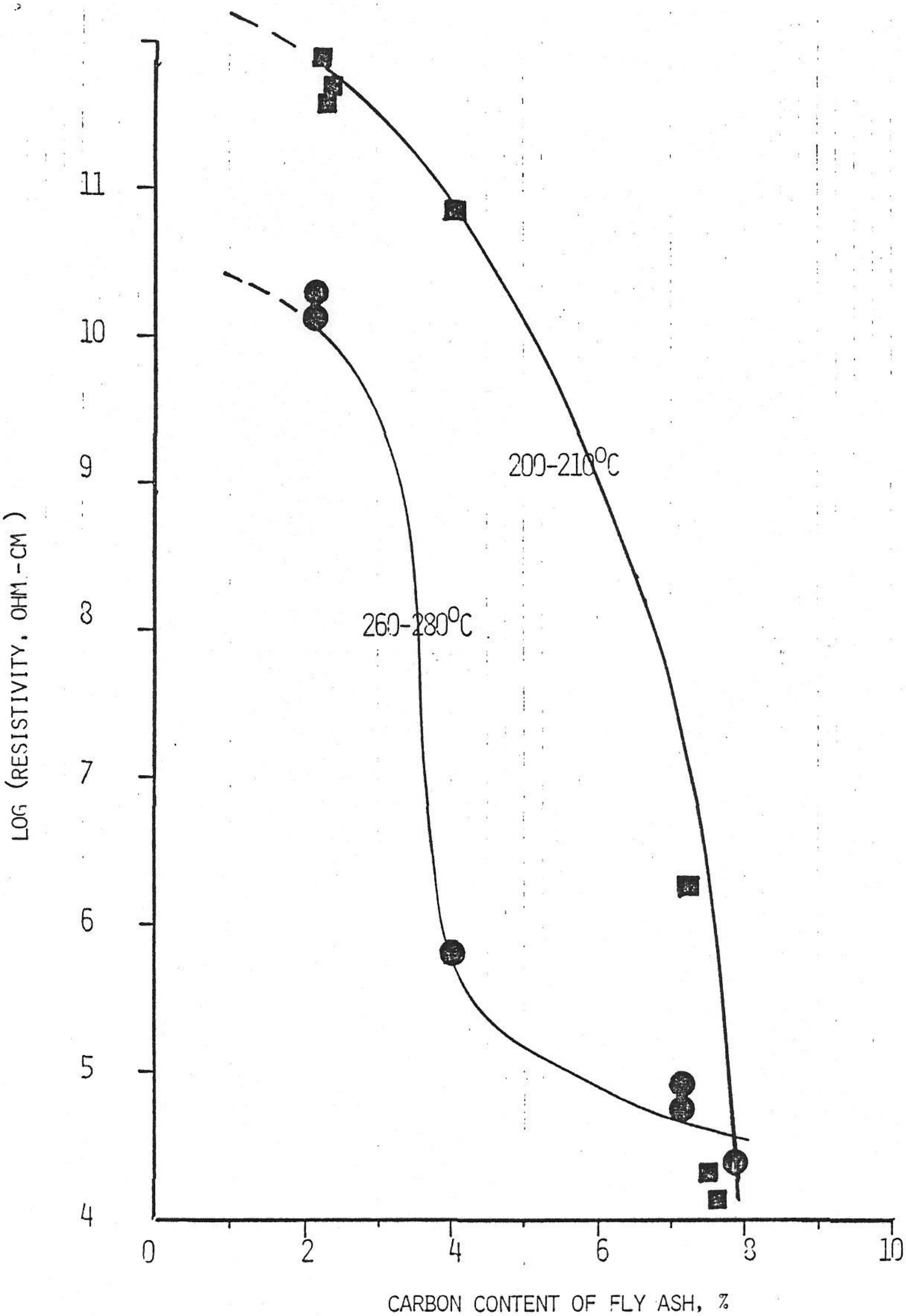


Figure 7 Effect of Unburnt Carbon in the Fly Ash on Fly Ash Resistivity

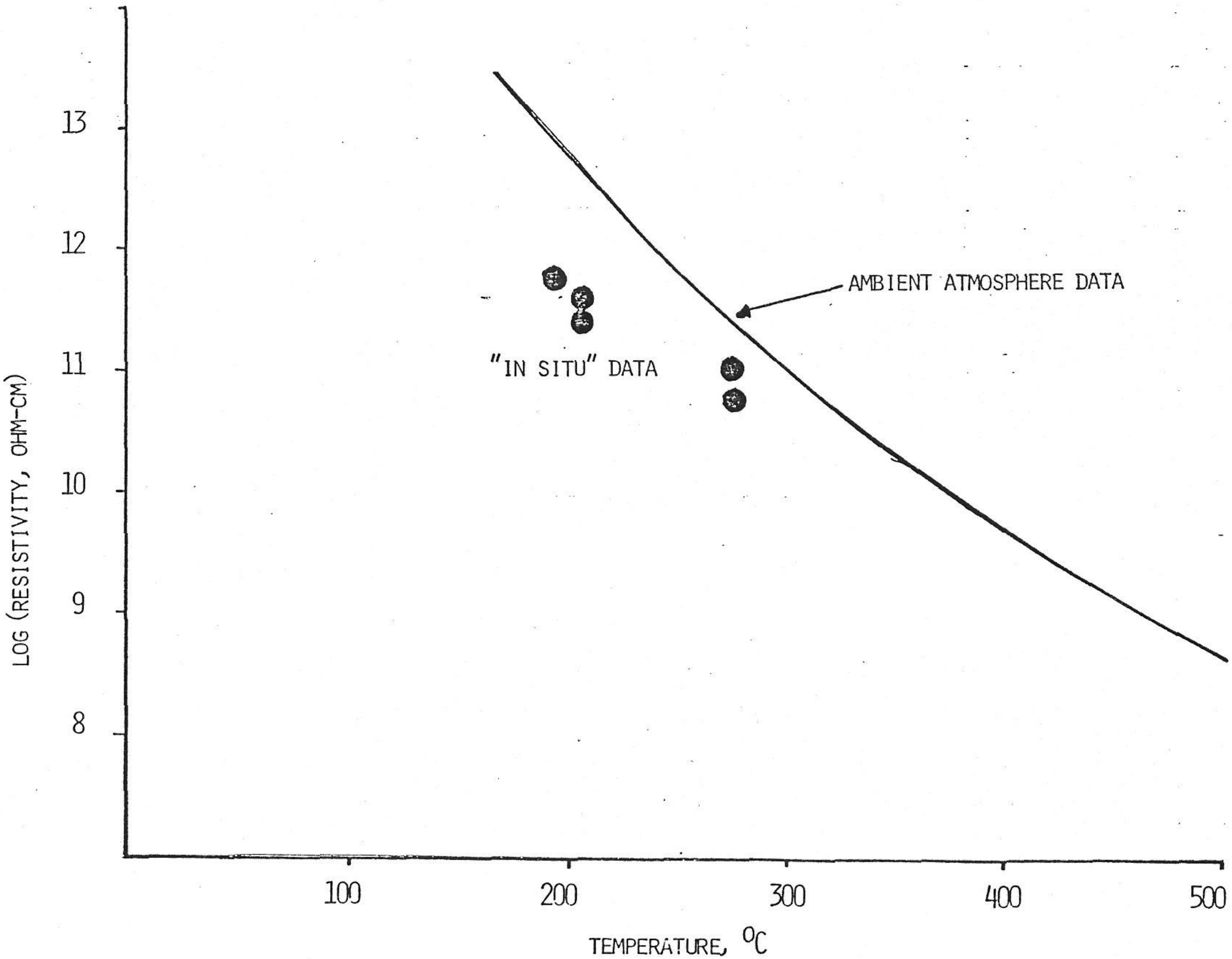


Figure 8 Effect of Temperature on Fly Ash Resistivity

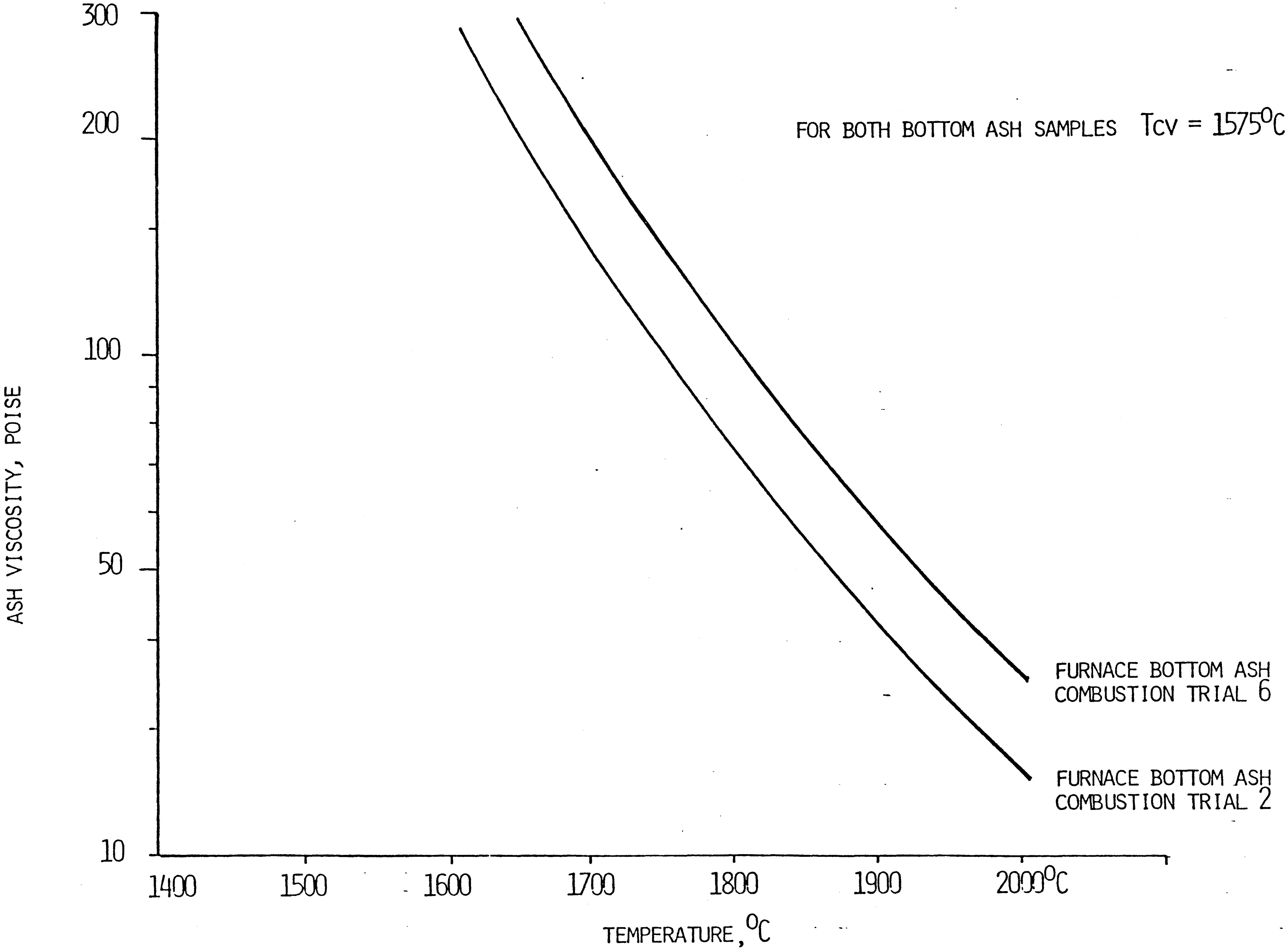


Figure 9 Effect of Temperature on Calculated Ash Deposit Viscosity

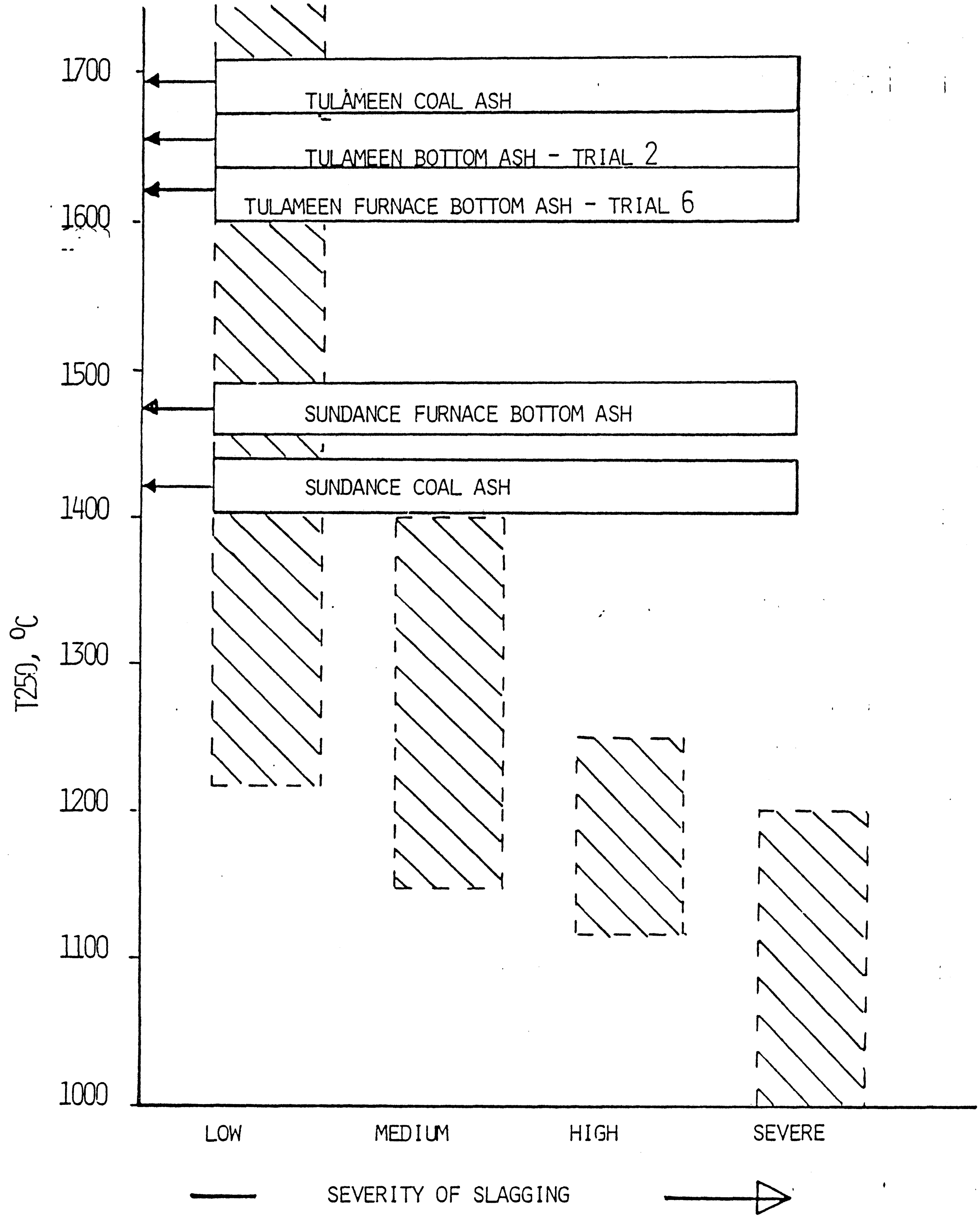
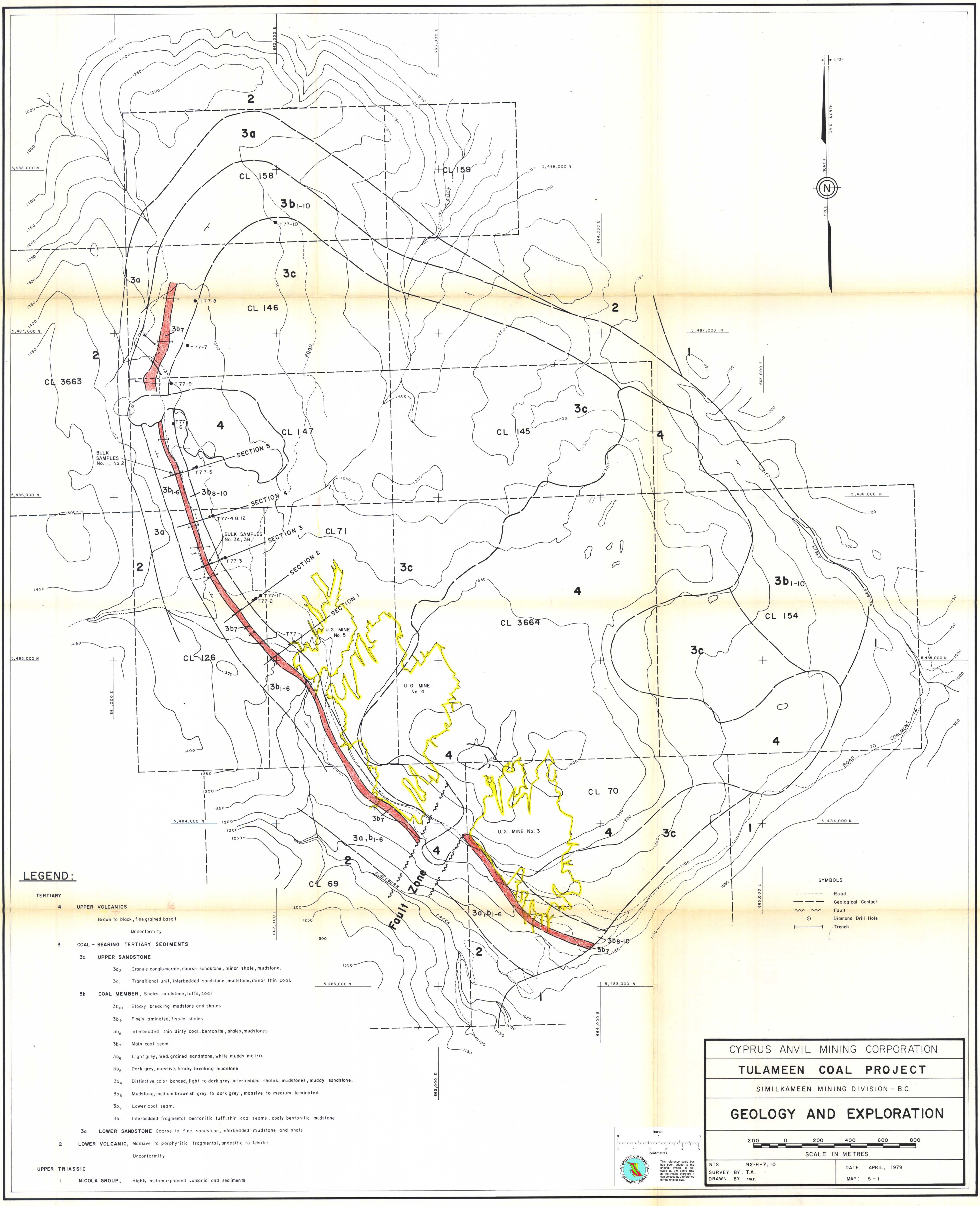


Figure 10 Slagging Severity as a Function of the Temperature at which Ash Viscosity is 250 poise.

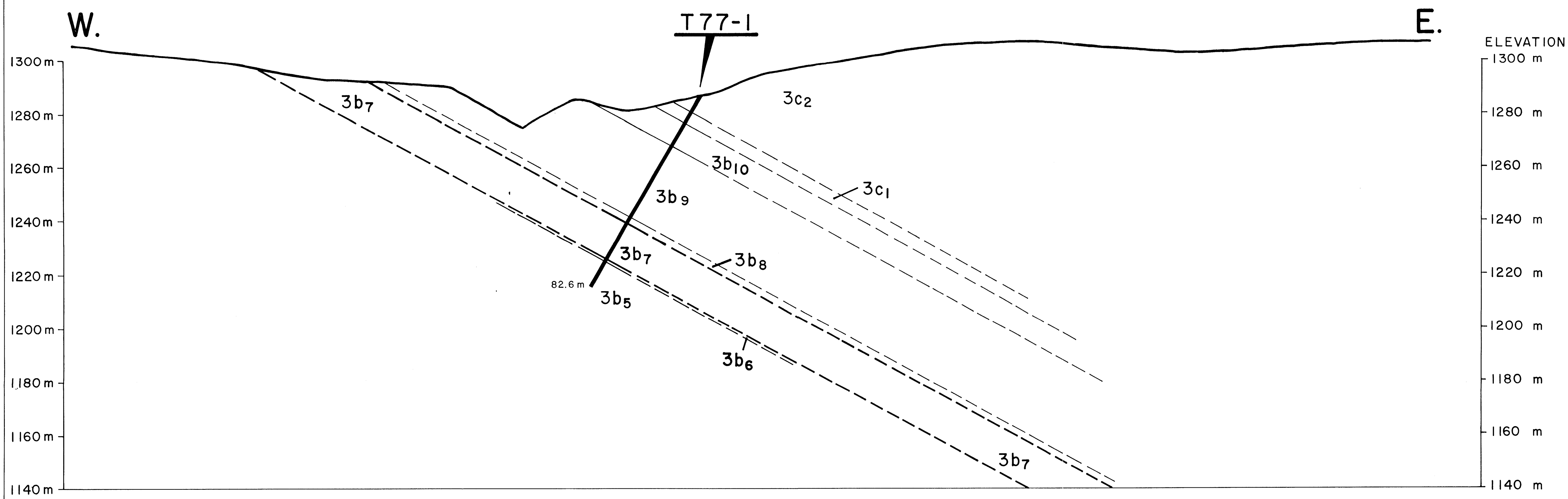
Map 5-1	TULAMEEN PROJECT	
	- Geology and Exploration	(1:10,000)
Map 5-2	REPRESENTATIVE X-SECTIONS	
	- Area of Proposed Open Pit Mine	(1:1,000)

Map 6-1 PRELIMINARY MINE SITE LAYOUT

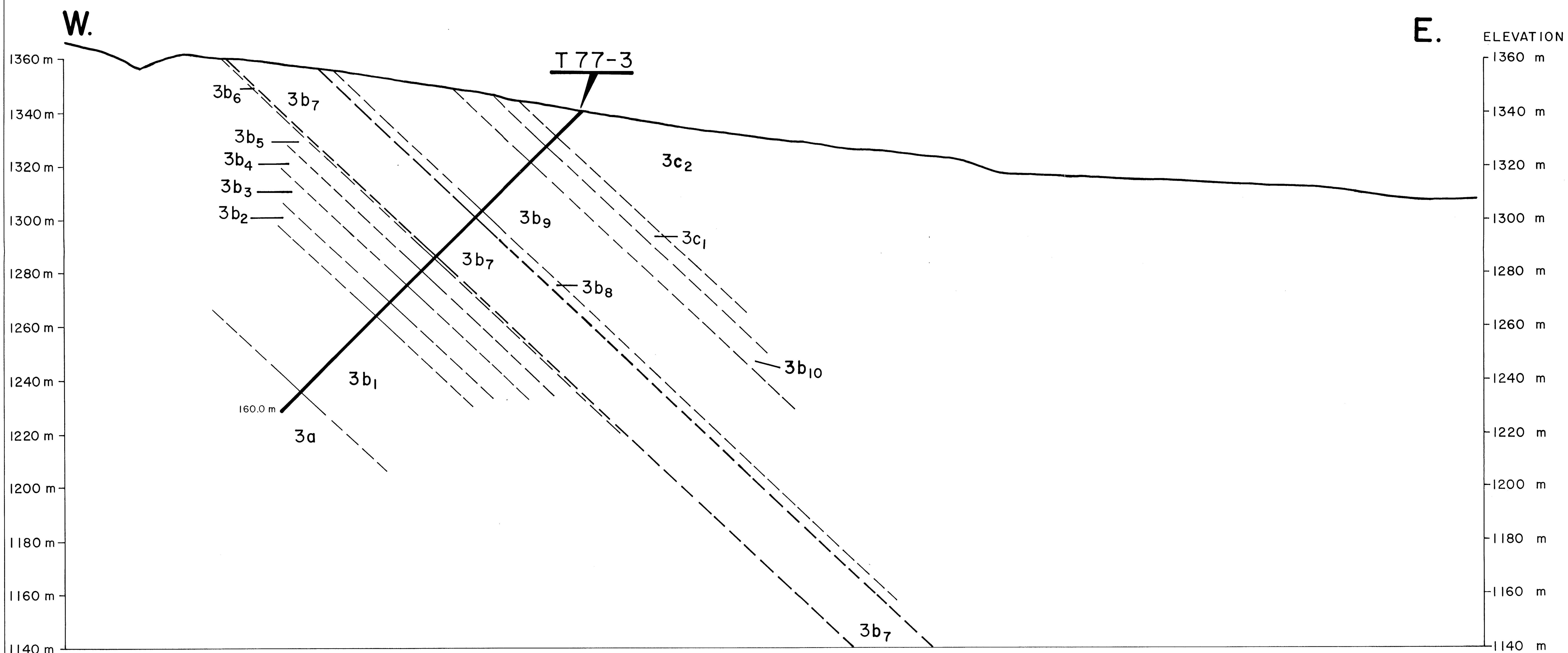
(1:10,000)


CYPRUS ANVIL MINING CORPORATION
TULAMEEN COAL PROJECT
SIMILKAMEEN MINING DIVISION – B.C.
GEOLOGY AND EXPLORATION
SCALE IN METRES
200 0 200 400 600 800
NTS. 92-H-7, 10
SURVEY BY: T.A.
DRAWN BY: r.w.r.
DATE: APRIL, 1979
MAP: 5-1
LEGEND:
TERTIARY
4 UPPER VOLCANICS
Brown to black, fine grained basalt
Unconformity
3 COAL - BEARING TERTIARY SEDIMENTS
3c UPPER SANDSTONE
3c2 Granule conglomerate, coarse sandstone, minor shale, mudstone.
3c1 Transitional unit, interbedded sandstone, mudstone, minor thin coal.
3b COAL MEMBER, Shales, mudstone, tuffs, coal
3b10 Blocky breaking mudstone and shales
3b9 Finely laminated, fissile shales
3b8 Interbedded thin dirty coal, bentonite, shales, mudstones
3b7 Main coal seam
3b6 Light grey, med. grained sandstone, white muddy matrix
3b5 Dark grey, massive, blocky breaking mudstone
3b4 Distinctive color banded, light to dark grey interbedded shales, mudstones, muddy sandstone.
3b3 Mudstone, medium brownish grey to dark grey, massive to medium laminated.
3b2 Lower coal seam.
3b1 Interbedded fragmental bentonitic tuff, thin coal seams, coaly bentonitic mudstone
3a LOWER SANDSTONE Coarse to fine sandstone, interbedded mudstone and shale
2 LOWER VOLCANIC, Massive to porphyritic fragmental, andesitic to felsitic
Unconformity
UPPER TRIASSIC
1 NICOLA GROUP, Highly metamorphosed volcanic and sediments
SYMBOLS
Road
Geological Contact
Fault
Diamond Drill Hole
Trench
TRUE NORTH
GRID NORTH
1.43°
U.G. MINE No. 5
U.G. MINE No. 4
U.G. MINE No. 3
Fault Zone
SECTION 1
SECTION 2
SECTION 3
SECTION 4
SECTION 5
BULK SAMPLES No. 1, No. 2
BULK SAMPLES No. 3A, 3B
CL 158
CL 159
CL 146
CL 3663
CL 147
CL 145
CL 71
CL 3664
CL 154
CL 126
CL 70
CL 69
ROAD TO COALMONT
5,488,000 N
5,487,000 N
5,486,000 N
5,485,000 N
5,484,000 N
5,483,000 N
661,000 E
662,000 E
663,000 E
664,000 E
665,000 E

SECTION 1 at 055°



SECTION 3 at 070°



LEGEND:

TERTIARY

4 UPPER VOLCANICS

Brown to black, fine grained basalt

Unconformity

3 COAL - BEARING TERTIARY SEDIMENTS

3c UPPER SANDSTONE

$3c_2$ Granule conglomerate, coarse sandstone, minor shale, mudstone.

$3c_1$ Transitional unit, interbedded sandstone, mudstone, minor thin coal.

3b COAL MEMBER, Shales, mudstone, tuffs, coal

$3b_{10}$ Blocky breaking mudstone and shales

$3b_9$ Finely laminated, fissile shales

$3b_8$ Interbedded thin dirty coal, bentonite, shales, mudstones

$3b_7$ Main coal seam

$3b_6$ Light grey, med. grained sandstone, white muddy matrix

$3b_5$ Dark grey, massive, blocky breaking mudstone

$3b_4$ Distinctive color banded, light to dark grey interbedded . shales, mudstones, muddy sandstone.

$3b_3$ Mudstone, medium brownish grey to dark grey; massive to medium laminated.

$3b_2$ Lower coal seam.

$3b_1$ Interbedded fragmental bentonitic tuff, thin coal seams, coaly bentonitic mudstone

3a LOWER SANDSTONE Coarse to fine sandstone, interbedded mudstone and shale

2 LOWER VOLCANIC, Massive to porphyritic fragmental, andesitic to felsitic

Unconformity

UPPER TRIASSIC

1 NICOLA GROUP, Highly metamorphosed volcanic and sediments

CYPRUS ANVIL MINING CORPORATION

TULAMEEN COAL PROJECT

SIMILKAMEEN MINING DIVISION - B.C.

GEOLOGICAL CROSS SECTIONS
N°. 1&3

20 0 20 40 60 80

SCALE IN METRES

N.T.S. 92-H-7, 10	DATE: APRIL, 1979
SURVEY BY: T.A.	MAP N°. 5-2
DRAWN BY: r.w.r.	