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Hat Creek Coal Beneficiation
INTERIM REPORTS

VOLUME II

POTENTIAL APPLICATION OF ALTERNATIVE PROCESSES (INC. APPENDICES I & II) BENEFICIATION OF LOW GRADE COALS

Simon-Carves of Canada Ltd.
2025 Sheppard Ave. East
Willowdale, Ontario M2J 1W2

SIMON-CARVES

HAT CREEK
COAL BENEFICIATION

INTERIM REPORTS 1977-8

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WASHABILITY TESTWORK OF 1977 BULK SAMPLES

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VOLUME II

REPORT ON THE POTENTIAL APPLICATION OF ALTERNATIVE PROCESSES FOR THE BENEFICIATION OF HAT CREEK COALS

SECTION 1

SUMMARY

This Report considers the samples taken in 1976 and 1977 through detailed calculations of the yields and qualities which may be obtained by the whole range of available Beneficiation Processes.

Practical observations made during the 1977 Testwork are also taken into account in assessing normal practice for preparing Thermal Plant feed coals.

The principal conclusion is that any beneficiation plant scheme would not be as effective on Hat Creek coals as on normal coals, i.e. firstly the degree of beneficiation which can be achieved is much lower and secondly that the heating value recovery is also lower. This is illustrated in Table 1 overleaf.

This study was used in the total context of the Mining Feasibility Study and B.C. Hydro's reviews to determine which process plant schemes warranted evaluation in terms of capital and operating costs. These are summarized in Table 2 overleaf and detailed in Volume IV.

Footnote: October 1978

This report was issued in draft from in December 1977. Data has since been added from the 1977 Washability Testwork and its subsequent evaluation. Pages which are the subject of revisions for additional information are dated October 1978. Figures generally revised.

TABLE 1

Theoretical Beneficiation Potential of Hat Creek Coals with Typical Coals Not Having Clay Inclusions

Hat Creek Coal Beneficiation Report 1978

	Hat Creek Coal Samples A	X + Y	B	C	Z	Typical Sub-Bituminous Coal with Soft Shale and Clay Partings	Typical High Volatile Bituminous Coal with Firm Shale and No Clay
Raw Coal							
Calorific Value	5176	6304	7331	8372	8575	7800	9939
Ash Content	51.2	43.4	36.3	29.1	27.7	34.8	30.7
Product from Partial Washing (+13mm separated at 1.60 sp. gr. blended with -13mm untreated)							
Yield Wt. %	88.2	86.4	94.7	95.9	90.5	92.6	82.8
Calorific Value	5697	6998	7570	8627	9140	8007	11323
Ash Content %	47.6	38.6	34.7	27.3	23.8	33.0	21.0
Btu Yield %	97.1	95.9	97.8	98.8	96.5	95.1	94.3
Degree of Beneficiation	1.18	1.25	1.08	1.10	1.24	1.08	1.66
Product from Conventional Total Washing (+28mesh separated at 1.60 sp. gr., -28mesh rejected to tailings)							
Yield Wt. %	45.8	54.2	64.8	65.0	68.9	60.2	64.7
Calorific Value	8546	9485	9127	10035	9723	10698	13021
Ash Content %	27.9	21.4	23.9	17.6	19.8	10.5	9.2
Btu Yield %	80.1	81.6	80.7	77.9	78.1	82.6	84.8
Degree of Beneficiation	3.02	3.05	1.89	1.98	1.59	4.53	4.39
Product After Wet Attrition and Total Washing (+28mesh separated at 1.60 sp. gr., -28mesh rejected to tailings)							
Yield Wt. %		45.5			66.2		
Calorific Value		10129			10020		
Ash Content %		17.0			17.7		
Btu Yield		73.1			77.4		
Degree of Beneficiation		4.10			1.83		

NOTE: 1. These are theoretical results which do not take account of misplaced materials in processes. Due to the difficult washability characteristics of the Hat Creek coals results from practical plant schemes would be significantly poorer.

2. For the A, B and C samples, the untreated coal fraction is calculated as the ¼ x 0 material in the Partial Washing case to allow for the higher fines content resulting from the auger sampling method.

TABLE 2

Summary of Beneficiation Schemes

Hat Creek Coal Beneficiation Report 1978

	Target Fuel Specification (BCHPA)	Raw Coal (C-MJV Mining Scheme)	Results and Costs of Processing C-MJV Raw Coal. A, B and C Zone coals (1000 MTPH) cleaned and blended with D Zone coal (741 MTPH) which does not need cleaning					
TREATMENT SCHEME			1	2	3	4	5	6
Coarse Coal (+13mm) Fine Coal (-13mm)			H.M. Bath W.O.C.	H.M. Bath None	Baum Jig None	None Dryer/ Classifier	W.O.C. W.O.C.	H.M. Bath Dryer/ Classifier
PRODUCT - Dry Basis Analysis								
Calorific Value, Btu/lb	7875	7327	9043	7882	7853	7683	9136	8333
% Ash	33.7	36.3	24.5	32.5	32.7	33.9	23.8	29.4
% Sulphur	0.45	0.48	0.39	0.47	0.47	0.45	0.39	0.43
lb Ash per 10^6 Btu	42.8	49.5	27.1	41.2	41.6	44.1	26.1	35.3
lb Sulphur per 10^6 Btu	0.57	0.66	0.43	0.60	0.60	0.59	0.43	0.52
- As Received Analysis								
Calorific Value, Btu/lb	6300	5495	6686	5891	5870	5796	6693	6266
% Ash	27.0	27.3	18.1	24.3	24.4	25.6	17.5	22.4
% Moisture	20.0	25.0	26.1	25.3	25.3	24.6	26.7	24.8
Yield % Weight (as received)	-	Base Case	75.0	91.1	90.5	91.0	73.0	82.1
Yield Btu %	-		91.2	97.6	96.6	96.0	88.9	93.6
Degree of Beneficiation	-		1.83	1.20	1.19	1.13	1.90	1.39
MTPH of Dewatered Tailings for Disposal		0	365	83	83	0	548	83
Capital Costs of Beneficiation and Tailings Plant $000,000's	-	0	32.7	19.2	16.0	6.3	*	25.5
Operating Costs for Total Average Product $ per tonne	-	0	1.10	0.45	0.38	0.24	*	0.76

* Scheme 5, which is equivalent to the EMR Canmet proposal, has not been costed. H.M. = Heavy Medium. W.O.C. = Water Only Cyclones.

SECTION 2

INTRODUCTION

At the commencement of the C-MJV Study SCAN reviewed the Washability Data obtained in 1976 and set out a programme and flowsheet for obtaining further data as part of the 1977 Test Programme.

The 1977 Test Programme was initially conceived to mine quantities of coal for Test Burns by Thermal Department. Advantage was taken, extending this programme to include: -

2.1 Obtaining Washability Data for "as mined" coal rather than by auger or bore-cores used in previous work at Hat Creek. This work to include sulphur as well as ash beneficiation data. Volume I details the results of this programme.

2.2 Observations of the Handling/Breaking/Screening characteristics.

2.3 Total Washing Test Wash by EMR using their Compound Water Only Cyclone Pilot Plant. This programme, designed by EMR in conjunction with BCH, included Tailings Flocculation Testwork. The Draft Report on this work was received in April 1978,

The initial review of 1976 Data which included computerized yield/quality predictions, confirmed that the "very difficult" washability characteristics of the Hat Creek Coal would result in a significant difference between theoretical and actual yields by practical beneficiation schemes. From this review and an outline coal washery flowsheet a graphical presentation to Mining Section was made to facilitate calculation of yields (of the Qualities called for in the Thermal Department's Draft Boiler Fuel Specification) from a wide range of raw coal qualities (Fig.1)

The initial review confirmed that even with comprehensive beneficiation facilities it would not be practicable to prepare a specified product quality from the range of raw coals. Thus the attention of Mining Section was directed to the need for a Mining Plan to provide suitable blends of raw coal.

This review of the washability data has now been extended to include the 1977 data. SCAN have examined (using Computer Predictions which are included as Appendix III to this Report, where appropriate):-

SECTION 2

INTRODUCTION

2.4 The capability of available Coal Beneficiation Processes.

- 2.4.1 Dense Medium Bath
- 2.4.2 Dense Medium Cyclones
- 2.4.3 Water Only Cyclones (both for coarse and fine coals)
- 2.4.4 Baum Jig
- 2.4 5 Dry Cleaning (Air jigs) - not yet available
- 2.4.6 Dry Cleaning (Air Tables)
- 2.4.7 Fines Extraction (Dedusting)
- 2.4.8 Fines Extraction (Screening)
- 2.4.9 Thermal Drying
- 2.4.10 Thermal Drying with Fines Extraction
- 2.4.11 Froth Flotation
- 2.4.12 Differential Crushing

2.5 The capability of alternative Coal Beneficiation Schemes.

The individual processes are examined in practical combinations to optimize beneficiation. It is recognized that wherever possible Thermal Plants are designed to operate without beneficiation, and that partial beneficiation (i.e. washing coarse coal and blending with untreated small coal) is normally the second best alternative since it achieves a minimal tailings effluent production.

SECTION 2

INTRODUCTION

2.5 The capability of alternative Coal Beneficiation Schemes - cont.

2.5.1 Total Washing - Dense Medium Bath + Dense Medium Cyclone + Water Only Cyclones

2.5.2 Total Washing - Baum Jig + Water Only Cyclones

2.5.3 Total Washing - Dense Medium Bath + Water Only Cyclones

2.5.4 Total Washing - Water Only Cyclones

2.5.5 Total Washing - EMR Canmet Alternative (not yet available)

2.5.6 Partial Cleaning - Dense Medium Bath + Untreated Smalls

2.5.7 Partial Cleaning - Dense Medium Bath + Thermal Dried Smalls with Fines Extraction

The potential application of alternative schemes is primarily concerned with the ash - BTU/yield relationship, but the effects on moisture and sulphur contents are also considered.

The Conclusions and Recommendations for further study contained in this Alternative Beneficiation Report of necessity take account of practical observations made during the 1976 and 1977 Test Programmes. They are of course, subject to review on completion of the latter work. The data available was considered adequate to identify the schemes which should be costed to facilitate the selection of any beneficiation plant proposal required as part of the Phase I Report. (i.e. the Cominco-Monenco Joint Venture Mining Feasibility Report. The work on beneficiation is summarized in Volume VIII, Appendix B "Hat Creek Coal Beneficiation" prepared for C-MJV by Simon-Carves).

2.6 Further Considerations - October 1978

Six schemes were selected for preliminary design and costing as detailed in Volume IV of these Interim Reports. To a large extent, the C-MJV Volume VIII is an updating and amplification of this report based on the eventual requirements of the Mining Plans and Revised Fuel Specifications.

SECTION 2

INTRODUCTION

2.6 Further Considerations - October 1978 - cont.

Scheme 1	Total Washing - Heavy Medium Bath + Water Only Cyclones
Scheme 2	Partial Cleaning - Heavy Medium Bath + Untreated Fines
Scheme 3	Partial Cleaning - Baum Jig (for coarse coal only)
Scheme 4	Dryer/Classifier Scheme
Scheme 5	Total Washing - Water Only Washing Cyclones (equivalent to EMR Canmet Proposal)
Scheme 6	Total Beneficiation - (2) + (4)

In view of the unfavourable economic evaluation (particularly resulting from the loss of heating value relative to the degree of beneficiation achieved) no beneficiation plant was included in the eventual C-MJV mine design.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions

3.1.1 Hat Creek Number One Deposit contains a series of coals such that an unacceptable variation in product quality could result.

To meet Draft Boiler Fuel Specifications, A and C Zone coals require a high degree of beneficiation. B Zone coals require some beneficiation. The bulk of D Zone coal would be better than Specification.

Thus a prime requirement is Mining Plans to provide acceptable proportions from the zones and comprehensive product blending.

3.1.2 Washability data shows coals are theoretically "very difficult" to clean (i.e. contain a high proportion of middlings) and product yields will thus be comparatively low for a given degree of beneficiation.

3.1.3 Furthermore, the finer size fractions have increasingly "difficult" washability characteristics. Since all cleaning processes have lower efficiencies for finer size fractions, the overall efficiency of any cleaning plant treating all size fractions would be abnormally low.

3.1.4 The low efficiency of available dry cleaning processes makes them unacceptable for "difficult" coals.

3.1.5 Soft clays rather than competent shales form the non-combustible fractions of the raw coals. Thus practical difficulties in washing process ancilliaries are anticipated.

3.1.6 The theoretical and practical difficulties indicate that alternatives to conventional total washing schemes must be fully investigated.

3.1.7 Conventional beneficiation for thermal plant feeds is the preparation of "part washed blended smalls", i.e. washed coarse coal blended with untreated small coal. This method will not be as effective as usual since the finer size fractions have higher ash contents.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

3.1 Conclusions - cont.

3.1.8 The degree of beneficiation which could be achieved by washing coarse coals from A, B and C Zones is currently anticipated to be necessary to achieve boiler fuel specifications and to be cost effective. This is particularly relevant where defined partings are present which are too thin to be segregated in mining.
(This assumes blending with D Zone coals).

3.1.9 Extraction of high ash fines, as an alternative to conventional washing of finer coals, is potentially an effective beneficiation method for dirtier raw coals.

3.1.10 The raw coals have high total moisture contents. Thermal drying would therefore beneficiate in terms of net calorific value and blended product handling characteristics.

3.2 Recommendations

The cost effectiveness of the following schemes should be investigated:

3.2.1 Conventional "part washed blended smalls" using dense medium baths for washing coarse coal.

3.2.2 Baum jigs as an alternate to dense medium baths.

3.2.3 Drying of small coal with extraction of high ash fines prior to blending with coarse coal.
These were investigated separately.

3.2.4 (Added: October 1978) Based on the Draft EMR Canmet Test Report any further evaluation should include costing of a scheme which makes maximum use of wet attrition to liberate high ash clays.

3.2.5 Prior to any proposal for a wet beneficiation process it will be necessary to conduct pilot plant tailings dewatering studies.

SECTION 4

PRINCIPLES OF COAL BENEFICIATION FOR THERMAL GENERATION PLANT

4.1 Background Considerations

It is recognized that wherever possible Thermal Generating Plants are designed to operate on the raw coal without beneficiation. Thus (in para. 47 page 22 of their March 1977 Draft Report No. 9) PD-NCB have not included any cleaning plant proposals, but have concluded: "On balance, it is considered that cleaning is to be avoided if an acceptable boiler design can be produced to burn the untreated, but blended, coal."

Blending does not, of course, change the average quality, only the variance. Beneficiation (or cleaning) is concerned with improving the average quality to a desired value or range of values. (This report is concerned solely with beneficiation, although from data in this report the requirements for blending are emphatically endorsed.)

However, since the coals within this deposit vary considerably, and such inferior coals are inevitably mined in the open-pit envisaged, it was recognized that the need for beneficiation, as well as blending, might occur at least for part of the output for part of the mine life. Thus it must be acknowledged that beneficiation substantially reduces the variance in product quality.

Having accepted the basic thesis from the first paragraph that the boiler should be designed to treat untreated coal, it is noted that most boiler feeds are in fact at least partially beneficiated. The reasons for this are: -

4.1.1 Deterioration in available coal qualities. This usually applies to older plants, it being found economic to beneficiate the coal rather than downrate the generating station or re-furbish the boiler.

4.1.2 Reduction in Boiler Plant Operating Costs. It is believed that a world-wide survey would reveal that a significant proportion of coal-fired thermal generating plants purchase a fuel of lower ash content than the maximum for which they were designed. Operating costs and plant availability are the parameters, and these are frequently determined by the costs of milling high ash material and disposal of the resultant fly ash.

SECTION 4

PRINCIPLES OF COAL BENEFICIATION FOR THERMAL GENERATION PLANT

4.1 Background Considerations - cont.

4.1.2 - cont.

In the overall economic appraisal of Hat Creek, it must be acknowledged that alternative schemes will have to dispose ultimately of the same weight of ash. Only the proportions will vary between the following categories:

a) Mine Waste - Overburden & Major Partings
b) Beneficiation Plant - Discard
c) Beneficiation Plant - Tailings
d) Boiler Plant - Bottom Ash
e) Boiler Plant - Fly Ash

Thus, for example, there is a strong case for simple cleaning to remove coarse shale particles, since these are much easier to dispose of than the equivalent weight of fly ash.

4.1.3 Reduction of Handling and Transport costs. Obviously this is not relevant in the Hat Creek situation, but as a general rule it should be noted that some cleaning is economic for coals which have to be transported more than 100 km, and drying for transport more than 1,000 km.

4.2 Objectives

The objectives in designing a beneficiation scheme as part of a Mine and Thermal Generating Station complex may therefore be stated as:

4.2.1 Reduction of Ash Content (since on a dry basis there is a strict correlation with calorific value, this is virtually synonymous with Increase in Calorific Value) to an acceptable level, both on instantaneous and average basis. Acceptable must be defined in terms both of limiting values and those which give most economic overall operation.

SECTION 4

PRINCIPLES OF COAL BENEFICIATION FOR THERMAL GENERATION PLANT

4.2 Objectives - cont.

4.2.1 - cont.

Beneficiation for Thermal Generation may thus be seen as reduction of ash content to an acceptable compromise level. Generally the scheme will be designed and operated only to remove high ash particulate material, as part of the product. Thus it is an extension of the coal-shale separation process which occurs in the Mining Operation. (For example, the mining system may remove partings greater than say 0.5 metre, but this could still give too high a product ash. The Beneficiation Plant will then be required to remove say the 0.5 metre by 25 mm partings.)

4.2.2 Obtaining the Correct Size Consist Product. Although a -200 mesh product is fed from the mills to the boilers, the station feed is generally of the order of 30 mm x 0. This top size is necessary to give acceptable handleability characteristics. Some "difficult washability" coals which liberate "ash" on crushing give a higher yield for a given quality, but the resultant product may be difficult to feed consistently to the mills/boilers.

4.2.3 Avoidance of Moisture Content Increases. Most coals "as mined" have an acceptable moisture content. it being practicable to design a boiler plant to accept any inherant moisture content. However, wet beneficiation methods increase the surface moisture, in many cases so as to adversely affect the handleability characteristics. Thermal drying to correct this increase is not normally found economic.

Moisture content also affects the nett calorific value of the fuel. Increases in surface moisture for a high inerts content coal are particularly significant.

These objectives have been interpreted relevant to Hat Creek in the Thermal Department's Draft Boiler Fuels Specification. They have been further clarified in subsequent meetings in terms of the following limiting values:

a) Maximum Inerts Content : 50% by weight.

b) Acceptable Quality Range over design life : ± 15% by Calorific Value; see design of blending scheme by C-MJV.

SECTION 4

PRINCIPLES OF COAL BENEFICIATION FOR THERMAL GENERATION PLANT

4.2 Objectives - cont.

4.2.4 Beneficiation to Reduce Sulphur Dioxide Emmissions. This is subject to considerable attention, the U.S. Environmental Protection Agency having set a criterion of 1.2 lb SO_2 per 10^6 BTU. The requirements for Hat Creek, nor indeed Federal, Provincial or other locally applicable standards have not been specified.

It is noted however that to achieve the U.S. E.P.A. criteria would dictate a greater degree of beneficiation of coals generally, and Hat Creek coals in particular, than to meet the previously mentioned objectives.

4.3 Normal Practice

The majority of coal-fired Thermal Generating Stations operate on a feed which can be described as "Part Washed Blended Smalls".

In some cases this is achieved by station blending of lower ash washed coals (maybe from long-haul supplies of specific, e.g. low sulphur, qualities) with untreated coals (usually from a local source).

As a result of due attention to the above objectives and overall economic operations, many mines produce "Part Washed Blended Smalls" as a specified quality. The more easily cleaned coarser coal is washed and proportioned by an ash monitoring system with the untreated finer coal. The proportion of raw coal washed is varied on a periodic or even instantaneous basis in accordance with the raw coal quality. The net effect of this system is to minimize the moisture content increase by beneficiation, and in many cases eliminate the production of washery tailings.

Established dry cleaning processes are not as efficient as wet cleaning processes. Their application has virtually ceased: dust suppression techniques used to meet Health and Safety legislation have resulted in damp raw coals which render them almost totally ineffective.

SECTION 4

PRINCIPLES OF COAL BENEFICIATION FOR THERMAL GENERATION PLANT

4.3 Normal Practice - cont.

Since Hat Creek presents a unique situation in terms of Geological, Mining and Coal Quality criteria, the full range of beneficiation alternatives has been investigated. In this context it should be noted that generally waste is harder than coal resulting in a concentration of "ash" in the coarser, more easily cleaned, size fractions. At Hat Creek the reverse is the case.

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content

Reduction and control of ash content, or cleaning, is the primary operation in coal beneficiation. Unfortunately there is no one process which can clean all size particles of coal. Frequently two cleaning processes are employed, and when preparing difficult coals to tight specifications (e.g. prime coals for export) three or four cleaning processes may be combined to optimise yield.

To provide simpler plants and acceptable operating costs, most of the "Part Washed Blended Smalls" schemes are based on optimised application of a single cleaning process.

(Many terms have been used to describe the accuracy/efficiency of coal cleaning processes. Only one system, the Partition Curve (including use of Ecart Probable), gives a measure of process performance which is independent of coal characteristics. Its use is set out as an introduction to Appendix III. Results are given within this Report in terms of yield, both by Weight % and B.T.U. Recovery %. The most significant derived term is Yield Error = difference between actual and theoretical yields at the stated product ash content).

The processes 1 - 6 listed below are gravimetric cleaning processes. There is a smooth curve relationship between the specific gravity of a particle and its ash content - see columns "S.G. Fraction" and "% Inst. Ash" of any Prediction Table in Appendix III. Thus by setting the operating gravity of the process item (cut-point, or more correctly PD = Partition Density) the required separation between higher and lower ash particles is achieved.

Wet Processes are generally referred to as "washing".

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content - cont.

Process (Size Range which may be cleaned)	Comments
Wet Cleaning (Washing) Processes - Dense Medium	
5.1.1 Dense Medium Bath (500 x 6mm)	Most accurate process available - necessary to achieve acceptable low yield error for high middlings content coals. Is virtually a large scale mechanised form of true float and sink method. All modern forms use a readily recovered magnetite medium suspension. Simple to operate with easy adjustment of cut-point.
5.1.2 Dense Medium Cyclone (40 x 0.5mm)	High accuracy. Uses magnetitemedium as in bath process. Cyclone construction employs centrifugal force to extend gravimetric separation to finer size range. 0.5mm normally finest size treated due to practical limits in recovery of medium. Efficient removal of -0.5mm particles from feed is required.
Wet Cleaning (Washing) Processes - Water Medium	
5.1.3 Water Only Washing Cyclones (40mm x 200 mesh)	Obtains gravimetric separation by interactions between coal and shale particles in special cyclone. (Also known as "autogenous medium" cyclone). Accuracy low: two stages usually required even for easy to wash coals. Smaller size units have higher accuracy but can only accept finer coals - and very large numbers are required. Thus separate circuits are frequently employed for coarser and finer coals.

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content - cont.

5.1.3 - cont.	Developments, particularly by EMR = Canmet, have potential of improved efficiency by recirculation which also liberates "ash" by coal degradation. There are however disadvantages in terms of costs and fine rejects production. Most installated plants are for 0.5mm x 100 mesh coal; for this size range it is the only proven gravimetric process.
5.1.4 Baum Jig (150 x 0.5mm)	Most widely employed process. Obtains gravimetric separation by interactions between coal and shale particles in water suspension in a "jig" bed. Accuracy lower than Dense Medium methods to the extent that yield error is significant when treating high middlings content coals. Does not require removal of -0.5mm particles from feed - these are usually recovered from associated water circuits by cyclones. Requires skilled operator attention. Large capacity units available.
5.1.5 Concentrating Tables (10mm x 0.25mm)	Utilizes hindered settling and stratification phenomena on water dressed riffled vibrating table to obtain a separation equivalent to gravimetric. Shape factors of coal and discard particles affect performance considerably such that tables are widely used in Eastern U.S.A. Considerable skilled operator attention required. Low unit capacity. Lower consumption of water and power than other washing processes.

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content - cont.

Dry Cleaning Processes

5.1.6 Dry Cleaning (Air Jigs) (50 x 2mm)	Still in development. Accuracy low but has advantage of not wetting coal, and may therefore be acceptable for thermal coal scalping. Problems with damp raw coal feeds. Skilled operator attention essential.
5.1.7 Dry Cleaning (Air Tables) (50 x 6mm)	Low accuracy. Virtually impossible to operate on damp feeds. Requires pre-screening of raw coal into say 50 x 25, 25 x 12, 12 x 6mm size fractions. Small unit capacity: thus plants are very complex. No new plants installed since 1950s.

Miscellaneous Processes

The processes 8 - 11 listed below are classification processes dependent primarily on the relative hardness of the coal and shale materials. Some beneficiation may therefore be achieved if the shale material is significantly concentrated in certain size fractions.

5.1.8 Fines Extraction (Dedusting)	Generally employed as means of removing dry, say 50% of -0.5mm fines from feed to Baum Jig or Dense Medium Cyclone plant to reduce load on associated water clarification and tailings disposal facilities. Warmed air assists operation on damp feed. Low ash fines may be blended with washed coals, high ash fines discarded.

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content - cont.

Miscellaneous Processes - cont.

5.1.9 Fines Extraction (Desliming)

In a water-borne system, fines may be extracted and/or recovered using classifying cyclones. This method is highly efficient, e.g. 90% extraction of -100 mesh material from 28 mesh x 0 could be achieved. Resulting tailings problems no less than for washing processes.

5.1.10 Fines Extraction (Screening)

Dry screening is generally limited to 12mm, or 6mm if heated or other special decks are used, due to the dampness of "as mined" coals. (This dampness results from coal bed surface moisture, wet mining conditions and often from dust suppression requirements).

Wet screening may be used at high efficiency to 2mm using conventional screens, and to 0.25mm using Sieve Bends. Underflow volumes would be large and require combined recovery using classifying cyclones; again the resultant tailings problems no less than for washing processes.

5.1.11 Differential Crushing

Where the coal is significantly harder than the associated shale, or vice versa, the potential of Fines Extraction - Dedusting or Screening - may be increased. For example: by tumbling a coal associated with a soft shale in a drum with water prior to wet screening.

The Bradford Breaker is used to reject hard shale whilst simultaneously breaking softer coal below say 200mm to 50mm. At Centralia it is uniquely used since some wet sticky clays agglomerate and pass out as Breaker rejects at 150mm. The Siebra Crusher is similarly used in Germany.

SECTION 5

COAL BENEFICIATION PROCESSES

5.1 Reduction of Ash Content - cont.

The processes 12 and 13 are true cleaning methods dependent on the difference in surface properties of coal and shale materials. Basically shale is "hydrophilic" and coal "hydrophobic". The reverse applies to their affinity for certain oils.

5.1.12 Froth Flotation (28 Mesh x 0)	Coal, lightly coated with "flotation oils" readily attaches to small air bubbles using conventional flotation cells. Lower rank bituminous coals require heavy quantities of oil. Sub-bituminous coals are not commercially cleaned by flotation.
5.1.13 Oil Agglomeration (28 Mesh x 0)	Coal particles from a slurry are "pelletised" by agglomeration, under controlled agitation conditions, by use of a "bridging-oil". Still at Research/Pilot Plant Scale: encouraging results have been obtained with low ash low rank coals.

5.2 Reduction of Sulphur Content

This may be achieved by washing processes simultaneously with reduction of ash content dependent on the distribution of sulphur within the specific gravity fractions.

5.3 Reduction of Moisture

Reduction of moisture normally follows wet washing processes. For the purpose of this survey it is assumed that all such plants contain efficient modern dewatering screens. Thus +25mm cleaned coal would contain a surface moisture of the order of 2.0% by weight above the raw coal moisture. On crushing to say a 25mm x 0 product size, this product fraction would appear dryer than the raw coal.

The retained surface moisture increases almost exponentially as particle size decreases below 12mm. Available dewatering/drying equipment is:-

SECTION 5

COAL BENEFICIATION PROCESSES

5.3 Reduction of Moisture - cont.

5.3.1 Vibrating Basket Centrifuge (25mm x 0.5mm)	Perforated Basket (wedge-wire) continuous "spin dryer". Widely used for clean coal and discard dewatering following dewatering screens.
5.3.2 Screen Bowl Centrifuge (28M x 200M)	A continuous centrifugal bowl dryer with a screen-basket section. Used for Froth Concentrates with low -100 mesh content and Water Only Washing Cyclone Products.
5.3.3 Solid Bowl Centrifuge (28M x 0)	Similar to above, but solid bowl only. Mainly used for Tailings. To retain -200 mesh material is dependent on flocculated state of feed.
5.3.4 Vacuum Filter (28M x 0)	Widely used for Froth Concentrates, special high capacity disc filter versions having been designed for the coal industry. Also gives satisfactory performance on flocculated uncleaned coal below 25% ash content. Performance deteriorates rapidly as 28 x 65 mesh size fraction content decreases.
5.3.5 Pressure Filter (Filter Press) (28M x 0)	Recognised as the only fully developed equipment for Tailings and high ash Flocculated Coal slurries. High capital and operating labour costs frequently reported, but considerable degree of automation now available. Batch process. Is used for material as fine as 200 mesh x 0. Originally developed in the Clay Industry.

SECTION 5

COAL BENEFICIATION PROCESSES

5.3 Reduction of Moisture - cont.

Mechanical Dewatering by an appropriate selection of the above processes would preceed any Thermal Drying to give acceptable thermal efficiency.

5.3.6 Fluidised Bed Dryer (25mm x 0)

Most widely used dryer for coal.

Problems if 28 mesh x 0 content exceeds 40%. Removes only bulk of surface moisture: fines content of product may still have significant moisture content.

5.3.7 Flash Dryer (usually 1mm x 0)

Low unit capacity.
Can remove about 50% of inherant moisture in addition to surface moisture. Product recovered by dry cyclones from high temperature air stream: may be difficult to achieve safe operating conditions for high volatile coals.

5.3.8 Roto-Louvre Dryer

Can remove about 50% of inherant moisture in addition to surface moisture. Being successfully applied to low rank coals.

High capital cost per unit capacity.

5.4 Definition of Capability

Most of the criteria used to evaluate and compare beneficiation processes have been developed for schemes preparing coals to meet stringent quality specifications for metallurgical and/or export markets. Less detailed consideration is normally required for thermal coals for local consumption which normally require only simple plants "scalping out" the readily removed high ash material. The difficult Hat Creek coals were found to require consideration of complex process schemes such as are conventionally used in metallurgical coal operations.

In presenting these schemes for comprehension in the context of Hat Creek complex, two terms became common parlance during these studies and are defined:-

SECTION 5

COAL BENEFICIATION PROCESSES

5.4 Definition of Capability - cont.

(a) Btu (or Heating Value) Yield =

$$\% \text{ by weight yield of cleaning process} \times \frac{\text{Calorific Value of Cleaned Coal}}{\text{Calorific Value of Raw Coal}}$$

For example, if the % Btu Yield is 94%, then 6.38% more coal would have to be mined to provide the same total heat input to the generating plant.

(b) Degree of Beneficiation =

$$\frac{\text{lb ash per } 10^6 \text{ Btu in Raw Coal}}{\text{lb ash per } 10^6 \text{ Btu in Cleaned Coal}}, \text{ or}$$

$$= \frac{\% \text{ Ash Content of Raw Coal}}{\% \text{ Ash Content of Cleaned Coal}} \times \frac{\text{Calorific Value of Cleaned Coal}}{\text{Calorific Value of Raw Coal}}$$

By using these factors, it is possible to compare the extent to which various coals may be theoretically beneficiated, and the extent to which alternative process schemes give less favourable results as a result of misplaced material in a practical plant.

SECTION 6

BENEFICIATION OF HAT CREEK COALS BY DRY CLEANING

The method by which cleaning process performance has been predicted is described in Appendix III, which also contains the computer predictions. For the Dry Cleaning Processes these predictions should be regarded as only a reasonable indication, since these processes went out of general use before the development of modern prediction techniques. Thus duly verified efficiency factors are not available.

The problems of Dry Cleaning are summarized in paragraphs 5.1.5 and 5.1.6.

Units would be of obsolete design (Air Tables) or new development (Air Jigs). Hence proved unit designs have capacities of the order of 50 TPH. Application at Hat Creek would require many machines with very complex raw coal and product handling facilities.

Figures 2 & 3 summarize the cleaning process predictions for the 2" x ¼" raw coals. It can be seen that the "yield error" when using Dry Cleaning would be very high. It should be noted that dry cleaning has only been applied for rough scalping of heavy dirt from otherwise comparatively clean, easy to clean coal. Thus practical experience has been in respect only of high gravity cut-points of say 1.7 s.g. or greater.

Under these conditions it can be seen that the % BTU Yield is as low as 90% with the achievement of only a small degree of beneficiation.

Table 6.1 Degree of Beneficiation for +6mm Raw Coals at 90% BTU Yield by Dry Cleaning.

Sample	Raw Coal Ash Content	Clean Coal Ash Content	Degree of Beneficiation
	(All Values Dry Basis)		
A	44.7	34.3	1.62
B	29.2	24.2	1.31
C	23.7	17.1	1.53
X & Y	39.0	28.9	1.63
Z	27.3	25.1	1.13

It can thus be concluded (particularly by comparison with the wet washing processes) that Dry Cleaning offers too low an efficiency to be acceptable for the Hat Creek Coals.

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

By far the largest portion of Appendix III is concerned with the detailed predictions of performance of the alternative washing processes. To keep this work to a reasonable level, the size ranges used for each of the several processes were selected to provide the basis of design for anticipated plant schemes. Because of this, direct comparison is not available between say Baum Jigs and Water Only Washing Cyclones.

As a "rule of thumb" it should be noted that there are two basic groups of gravimetric separation processes: Dense Medium and Water Medium. Differences in accuracy between alternative water medium processes for a specific size range are relatively small and depend on such factors as plant loading rate. A basic process selection having been made between Dense Medium or Water Medium Processes, the final selection would frequently be on the basis of practical plant operational and/or cost factors which are related to the particular plant duty.

7.1 Coarse (+6mm) Raw Coals

The predictions have only been separately determined for two processes:

Dense Medium Bath
Baum Jigs

It is noted that Dense Medium Cyclones may also be used for say 40 x 6mm (simultaneously with say the 6mm x 0.5mm size fraction). The efficiency would be similar to that for the Dense Medium Bath, but the plant is more complex in operation.

From the predictions for Baum Jigs it may be noted that the jig washes each size of coal at a different cut point. Thus, for example, on a given setting the cut point for 50 x 25mm may be 1.50, for 25 x 13mm : 1.55, for 13 x 6mm : 1.60, for 6mm x 28 mesh : 1.70.

The combined results are given in Figs. 2 and 3. It will be noted that the Dense Medium Bath gives yields not substantially below theoretical, whereas for the Baum Jig the "yield error" becomes significant. This is even more apparent when comparing the degree of beneficiation for a given BTU yield.

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.1 Coarse (+6mm) Raw Coals - cont.

Since the coarse coal washing would need to be efficient to offset the lower efficiency of any fine coal processing, the table below compares results at 95% BTU yield.

Table 7.1 Degree of Beneficiation for +6mm Raw Coals at 95% BTU Yield by Washing (All Values on Dry Basis)

Sample	Raw Coal Ash Content	Clean Coal Theoretical		Dense Medium		Baum Jig	
		%Ash	D of B*	%Ash	D of B*	%Ash	D of B*
A	44.7	29.7	2.40	31.0	1.91	35.0	1.57
B	29.2	23.0	1.41	23.6	1.36	24.3	1.30
C	23.7	15.8	1.69	16.3	1.62	17.4	1.50
X & Y	39.0	24.2	2.11	25.2	1.99	27.8	1.73
Z	27.3	23.2	1.26	23.6	1.23	24.6	1.16

7.1.1 It can firstly be concluded that the washing of Hat Creek Coals is a comparatively unrewarding operation. (Typical figures for an easy raw coal would be: Raw Coal 25% ash, Theoretical Clean Coal 7% ash, Dense Medium Product 7.5% ash, Jig product 9.0% ash).

7.1.2 Secondly, the advantages of cleaning are greater for the dirtier coals. (This effect is even more marked if the degree of beneficiation is expressed in say lb. fly ash per 10^6 BTU).

7.1.3 Thirdly, the case for the Dense Medium Bath as compared with the Baum Jig is strong. The cost effectiveness of the cheaper Baum process may yet need evaluation - e.g. it may be economic to achieve a given degree of beneficiation by washing a somewhat greater tonnage of coal by a cheaper method.

* D of B = Degree of Beneficiation

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.2 Small (6mm x 28 Mesh) Raw Coals

The predictions have been separately calculated for two processes:

Dense Medium Cyclones
Baum Jigs

Note that it was explained in para. 7.1 that these processes could also wash coarser sizes. In the case of the Baum Jig the 6mm x 28 mesh material must be washed with coarse coal; only the predictions are a separate exercise.

The results are given in Figs. 4 and 5. As for the coarser coals, the dense medium process gives results which are much closer to theoretical. The "yield error" for both processes is now significant due to lower efficiences at finer sizes. (This is one reason why thermal schemes produce "part-washed blended smalls", e.g. +6mm washed blended with -6mm untreated).

The table below compares the results at 90% BTU Yield for example:

Table 7.2 Degree of Beneficiation for 6mm x 28 Mesh Raw Coals at 90% BTU Yield by Washing (All Values on Dry Basis)

Sample	Raw Coal Ash Content	Clean Coal Theoretical		Clean Coal Dense Medium		Clean Coal Baum Jig	
		%Ash	D of B	%Ash	D of B	%Ash	D of B
A	51.8	35.6	2.13	38.6	1.85	43.0	1.51
B	37.9	28.3	1.60	29.1	1.54	31.2	1.38
C	29.5	15.8	2.31	17.2	2.08	20.4	1.68
X & Y	37.9	21.6	2.34	22.2	2.25	27.0	1.72
Z	28.8	20.7	1.59	21.3	1.53	24.5	1.26

7.2.1 It is concluded that the degree of beneficiation which can be achieved by washing the dirtier smaller coals is in fact greater than for the coarser coals.

7.2.2 Loss of yield would however be substantial, and high associated costs are involved (e.g. tailings disposal). The cost effectiveness as compared with coarse coal washing would require thorough investigation, even if practical reservations (see paragraphs 10.2.6 and 10.4) are removed.

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.3 Water Only Washing Cyclones

Water Only Washing Cyclones are available in a range of sizes, the larger units being able to accept coarser raw coal feeds (up to 50mm) but have lower efficiences. Unit efficiencies are also comparatively low requiring two stage processing.

Water Cyclones may therefore provide a total washing scheme by a variety of combinations of large cyclones (for coarser coals) and small cyclones (for fines, e.g. 28 mesh x 100 mesh for which no other gravimetric washing process is available). However their major applications to date have been in conjunction with processes detailed above.

The predictions have therefore been made for two stage water only cyclone systems:

a) 14" cyclones washing 6mm x 100 mesh coal

b) 24" cyclones washing 50mm x 28 mesh coal

c) 10" cyclones washing 28 mesh x 100 mesh coal

These results are summarized on Figs. 6 - 11. It is immediately obvious that the "yield error" for washing fine coals of the difficult characteristics of Hat Creek is very high. For example, we can only usefully aim for 80% BTU recovery when washing the 6mm x 100 mesh coal: Table 7.3.

Table 7.3 Degree of Beneficiation for 6mm x 100 Mesh Raw Coal at 80% BTU Yield (All values on Dry Basis)

Sample	Raw Coal Ash Content	Clean Coal Ash Contents 14" W.O. Cyclone	
		% Ash	D of B
A	55.0	42.8	1.78
B	39.7	31.5	1.48
C	31.4	22.3	1.64
X+Y (6mm x 28mesh)	37.9	24.7	1.95
Z	28.8	23.4	1.35

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.3 Water Only Washing Cyclones - cont.

Table 7.3 - cont.

It should be noted that this low degree of beneficiation has been computed for A, B & C Samples on the basis of straight interpretation of the conventional washability data. No attempt has been made to modify the data to take account of coal liberation by attrition within the process, and these results may therefore be pessimistic.

The 1977 Washability Testwork incorporates attrition testing, and when available can be expected to give more realistic performance predictions.

7.4 Total Washing Schemes

Since the size ranges which can be treated in the various processes overlap, there are many possible process configurations which provide a total washing scheme. Four of these are summarized on Fig. 12.

At many mines the -0.5mm material (28 mesh is approximately 0.6mm) can be flocculated, dewatered and put into the final product. The fines at Hat Creek are too high in ash for this approach; in fact extraction of these fines is a form of beneficiation. However there is a useful coal content and we have therefore included water only cyclones for 28 mesh x 100 mesh coal recovery at this stage in all of the schemes.

The 100 mesh x 0 material would be discarded - to attempt to dewater these fines and incorporate in the product (say from the cleaner coal zones) would give severe product moisture and handleability problems.

7.4.1 Dense Medium Washing is clearly the most efficient scheme as could be expected from the individual size range predictions, and might be considered a base case. However practical difficulties have already been revealed in using Dense Medium Cyclones on Hat Creek Coals (see paragraph 10.2.2).

Scheme A below - considered impractical for above mentioned technical reasons.

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.4 Total Washing Schemes - cont.

7.4.2 Baum jig washing is by far the most widely employed process for total washing Thermal Plant Coals. When treating "easy" to "moderately difficult" coals to such specifications is acceptable in the total financial evaluation.

An updated form of the jig, the Batac jig, shows some cleaning down to 100 mesh: for the purpose of this evaluation it may be assumed that the Batac jig is equivalent to conventional Baum jig supplemented by water only washing cyclones. (This would have to be further investigated if total washing by jigs were the favoured coal beneficiation scheme).
Scheme B below.

7.4.3 Dense Medium Bath (for coarse coal) + Water Only Cyclones (for fine coal) gives product quality yields closely comparable with the Baum jig. It is considered that this alternative, for which a preliminary scheme has already been costed (Modular Coal Washery Report submitted October 14, 1977), may offer practical advantages over the Baum jig for Hat Creek coals (see paragraphs 10.2.7 and 10.2.8). Scheme C below. Scheme 1 of Final Report (see Table 2)

7.4.4 Water Only Cyclones, on the basis of this preliminary evaluation do not show acceptably high yields for a useful degree of beneficiation. Scheme D below, Scheme 5 of Final Report (see Table 2)

Table 7.4 below summarizes the benefits of total washing on a weight % yield basis. It can be seen that conclusion 7.1.1 applies also to total washing of Hat Creek Coals - i.e. the benefits of washing are comparatively low.

SECTION 7

BENEFICIATION OF HAT CREEK COALS BY WASHING

7.4 Total Washing Schemes - cont.

Table 7.4 Degrees of Beneficiation by Total Washing (All values Dry Basis)

Sample	Raw Coal Ash Content	Yield Wt %	Clean Coal (Schemes) A %Ash	A DofB	B %Ash	B DofB	C %Ash	C DofB	D %Ash	D DofB
A	51.2	55	33.3	2.31	36.0	2.03	36.0	2.03	37.4	1.90
B	36.3	65	24.9	1.79	25.6	1.72	26.6	1.63	27.5	1.55
C	29.1	75	18.5	1.86	19.9	1.70	20.7	1.61	21.2	1.56
X+Y	43.4	55	21.2	3.09	23.4	2.66	22.6	2.84	23.2	2.74
Z	27.7	75	20.6	1.51	23.2	1.29	22.6	1.33	21.3	1.44

It must be noted that these calculations are on the basis of washability data which does not allow for "dilution" of the coal in mining. Thus it is necessary to note that the actual degree of beneficiation will be somewhat greater on average. The results above however represent the norm. The significant dilution will occur when mining adjacent to a major parting, giving massive instantaneous dilution which must be separately considered as a special case.

Relating these total washing results to the Draft Boiler Fuels Specifications it can be generally concluded that:

7.4.5 Only A and C Zone coals would require total washing to meet the Fuels Specifications. B Zone coals require some beneficiation, D Zone coals are considerably cleaner than these Fuels Specifications. Thus, if Mining and/or Storage can be planned to give the necessary blending of the Zones, total washing will not be required.

7.4.6 Since significant costs and practical difficulties are envisaged if Total Washing is employed, and the degree of beneficiation (related to BTU yields) is low, it would not be prudent to accept the alternative of Total Washing to obtain a better quality than called for in the Draft Specification.

SECTION 8

BENEFICIATION OF HAT CREEK COALS BY PARTIAL WASHING

The widely accepted practice of producing "Part Washed Blended Smalls" for Thermal Generating Plant Fuels has already been outlined (paragraph 4.3).

Since the finer size fractions are dirtier than the coarser size fractions at Hat Creek, the effectiveness of this method is not as great as where the high ash material is competent shale which concentrates in the coarser size fractions. This is illustrated by an example for coals of the same washability characteristics:-

(a) Hat Creek (Sample A Coal, 51% Raw Coal Ash Content)
Coarser Raw Coal, 50% by weight at 45% ash.

Yield on washing = 0.66 x 50% at 29% ash.
Blend with Finer Untreated Coal, 50% by weight at 57% ash.

Part Washed Blended Smalls = 83.0% yield at 45.9% ash.
(BTU yield =95.2 %).

(b) Equivalent Coal with Hard Shale (51% Raw Coal Ash Content)
Coarser Raw Coal, 50% by weight at 55% ash (= 33.75% at 45% ash + 12.75% at 85% ash).

Yield on washing = 0.66 x 33.75% at 29% ash.
Blend with Finer Untreated Coal = 50% by weight at 47% ash.

Part Washed Blended Smalls = 72.3% yield at 41.5% ash.
(BTU yield =92.2 %).

Fig.14 shows three cases for the A,B and C Samples using the Modular Washery Design:

8.1 Total Washing - Scheme 7.4.3, Dense Medium Bath + Water Only Cyclones. (Scheme 1 of Final Report - see Table 2)

8.2 Partial Washing - as above, but with only 50% of the 6mm x 0 being washed, the remainder being blended in without treatment. Equivalent to Scheme 3 of Final Report - see Table 2)

8.3 Partial Washing - as above, but with only the +6mm coal being washed and blended with the 6mm x 0 untreated fine coal.

It can be seen that the Modular Coal Washery provides the possibility of a wide range of product qualities/degrees of beneficiation from these raw coals. This clearly illustrates the quite different plant requirements for coals from the various zones. (See paragraph 7.4.5).

SECTION 8

BENEFICIATION OF HAT CREEK COALS BY PARTIAL WASHING

These results are a representation of the basic information given on Fig. 1. They have however been calculated using the more sophisticated "Optimise" program (see AppendixIII)and confirm the validity of that graph for quality/yield calculations.

The actual mining results give a coarser raw coal, results equivalent to 8.2 on X, Y and Z samples will leave all 6mm x 0 untreated, results equivalent to 8.3 will leave all 13mm x 0 untreated.

Current estimates of average raw coal quality are of the order of 37.4 % ash (7,300 BTU) dry basis. Thus on average it would be possible to obtain the required degree of beneficiation by washing only the +13mm raw coal. This conclusion must be further evaluated on the basis of year by year and month by month mine plans as these become available. Since the Dense Medium Bath can be used down to 6mm, there is thus a definite possibility that a single process Part Washed Blended Smalls scheme may be acceptable for Hat Creek.

It is noted in section 7.4 that the effect of dilution when mining adjacent to a major parting has to be separately considered as a special case. Also we have to consider the possibility of coal recovery from the inferior coal zones. In both of these cases we may anticipate, by projection of existing washability data, firstly that it will be essential to wash in these situations to recover valuable coarser coal without passing large dirt to the blending system, and secondly that the(-13mm or -6mm)smaller material will be so dirty that it should be rejected. A partial washing scheme would provide these facilities.

It will be noted (see Table 2) that Partial Washing of Hat Creek coals is far less effective than for typical thermal coals with relatively firm shales. In many cases a Degree of Beneficiation of 2 can be achieved at acceptable heating value yields.

SECTION 9

BENEFICIATION OF HAT CREEK COALS BY MISCELLANEOUS PROCESSES

This section is mainly concerned with the beneficiation which may be obtained simply by extracting fines. It has been observed that for the dirtier samples which will require some beneficiation (even for incorporation into a blended product) that the finer "coals" are high in ash - generally above 60% (dry basis).

A review of the prediction calculations in Appendix III relative to the fine coal beneficiation processes shows that the rejects are frequently of a similar order of 60% ash. Thus it is obvious that extraction of fines may be more attractive than fine coal washing, particularly if it can be achieved without producing a wet tailings.

Tables of the calculated results for Fines Extraction are given in Appendix II. These are summarized in the table below, and may be compared, for example, with Table 7.3.

Table 9.1 Potential Beneficiation by Removal of 100% of 28 mesh x 0 Fines from -13mm Raw Coal

Sample	Raw Coal Ash Content (Dry Basis)	After Fines Extraction Ash Content (Dry Basis)	After Fines Extraction Yield, Wt.%
A	53.7	51.1	80.4
B	40.0	36.5	85.1
C	30.3	27.8	75.7
X	53.5	44.1	56.3
Y	50.0	40.4	59.7
Z	31.5	27.5	61.1

9.1 Fines Extraction (Dedusting)

Benefits of this method are dubious due to the likely dampness of the coal. Moreover recent reports show that although say 50% of the -28 mesh fines may be removed, the proportion of -100 mesh and -200 mesh super fines (which are the highest ash materials at Hat Creek) removed are much lower. Thus results would at most be marginal. Its viable application is therefore restricted to reduction of tailings production from any total washing scheme.

SECTION 9

BENEFICIATION OF HAT CREEK COALS BY MISCELLANEOUS PROCESSES

9.2 Fines Extraction (Desliming)

Could be very efficiently achieved by cyclones and/or sieve bends. The tailings disposal problem would be somewhat greater than for beneficiation by water only cyclones, say, of the 28 x 100 mesh material, but the actual "beneficiation" plant very simple.

9.3 Fines Extraction (Screening)

It can be seen from the values in the tables (Appendix II) that there would be a very serious loss of yield by rejection of fines at the sizes where dry screening is applicable would be unacceptable. This method would however be useful when recovering coal from the "low grade" areas not covered by present testwork (as in last paragraph of Section 8).

9.4 Differential Crushing

9.4.1 This would be effective in conjunction with desliming (paragraph 9.2 above) by liberating more fine high ash material, e.g. by tumbling in water in a suitable drum system. (This is confirmed by observations and provisional results of the Wet Attrition Tests). The mode of operation of the E.M.R. Canmet Test Plant makes use of this effect to achieve degrees of beneficiation greater than predicted from the "straight" washability data (see paragraph 7.3).

9.4.2 Observations were made during the 1977 Test Mining programme to see whether clay would "ball up" in the Bradford Breaker as at Centralia. No such effect was observed. In fact the reverse "problem" was encountered - some of the best coal was not amenable to this operation and reported as "rejects".

9.5 Thermal Drying

The tables in Appendix II also illustrate how the calorific value (but not the ash content) of the coal may be improved by thermal drying (bottom line). The real value of this operation alone is questionable since any Dryer's Thermal Efficiency is unlikely to approach the equivalent efficiency in the Boiler Plant Pulverisers. (It must of course be taken into account that the coal moisture content will have to be removed in one and/or the other).

SECTION 9

BENEFICIATION OF HAT CREEK COALS BY MISCELLANEOUS PROCESSES

9.5 Thermal Drying - cont.

Benefits may however accrue in the handling of coal. (It has been established elsewhere that washed coarse coal blended with dried fine coal handles particularly well).

The potential has however been calculated of drying so as to facilitate extraction of fines at a high efficiency. The Appendix II Tables (section a of each) show the final product quality and yields of combining these two methods, i.e. Dense Medium Washing of +13mm and Drying following by fines extraction of -13mm.

This is, as far as can be ascertained, a process combination never previously investigated for any coal. Preliminary discussions between ourselves and Thermal Dryer Manufacturers confirm however that no fundamentally new technology is involved since recovery of say -28 mesh fines portion of the dryer product involves separate equipment.

The overall attraction of this method is that no tailings disposal would be involved - the high ash fine material being extracted dry prior to the Boiler Plant.

It is therefore recommended that this alternate to conventional beneficiation schemes be fully investigated for cost effectiveness.

NOTE: October 1978

Schemes 4 and 6 have been developed based on these concepts (see Table 2). The schemes do not give a good degree of beneficiation for the loss of heating value.

SECTION 10

PRACTICAL CONSIDERATIONS IN SELECTION OF BENEFICIATION PROCESSES

These considerations arise largely from visual observations during the 1976 and 1977 Testwork.

10.1 Raw Coal Handling and Screening

No particular problems were observed in handling the fresh mined coals from the dry conditions in 'A' Trench - (X and Y Samples). The water in 'B' Trench (Z Sample) does give rise to concern as to the likely raw coal moisture content since the bulk of the coal has to be mined from below the existing water table. It is essential that the Mining Engineers give full consideration to this situation.

Thus is was anticipated that 'A' Trench material, whilst damp, would not give screening problems say at 13mm. Problems would exist at finer sizes, necessitating say probability screens or heated deck screens if 6mm separation is required and preclude dry screening at finer sizes.

After a matter of only a few days exposure to atmosphere, the coal fissures open and the coal breaks up. Thus to ensure competent coal through any beneficiation process (and thereby achieve more efficient beneficiation) the feed should pass directly to the coal preparation complex. Any raw coal storage should be on a "by-pass and reclaim" basis.

10.2 Wet Processing

The clays, particularly the bentonitic clays, associated with Hat Creek coals are known to give problems in coal washing processes. It cannot be said that these are insurmountable.

10.2.1 Thus a visit to the Centralia Plant in Washington State was most valuable. There the clays include a "sodium bentonite" which is in fact more rapidly able to absorb moisture than the "calcium bentonite" found at Hat Creek. After some four years, during which extensive modifications have been made, total washing using Baum jigs is now being satisfactorily applied. On the basis of their experience alone, the application of total washing is to be avoided if possible.

Two points emerged which are different in their situation. Firstly, the coal has considerably easier washability characteristics, and thus the degree of beneficiation achieved by total washing is viable.

SECTION 10

PRACTICAL CONSIDERATIONS IN SELECTION OF BENEFICIATION PROCESSES

10.2 Wet Processing - cont.

10.2.1 - cont.

Secondly, the mining is in very wet conditions (both from rainfall and water table) and thus any dry treatment (even pre-screening at coarse sizes) is impossible, and the clay is bound wet rather than breaking into fine powder as in Hat Creek "A" Trench. As stated (paragraph 10.1) above, it is essential that the Mining Engineers confirm that mining in wet conditions will not occur at Hat Creek.

10.2.2 Observations of behaviour in a conventional total washing Pilot Plant (Coal Science and Minerals Testing) were made in 1976. (Notes on visit to Calgary and Vancouver with reference to the Preparation of Hat Creek Coals - J. Howard Griffiths, PD-NCB, 20th June, 1976). This plant consists of D.S.M. Dense Medium Cyclones (20mm x 28 mesh) and Water Only Cyclones (28 x 100 mesh).

The clays associated with the "A" Sample rendered the plant almost non-operational due to contamination of the magnetite medium. These problems were, in our view, compounded by test observers insisting on lumps of clay which could have been manually removed being put through the plant. Subsequent tests on the lower clay content 'B' and 'C' Samples were less troublesome.

However, having discussed these tests with C.S.M.T. personnel, and in the light of our wide background experience(as D.S.M. Licencees), we must recommend against the use of Dense Medium Cyclones. Thus the Total Washing Scheme (paragraph 7.4.1) should be regarded solely as an indication of potential beneficiation.

10.2.3 J. Howard Griffiths, on the basis of these observations of clay behaviour, advised that the Dense Medium Baths which use perforated lifters should be avoided. We agree with this, and suggest either Lee-Bar or Daniels baths be employed with special attention to the cleaning of their extraction scrapers and positioning of drainage ports.

SECTION 10

PRACTICAL CONSIDERATIONS IN SELECTION OF BENEFICIATION PROCESSES

10.2 Wet Processing - cont.

10.2.4 It was also noted during these tests that (after absorption of moisture), some of the clays were between 1.6 and 1.7 s.g. Thus the cut-point in any washing process should not be higher than 1.6. We consider this would not apply to all coal zones, and may not apply to fine coal washing in cyclones. Nevertheless, in arriving at any predicted value of coal yield/quality (e.g. Fig.1), we have not taken credit for any enhanced yield which might be achieved by washing at gravities above 1.6 s.g.

10.2.5 The contamination of the washing liquid (whether magnetite suspension or water) by the clays must not be ignored. In the predictions of washing results we have introduced a factor (F2 = 1.20,1.25 for Baum) to allow for the increased liquor viscosity. The magnetite medium cleaning and recovery circuits and water clarification circuits will have to be designed with greater liquor cleaning capacities than normal.

10.2.6 The Wet Attrition Tests are not yet fully reported, nor evaluated. The visual observations during these tests revealed that after some minutes handling in water, even the remaining coarser lumps of coal were "attacked". It would appear that even the better coals contain thin plates of clay which is "leached out" in wet handling giving a weakened coal structure. Also a very finely divided clay suspension which will be difficult to thicken in tailings plants.

Observations of various clays (U of B.C., Dolmage-Campbell) reveal that breakdown in water takes effect after 5 minutes in many cases.

For this reason our first recommendation on type of washing process is for a short-path Dense Medium Bath in which the coal is only immersed in water for say two minutes.

10.2.7 Consequently we consider that a Baum jig (washing say +13mm coal) may present severe operating problems due to the much longer immersion in water and the attrition between particles which occurs in this process.

SECTION 10

PRACTICAL CONSIDERATIONS IN SELECTION OF BENEFICIATION PROCESSES

10.2 Wet Processing - cont.

10.2.7 - cont.

For reasons already set out (paragraph 7.1.3), further investigation of the cost effectiveness of this process is necessary, but any definite proposal would have to be preceeded by a full-scale plant test-wash.

This "leaching-out" of clay and attrition would result in a greater production of a more difficult tailings than the same coal through a Dense Medium Bath circuit.

10.2.8 Evaluation of Water Only Washing Cyclone plant problems will come with the E.M.R. Pilot Plant Report. From the practical viewpoint we consider that the Water Cyclone will probably handle these clay containing coals with less difficulties than say the Baum jig. Any cyclone operation will, in fact, work with clay materials. Any problems will be in the processing of the tailings which will necessarily be high in quantity from a process which promotes coal/clay liberation by attrition.

10.3 Coal Crushing

Bradford Breakers may not be effective due to losses to rejects of better hard coal. This will be covered in the testwork report.

Difficulties are not expected with Swing Hammer Crushers commonly used to reduce to -20mm of the coarse coal after washing. The advice of crusher manufacturers must be sought regarding crushers for uncleaned coarse coal because of the clay lump content.

10.4 Tailings Disposal

These problems may be severe, particularly from washing processes which "leach out" clays. This will be the subject of a separate report. It is however relevant to note at this stage that the majority of "difficulties" in coal preparation plant operations reported are in the area of fine material flocculation, water clarification and tailings disposal.

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SECTION 11

APPENDIX I

LIST OF FIGURES

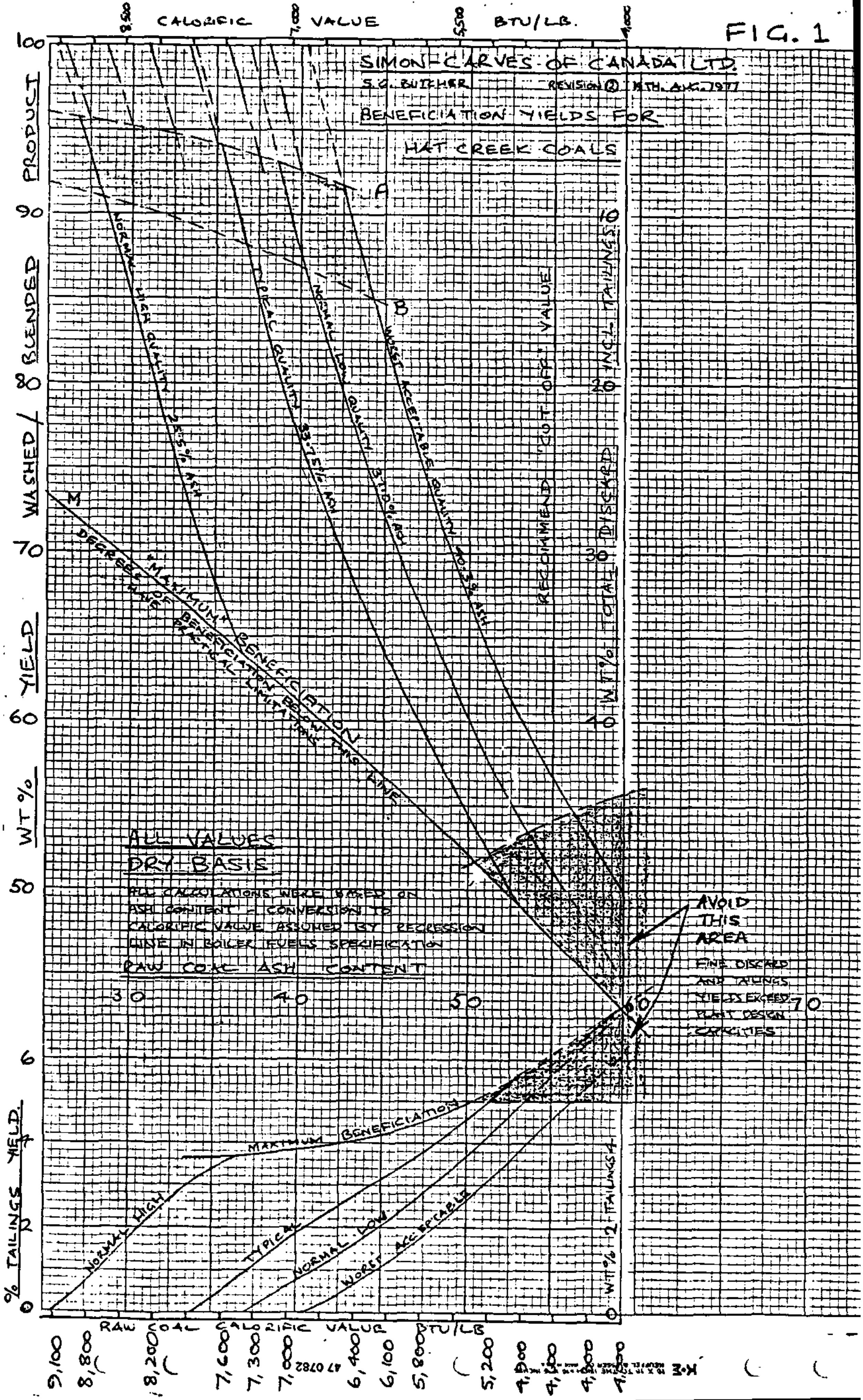

SIMON-CARVES OF CANADA LTD.
S.G. BUTCHER
REVISION ② 18TH. AUG. 1977
BENEFICIATION YIELDS FOR HAT CREEK COALS
CALORIFIC VALUE BTU/LB.
8,500
7,000
5,500
4,000
PRODUCT
WASHED / BLENDED
WT % YIELD
100
90
80
70
60
50
6
4
2
0
A
B
M
NORMAL HIGH QUALITY 25.5% ASH
TYPICAL QUALITY 33.75% ASH
NORMAL LOW QUALITY 37.0% ASH
WORST ACCEPTABLE QUALITY 40.3% ASH
RECOMMEND CUT-OFF VALUE
WT % TOTAL DISCARD INCL. TAILINGS
10
20
30
40
DEGREE OF MAXIMUM BENEFICIATION BEYOND THIS LINE
PRACTICAL LIMITATION
ALL VALUES DRY BASIS
ALL CALCULATIONS WERE BASED ON ASH CONTENT - CONVERSION TO CALORIFIC VALUE ASSUMED BY REGRESSION LINE IN BOILER FUELS SPECIFICATION
RAW COAL ASH CONTENT
30
40
50
60
70
AVOID THIS AREA
FINE DISCARD AND TAILINGS YIELDS EXCEED PLANT DESIGN CAPACITIES
% TAILINGS YIELD
MAXIMUM BENEFICIATION
NORMAL HIGH
TYPICAL
NORMAL LOW
WORST ACCEPTABLE
WT % TAILINGS
RAW COAL CALORIFIC VALUE BTU/LB
9,100
8,800
8,200
7,600
7,300
7,000
6,400
6,100
5,800
5,200
4,900
4,600
4,300
4,000

FIG. 1

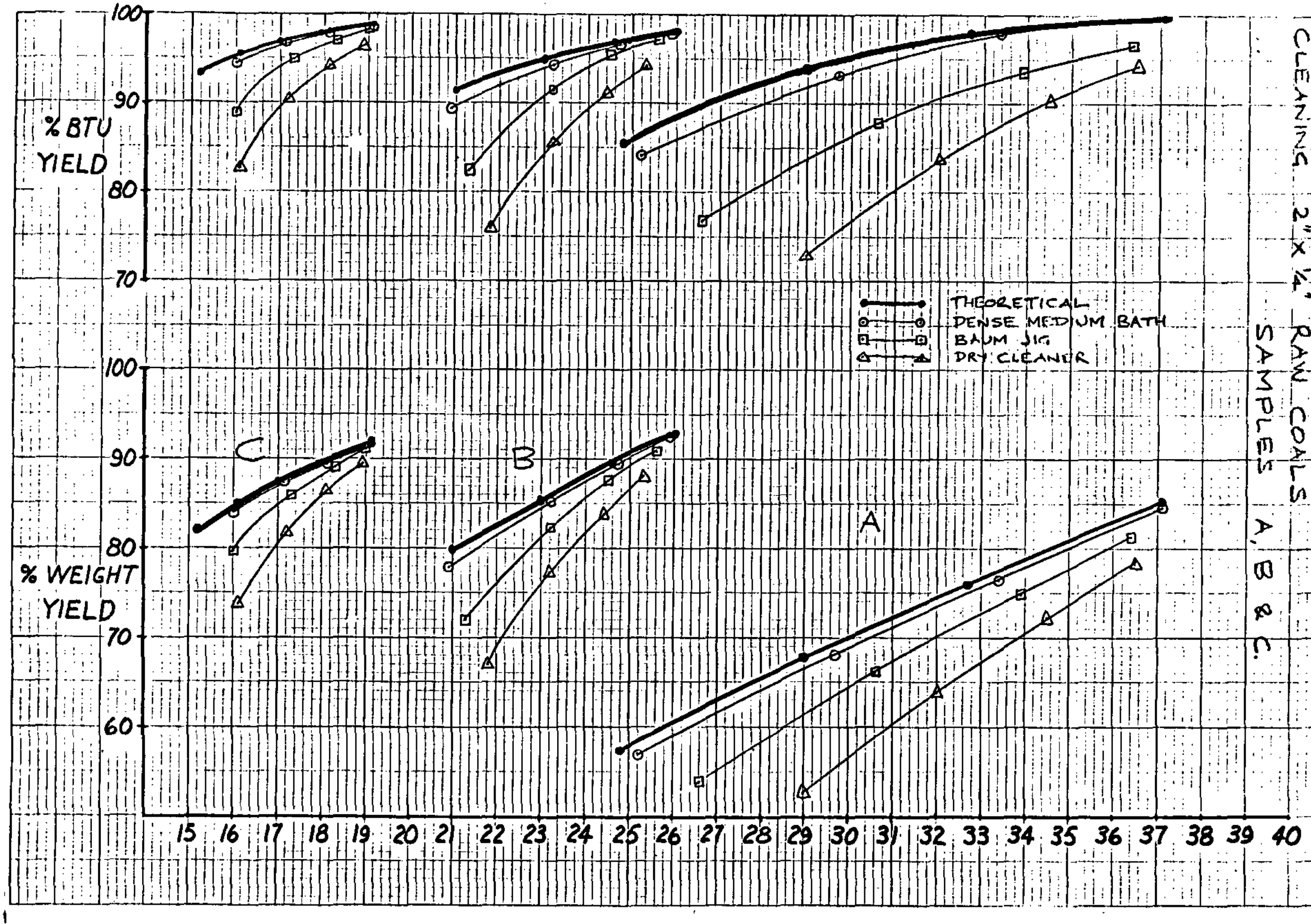

% BTU YIELD
% WEIGHT YIELD
100
90
80
70
60
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
C
B
A
THEORETICAL
DENSE MEDIUM BATH
BAUM JIG
DRY CLEANER
CLEANING 2" x ¼" RAW COALS
SAMPLES A, B & C.

FIG. 2

SIMON-CARVES

F1304 - HAT CREEK
C-MJV for B.C. HYDRO

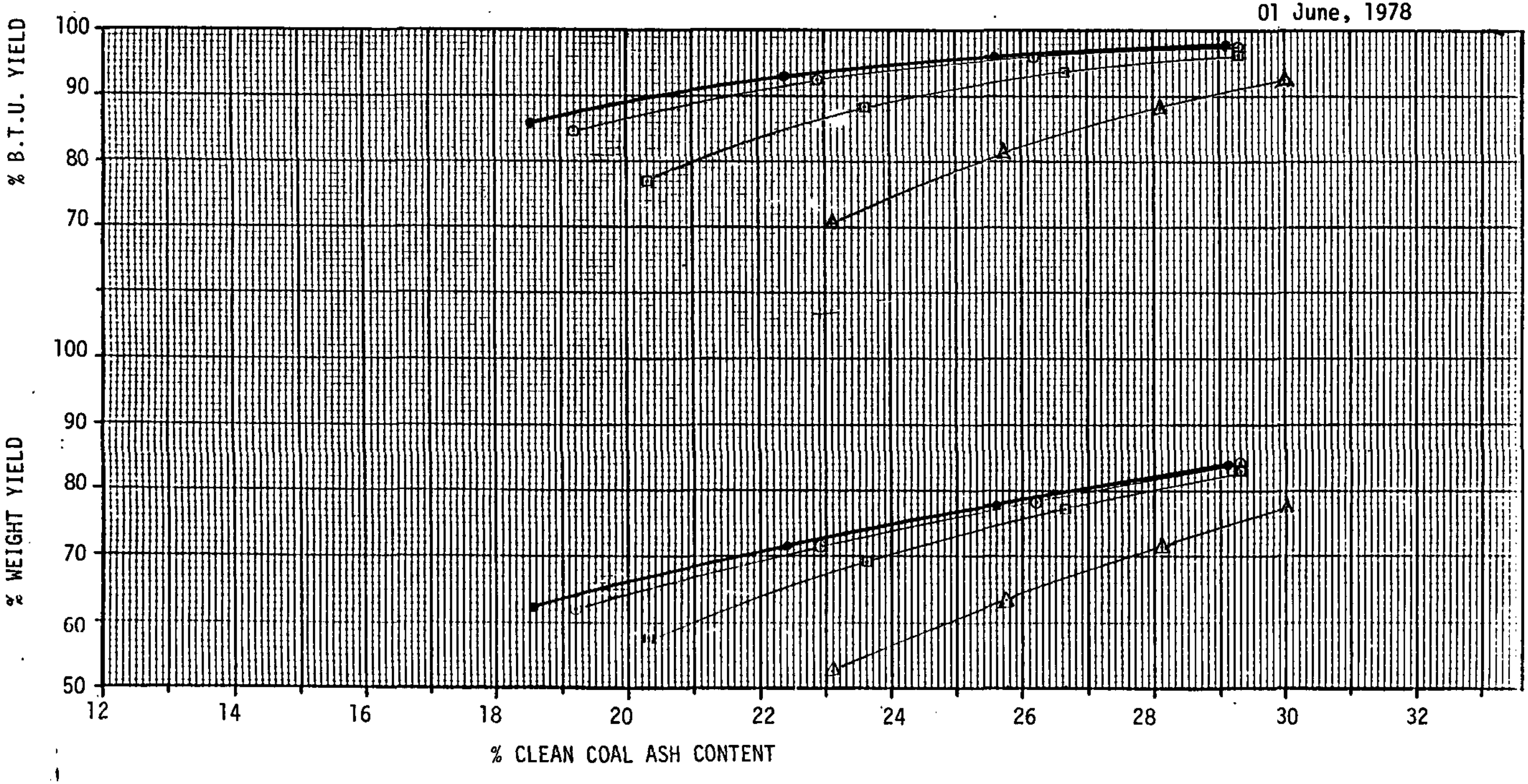
CLEANING 4"x½" RAW COAL
SAMPLES X+Y
Raw Coal Ash Content = 37.25

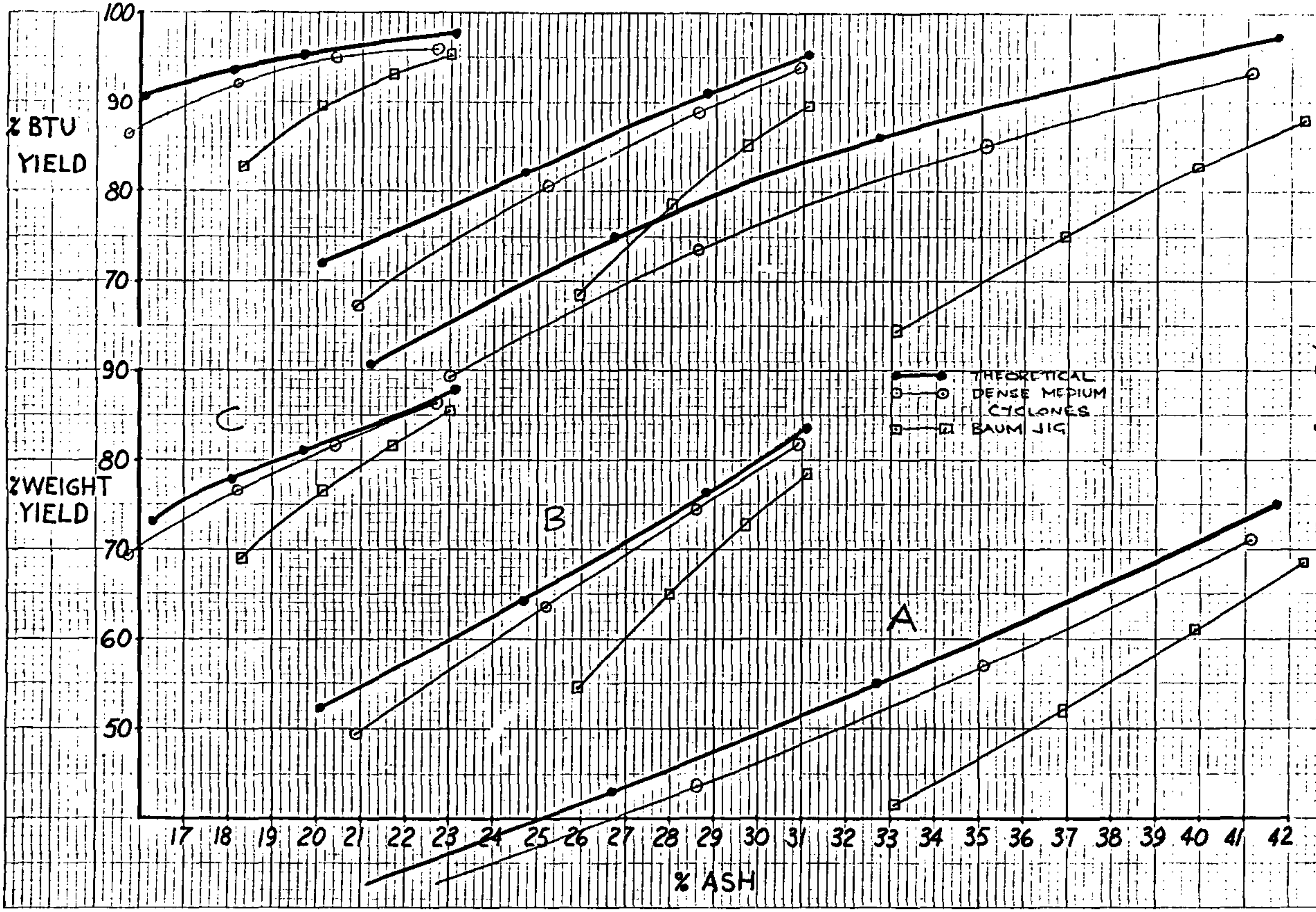
LEGEND

- ● Theoretical
- ⊙ Dense Medium Beth
- ⊡ Baum Jig
- △ Dry Clean

FIG. 3

01 June, 1978





CLEANING 1/4" x 28 M RAW COALS SAMPLES A, B & C

FIG. 4

SIMON-CARVES

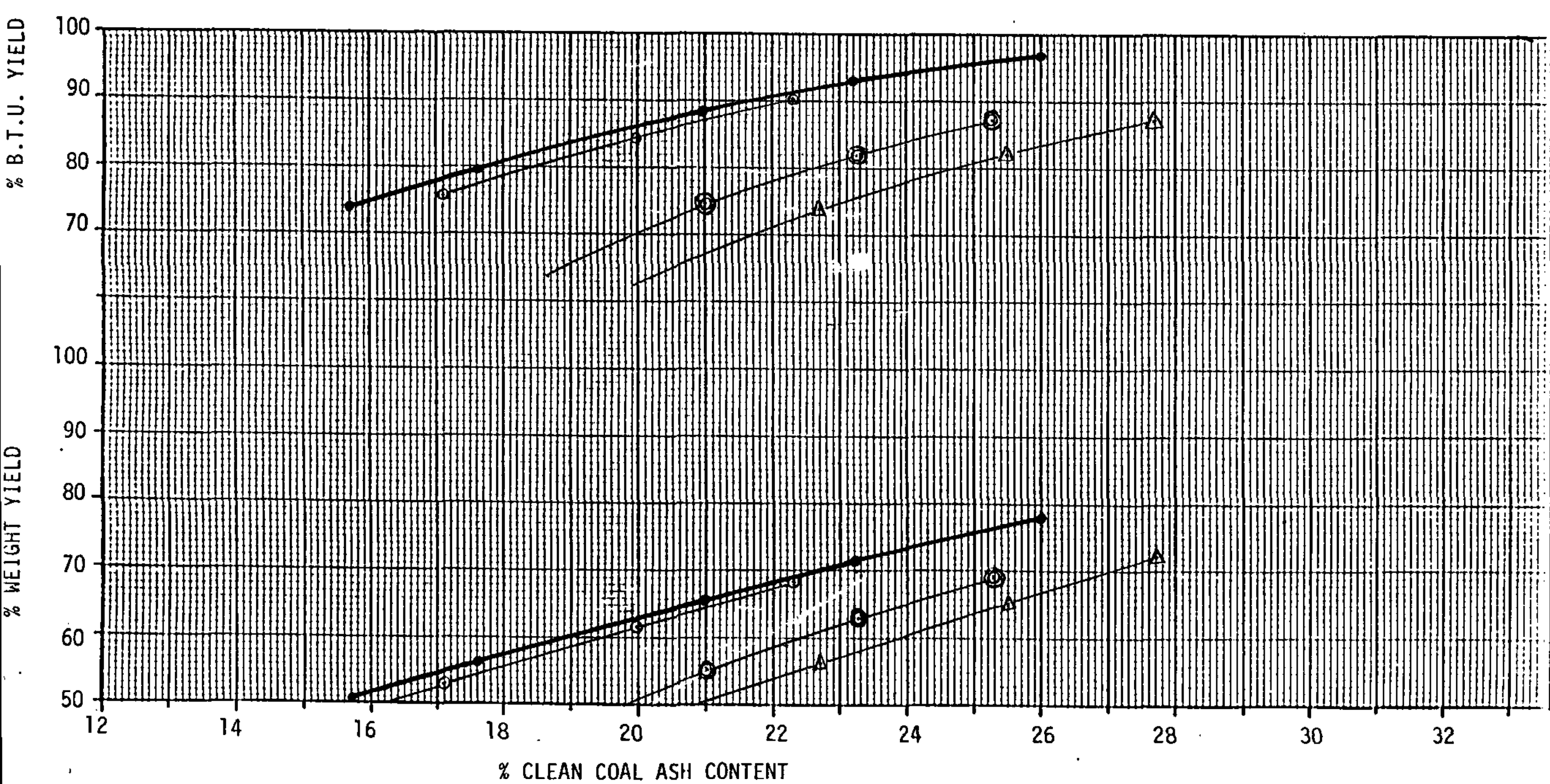
F1304 - HAT CREEK
C-MJV for B.C. Hydro

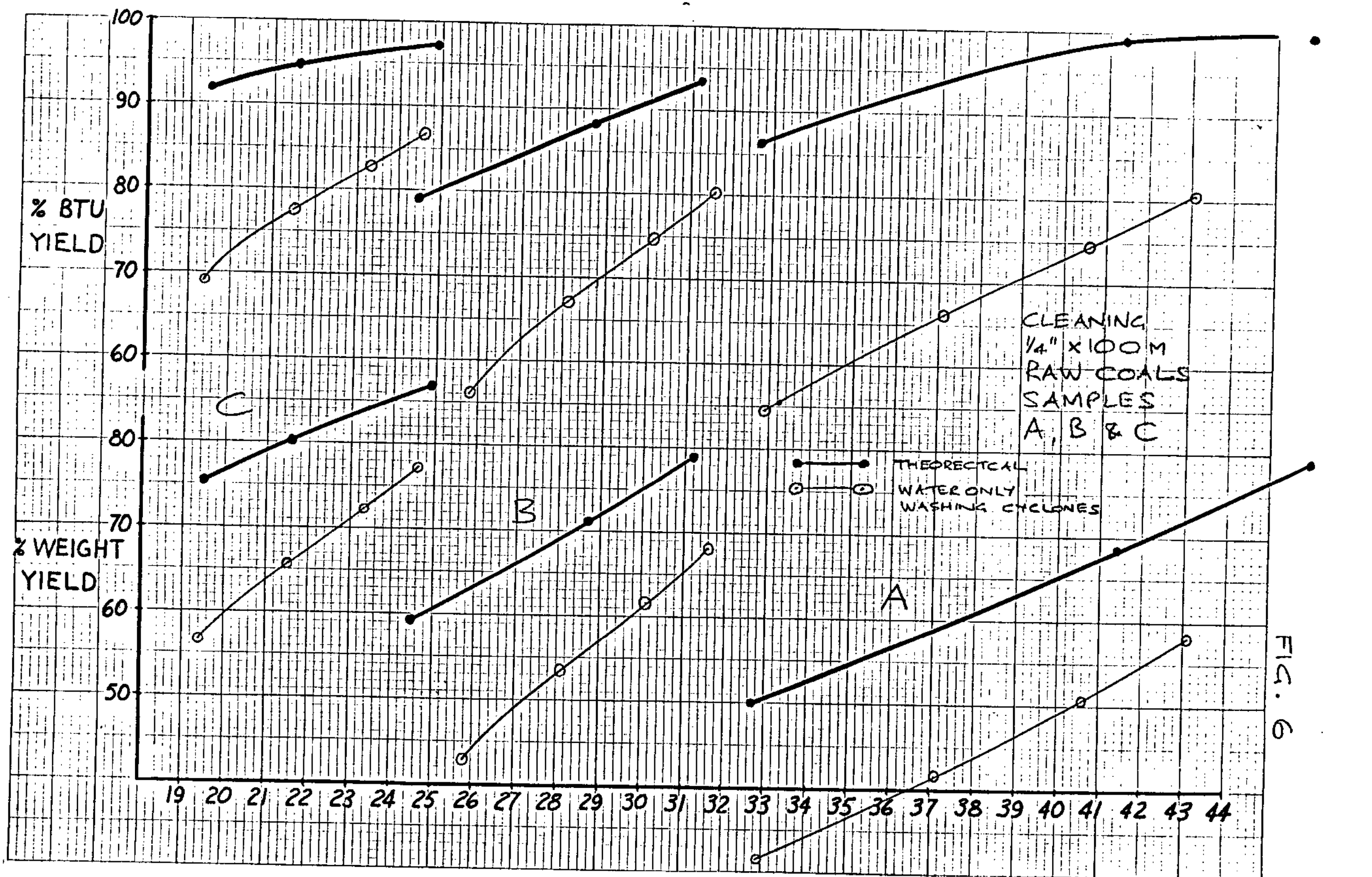
CLEANING ¼" x 28M RAW COAL
Samples X+Y
Raw Coal Ash Content = 37.94

FIG. 5

LEGEND

- Theoretical
- 26" Heavy Medium Cyclone
- Baum Jig
- 14" Water Only Cyclone





100
90
80
70
60
80
70
60
50
% BTU YIELD
% WEIGHT YIELD
19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44
C
B
A
CLEANING
1/4" x 100 M
RAW COALS
SAMPLES
A, B & C
THEORECTCAL
WATER ONLY
WASHING CYCLONES

FIG. 6

SIMON-CARVES

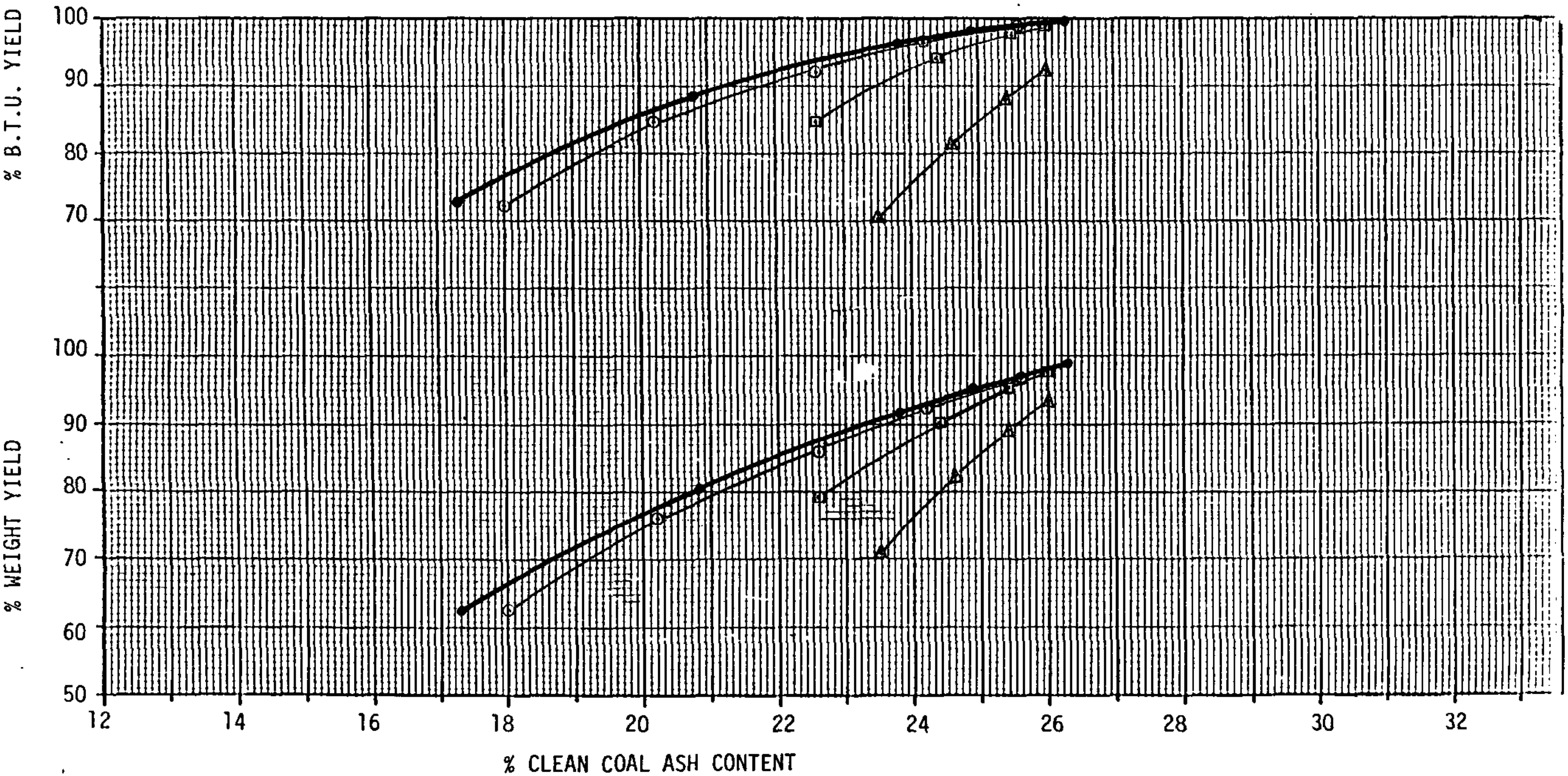
F1304 - HAT CREEK
C-MJV for B.C. Hydro

CLEANING 4" x ½" RAW COALS
SAMPLE Z
Raw Coal Ash Content = 26.96

FIG. 9

LEGEND

- ● Theoretical
- ⊙ Dense Medium Bath
- ⊡ Baum Jig
- △ Dry Clean



SIMON-CARVES

F1304 - HAT CREEK
C-MJV for B.C. Hydro

CLEANING ¼" x 28M RAW COAL
Sample Z
Raw Coal Ash Content = 28.85

FIG. 10

LEGEND

● Theoretical

⊙ 26" Heavy Medium Cyclone

⊡ Baum Jig

△ 14" Water Only Cyclone

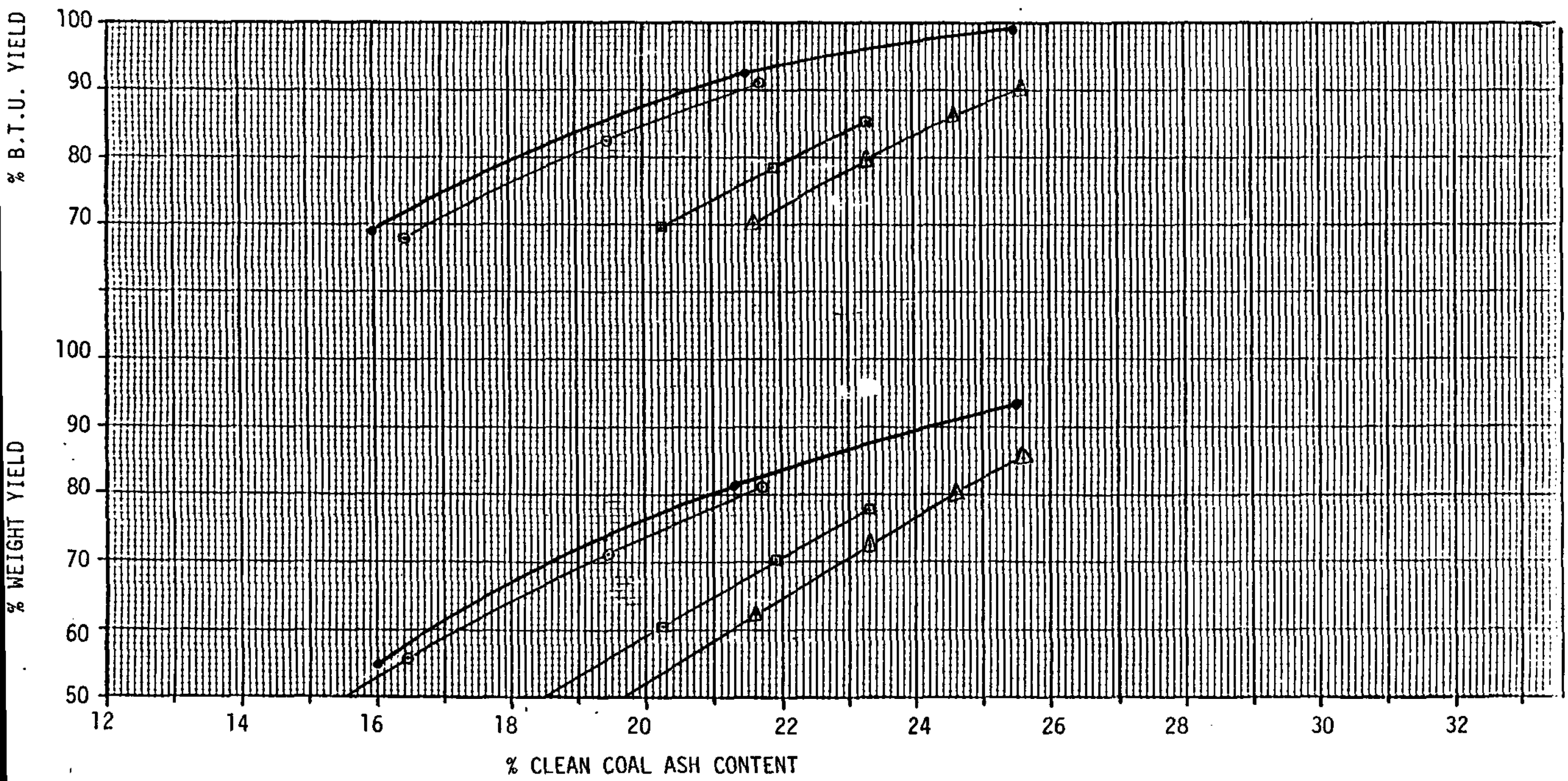


FIG. 11

SIMON-CARVES

F1304 - HAT CREEK
C-MJV for B.C. HYDRO

COMPARISON OF TOTAL WASHING
SCHEMES. SAMPLES X+Y & Z

LEGEND AND TOTAL WASHING SCHEMES DESCRIPTION

SCHEME (1) (●————●)
H/M Bath 4" x ½"
H/M Cyclones ½" x 28M
(Discard 28M x 0)

SCHEME (2) (○————○)
Baum Jig 4" x 28M
(Discard 28M x 0)

SCHEME (3) (□————□)
H/M Bath 4" x ½"
W.O. Cyclones ½" x 28M
(Discard 28M x 0)

SCHEME (4) (△————△)
W.O. Cyclones 2" x 28M
(Discard 28M x 0)

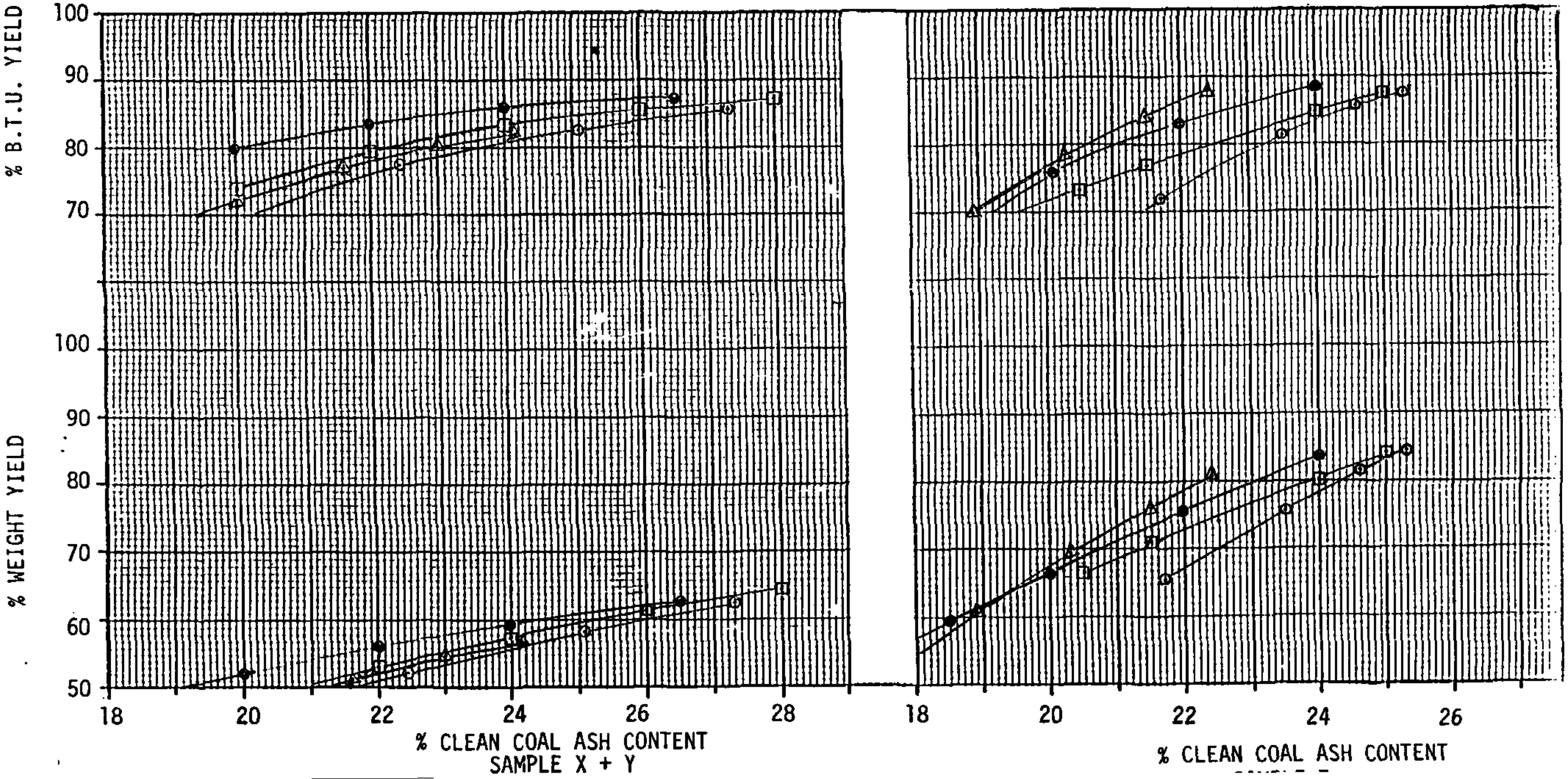


FIG. 12 (revised)

SIMON-CARVES

F1304 - HAT CREEK
C-MJV for B.C. HYDRO

COMPARISON OF TOTAL WASHING SCHEMES
SAMPLES A, B & C.

LEGEND AND TOTAL WASHING SCHEMES DESCRIPTION

SCHEME (1)	SCHEME (2)	SCHEME (3)	SCHEME (4)
+¼" D/M Bath ¼" x 28M - D/M Cyclone 28 x 100M - W/O Cyclone (100M x 0 - Discard)	+28M - Baum Jig 28 x 100M - W/O Cyclone (100M x 0 Discard)	+¼" - D/M Bath ¼" x 100M - W/O Cyclone (100M x 0 - Discard)	2" x 28M - W/O Cyclone 28 x 100M - W/O Cyclone (100M x 0 - Discard)

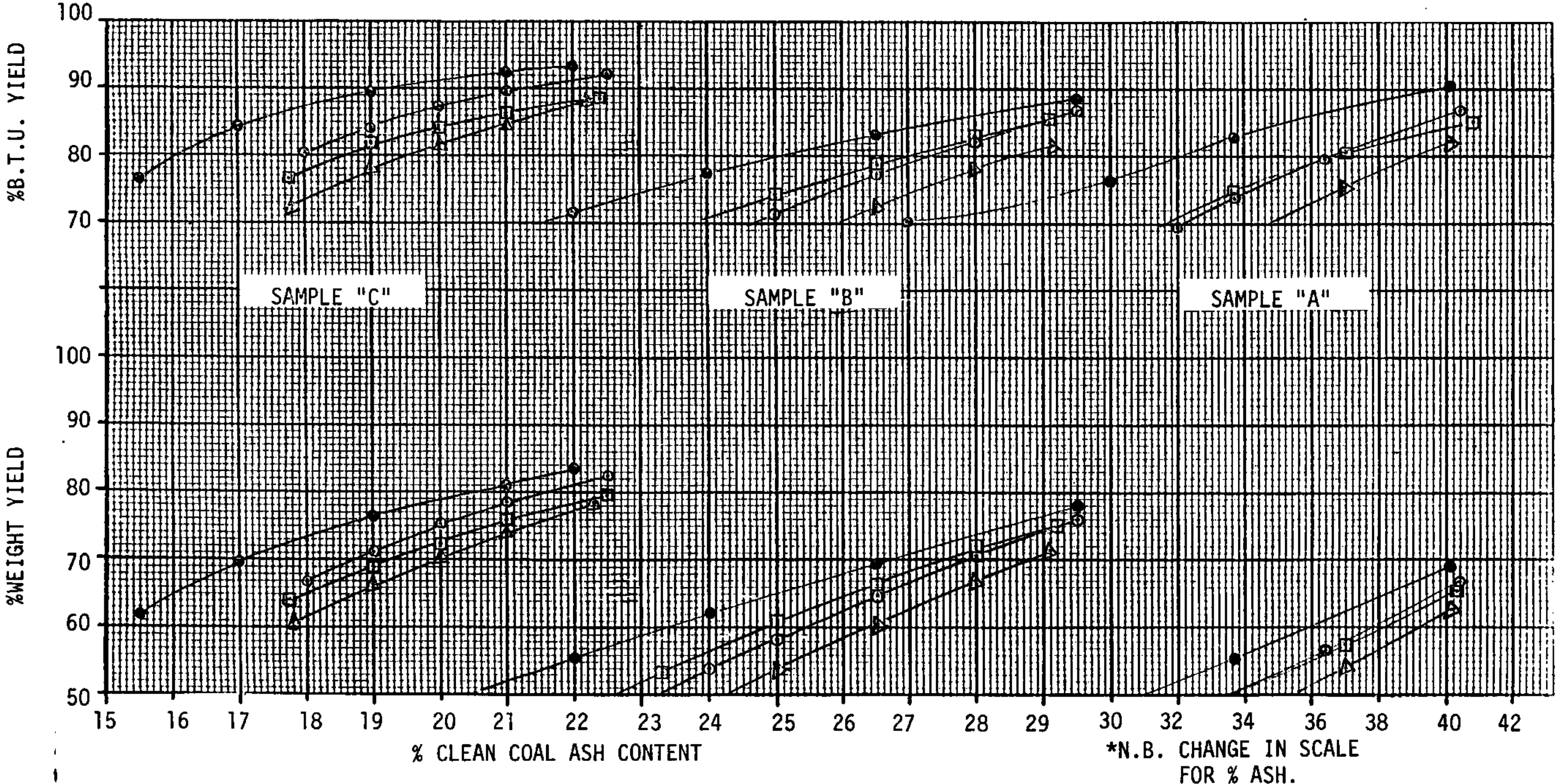


FIG. 13

SIMON-CARVES

F1304 - HAT CREEK
C-MJV for B.C. Hydro

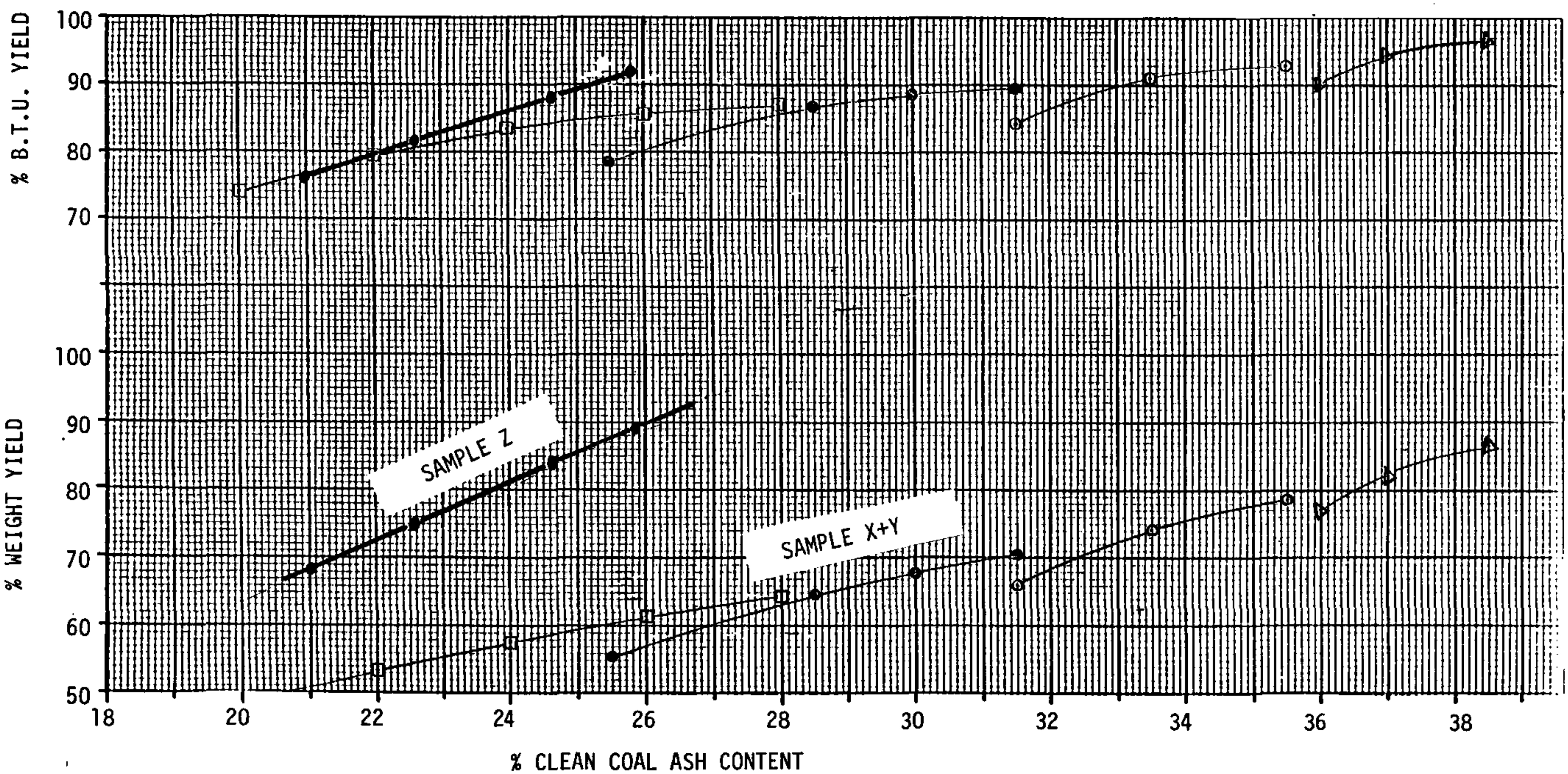
PARTIAL WASHING
OF SAMPLES X+Y, & Z

TOTAL WASH SCHEME (3) — 4" x ½" H/M Bath, ½" x 28M W.O. Cyclones (Discard 28M x D)

PARTIAL WASH (1) — -½" 20% Untreated

PARTIAL WASH (2) — -½" 50% Untreated

PARTIAL WASH (3) — -½" 80% Untreated



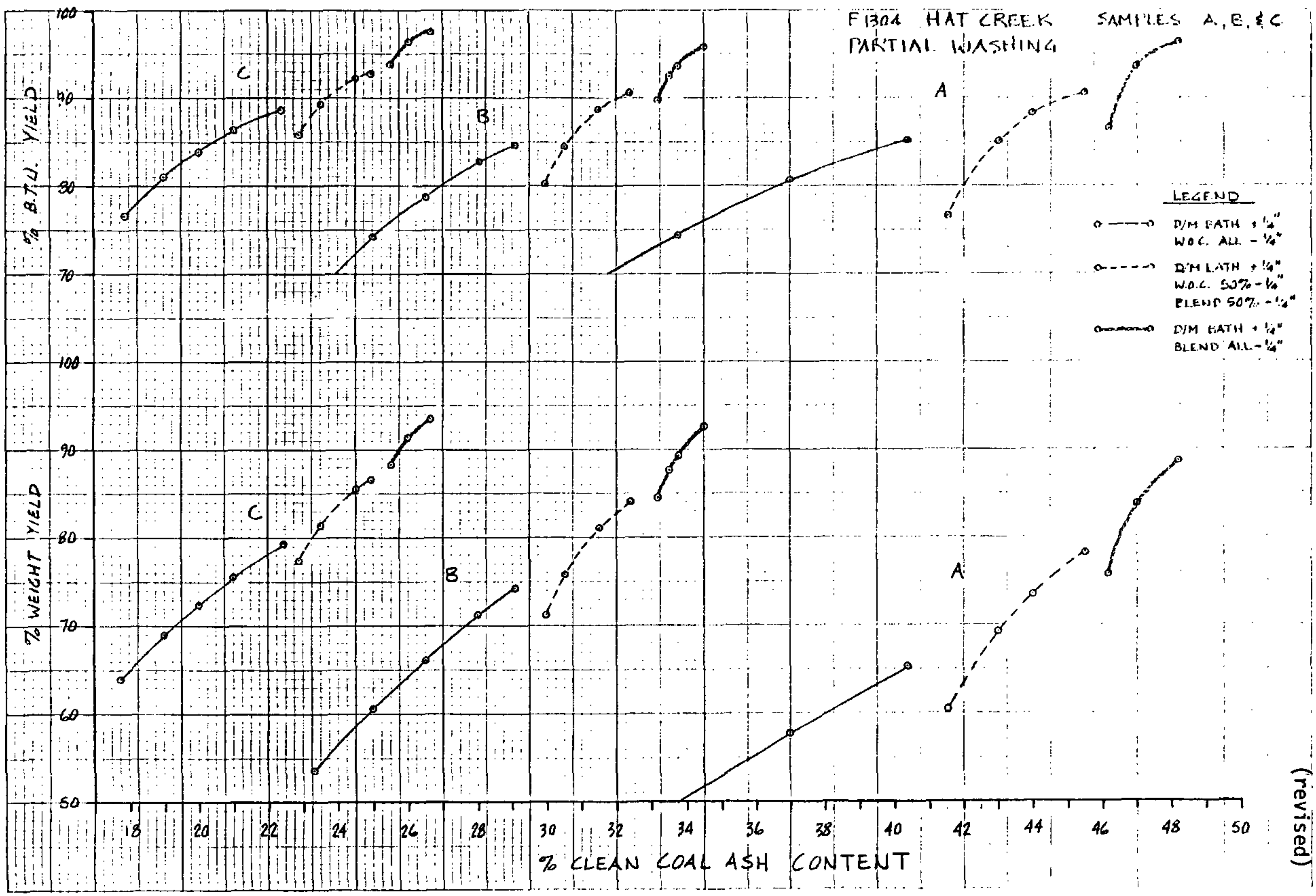
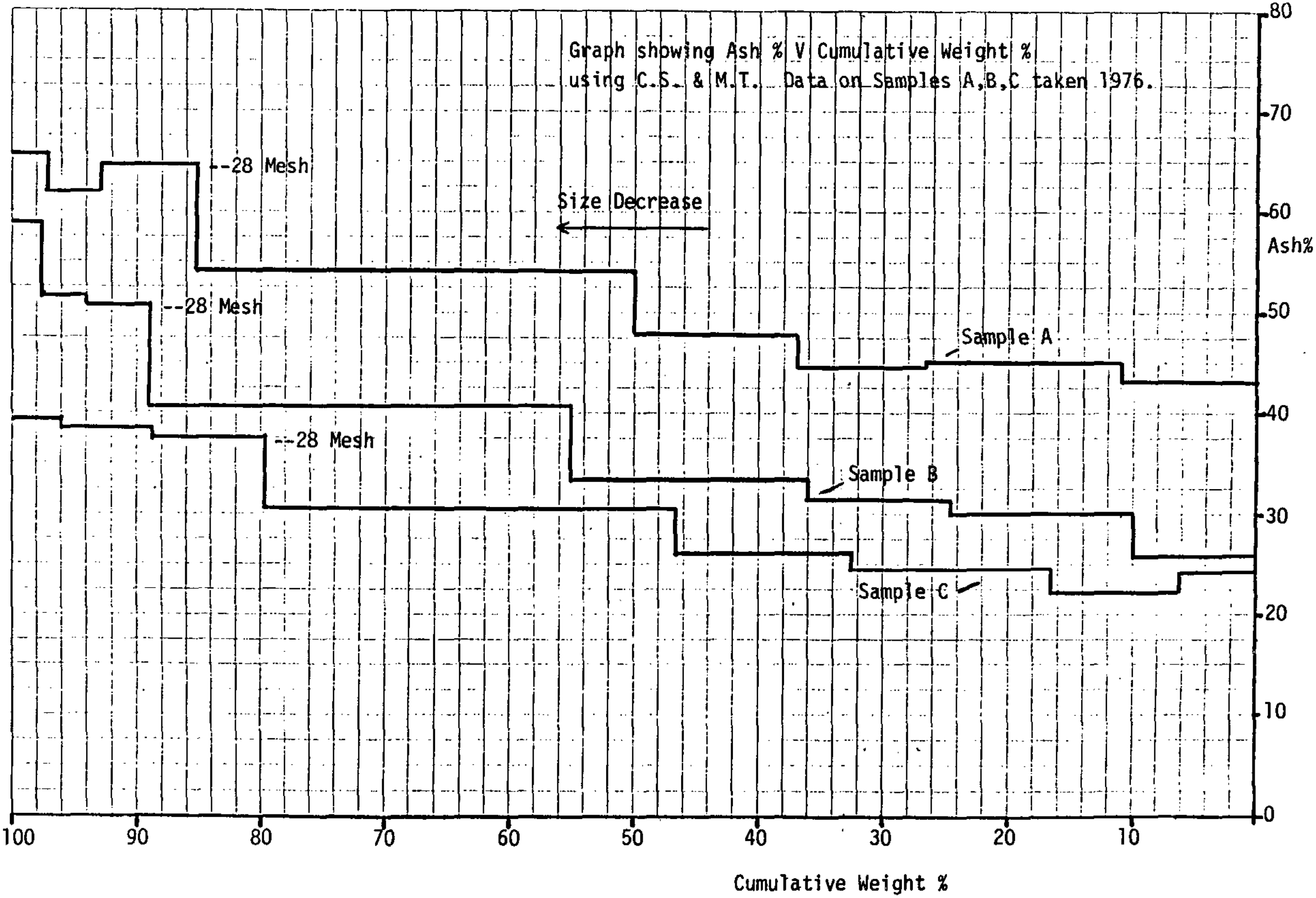


FIG. 14 (revised)

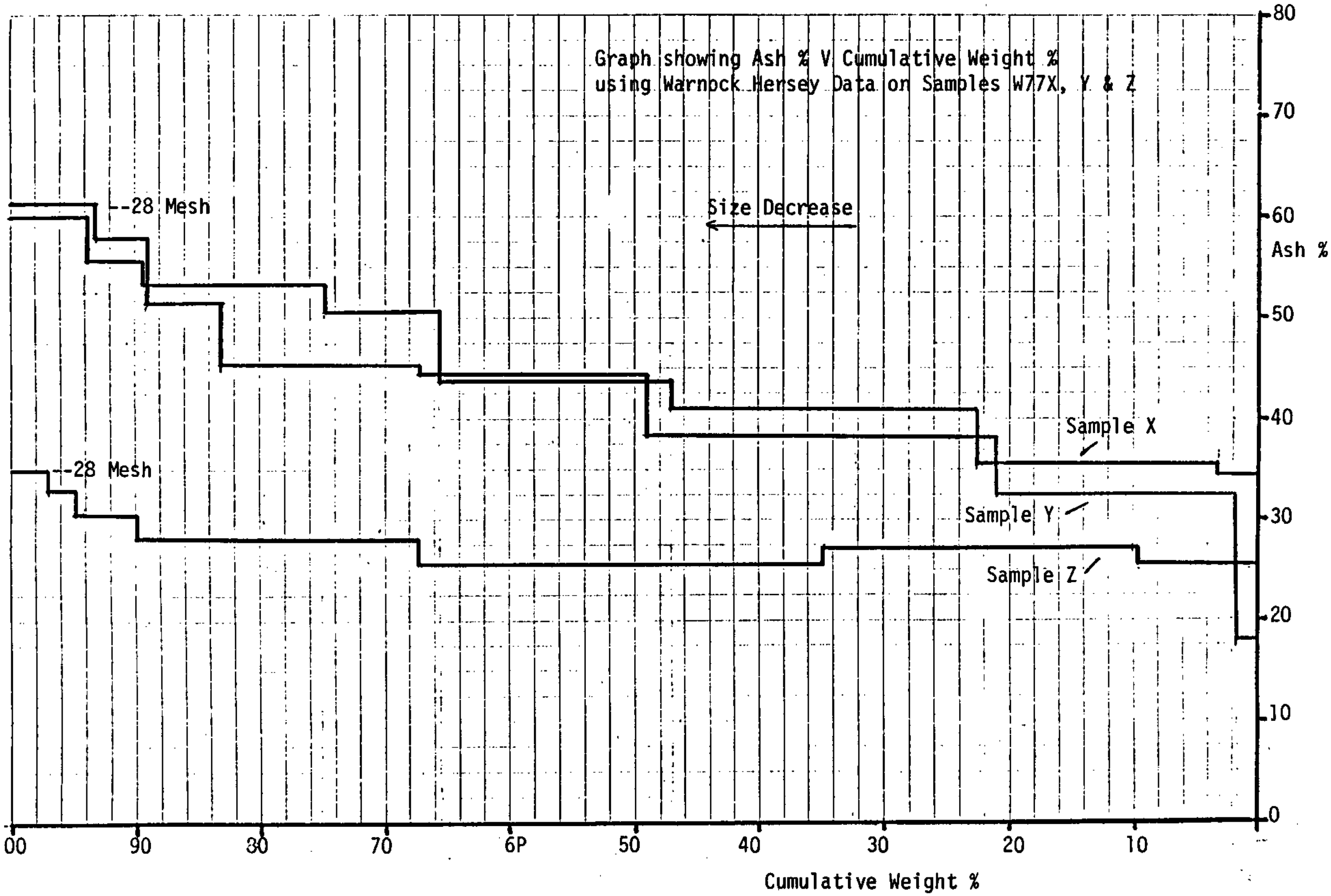
F1304 Hat Creek

Fig.15



F1304 Hat Creek

Fig.16



F1304 Hat Creek

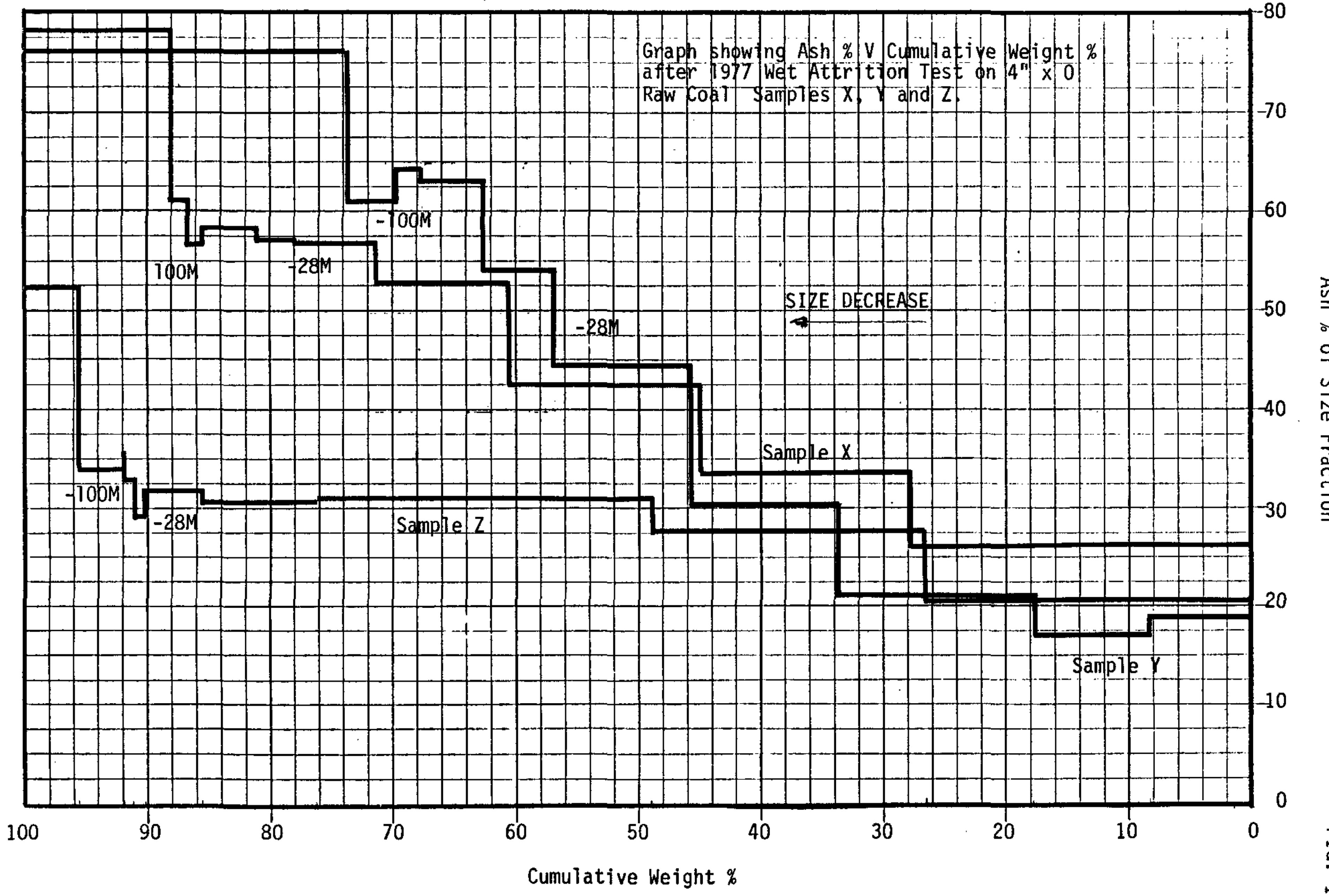


FIG. 17

F1304 Hat Creek

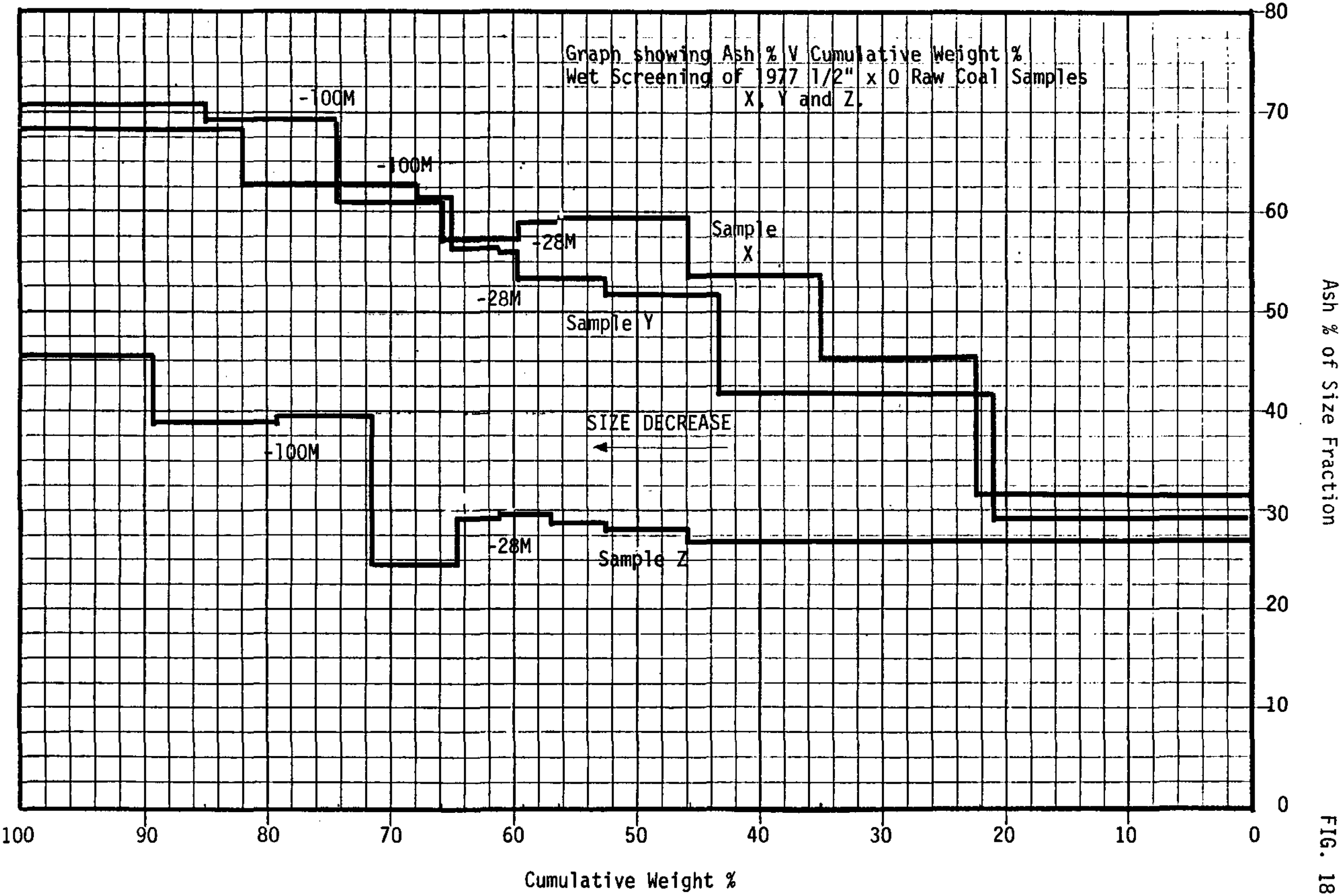


FIG. 18

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SECTION 12

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 1: Sample A - Classification and Drying.

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/8	46.3	31.7	6223	4978	5601	37.9
28 Mesh	51.1	80.4	5567	4454	5010	85.9
48 Mesh	52.5	89.7	5369	4294	4832	92.4
100 Mesh	53.2	96.1	5279	4223	4751	97.4
0	53.7	100.0	5210	4168	4689	100.0

Table 1a: Sample A - Classified and Dried Product Blended with Washed +½" Coal.

+½" Washed Combined With	Ash. % Dry Basis	Yield Wt.% Dry Basis	Product BTU/lb. Dry Basis	Gross BTU/lb.@20% Moisture	Gross BTU/lb.@10% Moisture	%Yield Gross BTU/lb.
½" - 28 Mesh	46.1	77.8	6236	4989	5612	82.9
½" - 48 Mesh	47.7	84.6	6031	4825	5428	87.2
½" -100 Mesh	48.5	89.3	5926	4741	5333	90.5
½" - 0	49.0	92.2	5849	4679	5264	92.2

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 2: Sample B - Classification and Drying.

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/8	32.4	40.3	8127	6502	7314	45.3
28 Mesh	36.5	85.1	7564	6051	6808	89.1
48 Mesh	37.5	92.0	7425	5940	6683	94.5
100 Mesh	38.3	96.6	7321	5857	6589	97.7
0	40.0	100.0	7227	5782	6504	100.0

Table 2a: Sample B - Classified and Dried Product Blended with Washer +½" Coal.

+½" Washed Combined With	Ash. % Dry Basis	Yield Wt.% Dry Basis	Product BTU/lb. Dry Basis	Gross BTU/lb.@20% Moisture	Gross BTU/lb.@10% Moisture	%Yield Gross BTU/lb.
½" - 28 Mesh	33.1	85.7	8049	6439	7244	89.2
½" - 48 Mesh	34.1	90.9	7915	6332	7124	93.0
½" -100 Mesh	34.8	94.4	7814	6251	7033	95.4
½" - 0	36.3	96.9	7733	6186	6960	96.9

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 3: Sample C - Classification and Drying.

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/8	25.1	35.8	9107	7286	8196	38.8
28 Mesh	27.8	75.7	8738	6990	7864	78.7
48 Mesh	29.0	86.1	8576	6861	7718	87.9
100 Mesh	29.8	95.2	8459	6767	7613	95.9
0	30.3	100.0	8400	6720	7560	100.0

Table 3a: Sample C - Classified and Dried Product Blended with Washed +½" Coal.

+½" Washed Combined With	Ash. % Dry Basis	Yield Wt.% Dry Basis	Product BTU/lb. Dry Basis	Gross BTU/lb.@20% Moisture	Gross BTU/lb.@10% Moisture	%Yield Gross BTU/lb.
½" - 28 Mesh	25.8	77.9	9042	7234	8138	81.0
½" - 48 Mesh	27.0	86.6	8878	7102	7990	88.4
½" -100 Mesh	27.8	94.2	8756	7005	7880	94.9
½" - 0	28.4	98.2	8695	6956	7896	98.2

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 4: Sample X - Classification and Drying

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/16"	40.6	45.8	6403	5122	5763	61.5
28 Mesh	44.1	56.3	5962	4770	5366	70.4
45 Mesh	44.8	59.2	5862	4690	5276	72.8
65 Mesh	46.1	65.9	5666	4533	5099	78.3
100 Mesh	47.8	74.1	5374	4299	4837	83.5
200 Mesh	50.5	85.2	5069	4055	4562	90.6
0	53.5	100.0	4766	3813	4289	100.0

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 5: Sample Y - Classification and Drying

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/16"	38.6	52.7	6162	4930	5546	67.9
28 Mesh	40.4	59.7	5984	4787	5386	74.7
45 Mesh	40.8	61.0	5947	4758	5352	75.8
65 Mesh	41.7	64.9	5828	4662	5245	79.0
100 Mesh	42.4	67.5	5737	4590	5163	80.9
200 Mesh	46.0	81.8	5263	4210	4736	89.9
0	50.0	100.0	4786	3828	4307	100.0

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 6: Samples X+Y combined - Classification and Drying.

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
28 Mesh	42.3	58.0	5972	4778	5375	72.5
45 Mesh	42.8	60.1	5904	4723	5314	74.3
100 Mesh	45.1	70.8	5553	4442	4998	82.2
0	51.8	100.0	4776	3820	4298	100.0

Table 6a: Samples X+Y combined - Classified and Dried Product blended with +½" Washed Coal.

+½" Washed Combined With	Ash. % Dry Basis	Yield Wt.% Dry Basis	Product BTU/lb. Dry Basis	Gross BTU/lb.@20% Moisture	Gross BTU/lb.@10% Moisture	%Yield Gross BTU/lb.
½" - 28 Mesh	36.8	64.6	9846	7877	8861	78.1
½" - 45 Mesh	37.1	65.7	9748	7798	8773	78.6
½" -100 Mesh	38.7	71.3	9263	7410	8337	81.1
½" - 0	43.9	86.5	8145	6516	7331	86.5

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 7: Sample Z - Classification and Drying

Classifying Size	Cum. Ash % Dry Basis	Yield % -½ Dry Basis	Cum.BTU/lb. Dry Basis	Cum.Gross BTU/lb.@20% Moisture	Cum.Gross BTU/lb.@10% Moisture	% Yield Gross BTU/lb.
1/16"	27.4	57.3	8651	6921	7786	61.6
28 Mesh	27.5	61.1	8636	6909	7772	65.6
45 Mesh	27.6	64.6	8586	6869	7727	68.9
65 Mesh	27.5	71.7	8619	6895	7757	76.8
100 Mesh	28.6	78.8	8475	6780	7628	83.0
200 Mesh	29.9	89.4	8309	6647	7478	92.3
0	31.5	100.0	8044	6435	7240	100.0

APPENDIX II

BENEFICIATION BY CLASSIFICATION AND DRYING OF 1/2" x 0 RAW COALS

Table 7a: Sample Z - Classified and Dried Product Blended with +½" Washed Coal

+½" Washed Combined With	Ash. % Dry Basis	Yield Wt.% Dry Basis	Product BTU/lb. Dry Basis	Gross BTU/lb.@20% Moisture	Gross BTU/lb.@10% Moisture	%Yield Gross BTU/lb.
½" - 28 Mesh	25.6	84.0	9062	7250	8156	86.5
½" - 45 Mesh	25.7	85.2	9038	7230	8134	87.5
½" -100 Mesh	26.1	89.9	8980	7184	8082	91.7
½" - 0	27.2	96.8	8804	7043	7924	96.8

VOLUME II

SECTION 13

INDEX

SECTION 1

SUMMARY

In the absence of washability data of the low grade coals projections of yield and quality are made from the higher grade coals.

Stockpiling of low grade coals "for future use" can only be considered a realistic approach whilst the quantities are relatively small. Production of significant quantities of low grade coal is not expected until year 15.

A total washing process is outlined which would be viable in its own right leading to a 3% increase in heat value available from the mine. The benefits to be obtained are not, however, likely to affect the overall complex viability.

Investigations leading to a suitable beneficiation plant design can, therefore, be delayed until the commencement of the second decade, when "as mined" samples will be available.

SECTION 2

INTRODUCTION

The Hat Creek deposit will yield a wide variety of raw coals. The "best" coals will have calorific values in the range up to 10,000 BTU/lb (dry basis) whilst the bulk of the coal will be in the 6,000 to 8,000 BTU/lb range. Thus the whole deposit is considerably poorer than the 10,000 - 12,000 BTU/lb fuels used as the basis for most current thermal plant design.

Beneficiation of the Hat Creek coals which lie in the range sampled for Washability Tests (5,600 BTU/lb Sample A to 8,800 BTU/lb Sample Z) has been considered in our Report on the Potential Application of Alternative Processes for the Beneficiation of Hat Creek Coals (Draft - December 1977).

The initial concepts for mining the Hat Creek No. 1 Deposit envisaged average "Run of Mine" product quality being maintained by rejecting low grade material. The value below which low grade coal is determined to be reject is the Cut Off Grade. (For example the 1976 Integ-Ebasco and March 1978 PD-NCB Report No. 9 used a cut-off grade of 4,500 BTU/lb to achieve a product of 7,438 BTU/lb).

Energy conservation considerations have led to suggestions from the appropriate authorities that it would not be acceptable practice to pass to waste disposal any material mined with a calorific value above 2,000 BTU/lb. Thus a Low Grade Coal Stockpile is envisaged for material in the 2,000 BTU/lb to "Cut Off Grade" range. It is envisaged that future technological developments may permit the cleaning and/or combustion of this material.

An initial mine plan (A. Bell Revision 2 Ultimate Pit - January 3, 1978) shows the following production over the 35 year effective mine life: -

TABLE 1

Cut Off Grade BTU/lb.d.b.	Remaining R.O.M. Coal @ 5% Dilution Tonnes	Run of Mine Coal BTU/lb.d.b.
2000	398,387,300	6595
3000	376,531,900	6845
4000	360,790,600	7000
5000	327,335,100	7265
6000	241,377,700	7990

SECTION 2

INTRODUCTION

Since the thermal plant fuel requirements correspond to approximately 360 million tonnes at 7,000 BTU/lb (dry basis) a 4,000 BTU/lb Cut Off Grade is thus envisaged. The Low Grade Coal stockpile would thus amount to some 37 million tonnes (or 10% of run of mine output) over the mine life.

It has been noted that the stockpiling of this low grade coal may require

a) Separate stocking area

b) Separate handling system

To prevent spontaneous combustion of such a stockpile substantial crushing, say to -50mm, will be necessary, followed by compaction. Simon-Carves have advised that this stockpiling procedure, together with ageing and weathering, would render the low grade material much more difficult to clean and impracticable to use in the future..

The purpose of this report is to examine the potential beneficiation of poorer Hat Creek coals. (i.e. those with less than 5,000 BTU/lb with are not considered in the December report.) The philosophy is that since this coal has to be mined (to obtain access to some better coals), and must be handled, crushed and stockpiled there is a significant cost involved. The objective is therefore to partially clean to extract any relatively useful material and give a reject within the 2,000 BTU/lb criteria. Thus the stockpiling would be eliminated and the overall output increased.

Unfortunately the need to investigate the properties of these low grade coals had not been accepted prior to the 1977 Test Programme. This report is therefore based on projections of the data obtained from the normal fuel samples.

It must be noted that this report is concerned only with the substantial in-situ coal "blocks" in the range 5,000/4,000 to 2,000 BTU/lb, and does not consider the requirements for any run of mine coal which may be below cut-off grade due to admixture of better coal with quantities of partings.

SECTION 3

CONCLUSIONS AND RECOMMENDATIONS

Note that these conclusions are concerned solely with true low grade coals and not with diluted higher grade coals. No washability data is available for these coals.

3.1 Concern is expressed that the alternative of stockpiling the low grade coals will lead to contamination and ultimately loss of the higher value coarser material by its admixture with the virtually valueless fines. Beneficiation by screening out the fines and stockpiling or using the coarser material is recommended as a minimum.

3.2 Beneficiation of the lower grade coals gives a recovered material which is below the average grade, and thus lowers overall quality.

3.3 Partial washing does not give an additional yield which is likely to be viable in terms of savings in run-of-mine coal production costs as against costs of a conventional beneficiation plant.

3.4 Total washing of low grade coals will be viable if a simplified plant can be developed, with particular attention to minimization of tailings production.

3.5 Further investigations of the low grade beneficiation characteristics are necessary prior to the design of any facility. This may require some development of currently available processes to meet the particular problems of washing Hat Creek coals.

3.6 Whilst the total washing proposal is likely to be financially viable in its own right, the additional 3.0% heating value made available to the Boiler Plant is not likely to affect the overall scheme viability.

3.7 The bulk of the low grade coal is anticipated to be mined after year 15. Obtaining the necessary design data can therefore be deferred until the mine is in full production. This must be reviewed as alternative mine plans are presented.

3.8 Space for a Beneficiation Plant must be allowed in the raw coal handling scheme.

SECTION 4

BENEFICIATION CHARACTERISTICS

It is noted in the Introduction that no Washability Data has been obtained for the low grade coals. It is, therefore, necessary to see how available data shows trends which may be projected into this quality range.

Inspection of the Washability Data shows two general trends.

a) Finer Sizes are dirtier than coarser sizes.

b) For a given size fraction the higher ash of the poorer coals is due to a lower proportion of low gravity (low ash) coal/higher proportion of middlings and not to an increase in the high gravity (high ash) clay/shale partings material. (Note that this is evidence that we are concerned with a trend in coal quality and not a trend in admixture of even minute partings with relatively good coal. If the latter were the case we should, with appropriate crushing, have a coal with a relatively easy beneficiation potential.)

4.1 Beneficiation by Fines Extraction

This has been considered for the six sets of washability data in Section 9 of the Alternative Beneficiation Report. (e.g. see Table 9.1, Appendix II and Figures 15 and 16.) The potential of this method is seen to be greater for the dirtier coals to the extent that rejection of minus 28 mesh fines from the material less than 7,000 BTU/lb (greater than 38.5% ash) R.O.M. coal could be a viable means of beneficiation.

Thus as the raw coal has a lower calorific value an even coarser fines extraction size may be acceptable. Ash content relative to the size consist for samples B, Y, X and A are plotted as curves in Figure I. The similar geometric shape is observed and further curves 1, 2 and 3 were generated for coals of 4,500, 3,700 and 3,000 BTU/lb.

These results show that if a Hat Creek run of mine coal of X% ash is screened to give 50% overflow yield by weight then the overflow has an ash content of (X-6)% and the underflow of (X+6)%. This is followed relatively closely for all the samples except the D Zone Sample Z. However, it would appear, by projecting these curves that this differential is a peak of about ± 7% at 35% head ash and falls to about ± 4% at 65% head ash. This trend has been assumed in the calculated results which follow, Table 2.

SECTION 4

BENEFICIATION CHARACTERISTICS

4.1 Beneficiation by Fines Extraction - cont.

Screening for 50% overflow yield would correspond to about 13mm.

Thus beneficiation of low grade coal by screening at say 13mm could be an acceptable method for run of mine coal up to say 4,000 BTU/lb quality.

Similar predictions could be made for other size separations. This exercise has been done at 13mm since this is the smallest size at which a high screening efficiency could be achieved with conventional screening equipment. The potential of more sophisticated methods has been reviewed in Section 9 and Appendix II of the Alternative Beneficiation Report. From those tables it can be seen that a smaller size separation is necessary for higher C.V. raw coals to give an acceptably low C.V. (high ash) undersize reject. But with finer size separations the degree of beneficiation achieved is comparatively lower, and would probably not justify the higher plant costs involved.

TABLE 2

Beneficiation by Screening of Low Grade Coals

Raw Coal		Product = Screen Overflow @ 50% Yield		Reject = Screen Underflow @ 50% Yield	
CV BTU/lb	Ash d.b.%	CV BTU/lb	Ash d.b.%	CV BTU/lb	Ash d.b.%
2000	73.2	2493	69.8	1507	76.6
2500	69.7	3022	66.1	1978	73.3
3000	66.3	3564	62.4	2436	70.2
3500	62.8	4106	58.6	2894	67.0
4000	59.3	4670	54.7	3330	63.9
4500	55.9	5220	50.9	3780	60.9
5000	52.4	5769	47.1	4231	57.7

SECTION 4

BENEFICIATION CHARACTERISTICS

4.1 Beneficiation by Fines Extraction - cont.

4.1.1 On the basis of the relative values of the underflow and overflow materials as shown in Table 2, we would recommend screening the run of mine low grade coal (2000 - 4000 BTU quality) at 13mm. The underflow should be passed directly to waste dumps and would contain the bulk of the clayish material. The 50% by weight as screen overflow would contain some two thirds of the total heat content. The size of any stockpiling operation would thus be halved, and the "better" material would not be contaminated in crushing and storage.

4.1.2 Alternatively consideration should be given to blending the +13mm screen overflow directly into the normal grade product.

Taking the values given in Table 1, the 18,798,350 tonnes of screen overflow from the 2000 - 4000 low grade coal, blended back with the 360,790,600 at 7,000 BTU/lb would yield:

379,588,950 tonnes at 6815 BTU/lb.

This is equivalent to approximately 370 million tonnes at 7000 BTU/lb. Thus the quantity to be mined would be reduced by about 9 million tonnes, and there would be no stockpiling requirement. The acceptability of this lower fuel grade is, however, questionable.

4.2 Beneficiation by Partial Washing

Some considerable time was spent trying to define the washability data trends as generally observed - paragraph (ii) page 4-1.

This was done on the usual basis of raw coal and product ash contents and yields for a series of separating gravities. The data was examined for each individual size range, and also for the composite plus 100 mesh. It can be seen from the examples in Tables 3 and 4 and Figure 2 that the trends were by no means conclusive, and would not permit meaningful interpolation or extrapolation. Thus prediction of the beneficiation product qualities and yields for untested intermediate coals, and more particularly the Low Grade coals was thought to be impracticable. (This exercise was computer assisted.)

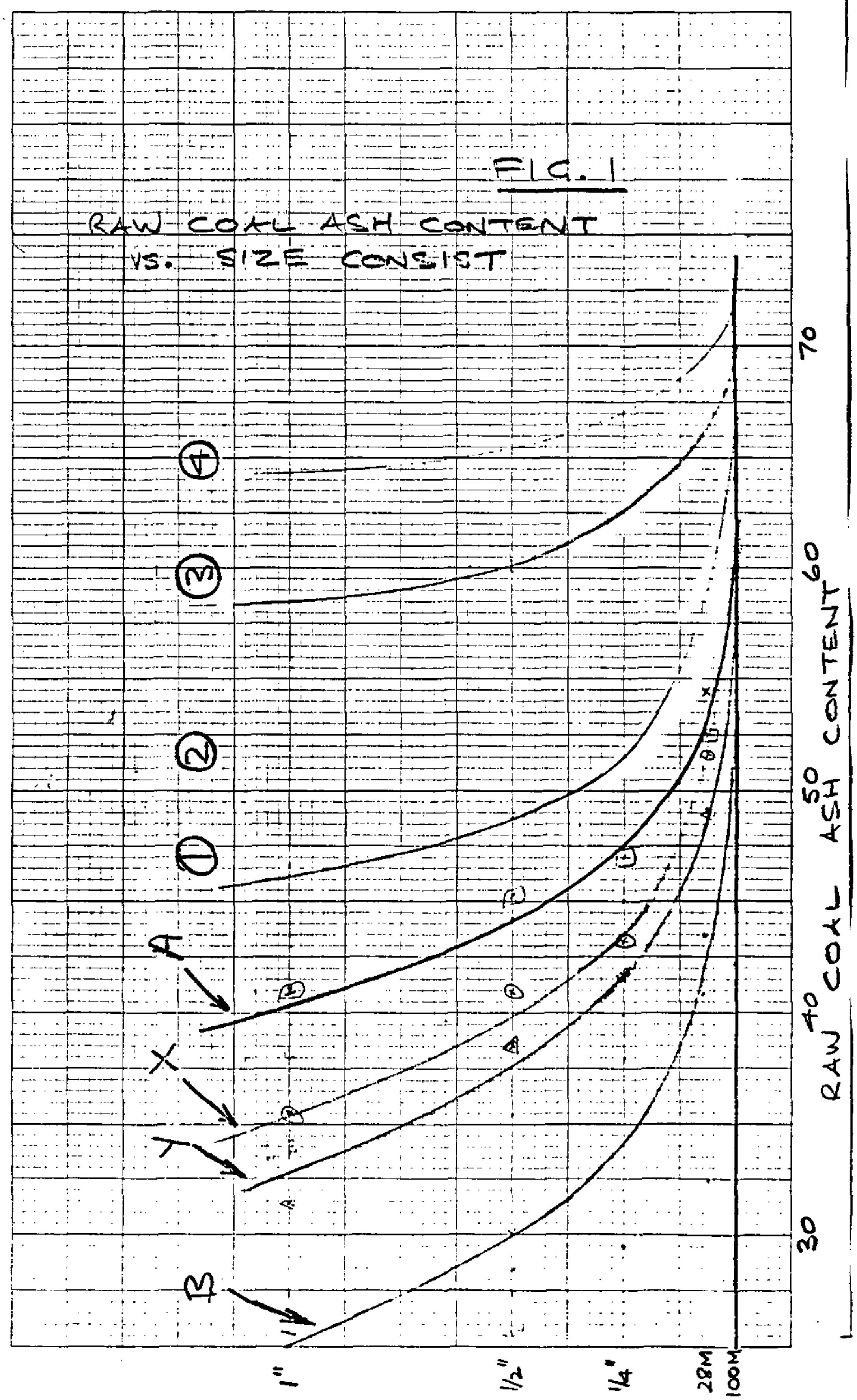


FIG. 1
RAW COAL ASH CONTENT
VS. SIZE CONSIST
1
2
3
4
A
X
T
B
RAW COAL ASH CONTENT
30
40
50
60
70
1"
1/2"
1/4"
28M
100M

SECTION 4

BENEFICIATION CHARACTERISTICS

TABLE 3

Quality Variation of Floats Product (at 1.80 S.G.) Compared to Raw Coal for Plus 1/2 Size Fractions

Sample	Ash Content of Raw Coal Size Fraction	Floats Product at 1.8 S.G. % Ash	Wt. % Yield
A 2" x 1"	43.4	36.0	86.3
1" x ½"	45.7	39.5	88.7
X 4" x ½"	39.2	33.1	87.0
Y 4" x ½"	35.3	25.0	81.1
B 2" x 1"	25.6	22.4	92.9
1" x ½"	30.0	27.2	93.7
Z 4" x 1"	27.1	26.7	99.1
1" x ½"	27.3	26.2	97.8
C 2" x 1"	24.0	19.1	91.6
1" x ½"	22.1	18.8	94.0

TABLE 4

Quality Variation of Floats Product (at 1.80 S.G.) Compared to Raw Coal (Composite)

Sample	Ash Content of Raw Coal	Ash Content of 1.80 S.G. Floats Product
A	50.1	27.2
X	44.7	33.7
Y	42.1	41.7
B	36.4	27.7
Z	27.7	25.9
C	27.7	21.5

SECTION 4

BENEFICIATION CHARACTERISTICS

TABLE 5

Beneficiation Potential of 28 x 100 Mesh Coals
- Separation in Two-Stage Water Cyclones at 1.60 S.G.

SAMPLE	% ASH OF RAW COAL		CLEAN COAL, 28 x 100 MESH		
				% YIELD	
	4" x 0	28 x 100M	% Ash	Theoretical	Actual
Z	26.9	29.2	22.0	75.0	63.2
C	29.1	36.7	27.0	77.2	59.4
B	36.3	50.7	32.6	50.7	31.1
X + Y*	42.9	59.2	38.6	44.0	28.9
A	57.2	68.5	41.7	44.8	25.1

*Clean Coal at 1.50 S.G.

TABLE 6

Beneficiation Potential of 1/4" x 28 Mesh Coals
- Separation in Two-Sage Water Cyclones

SAMPLE	% ASH OF RAW COAL		CLEAN COAL, ¼" x 28 MESH		
				% YIELD	
	4" x 0	¼" x 28M	% Ash	Theoretical	Actual
Z	26.9	28.9	21.6	82.0	62.4
C	29.1	27.2	16.9	78.5	65.2
B	36.3	34.3	25.3	77.2	65.1
X + Y	42.9	37.9	25.5	77.3	65.4
A	57.2	48.8	37.9	77.7	65.3

SECTION 4

BENEFICIATION CHARACTERISTICS

4.2 Beneficiation by Partial Washing - cont.

(Table 6 and 7 do show some useful trends which were extrapolated for the finer sizes. They were, however, compiled with hindsight after the concept of floating the separation gravity had been developed below.)

However, an alternate method revealed an unexpected and relatively good correlation which may be unique to Hat Creek. (Hopefully not unique to these size sets of washability data!) This correlation was found between the raw coal ash content and clean coal ash content for a series of clean coal yield values. (The yield values chosen were 80%, 70% and 60%. These yields are achieved at widely differing separation gravities, yet, all the gravities thus required lie within the working range of the appropriate washing equipment for the respective coal size fractions.)

Even more surprising is the fact that at a given yield value a single correlation curve applies to all size fractions.

The quality/yield values were obtained from the interpolated washability data (see Appendix III of the Alternative Beneficiation Report) and the curves shown in Figures 3 and 4 were determined by a computerized quadratic curve fit.

(Results from the first curve fit included points marked "R" obtained from the second (cumulative) washability test conducted by CSMT on the 1976 Sample A, 28 x 100 mesh size fraction.

Computations from this first curve fit showed unexplicably high rejects ash contents/high degrees of beneficiation for poorer coals. Reference to the test report shows this point to be very dubious as it is largely dependent on the 1.90 S.G. Sinks ash content which had been "modified" to 95.0% ash, (Table 32). The earlier CSMT results (Table 6) yielded the points marked "A", which although not included in the curve fit shown in Figures 2, 3 and 4, give credence to the use of these curves at the higher ash values.)

FIG. 2

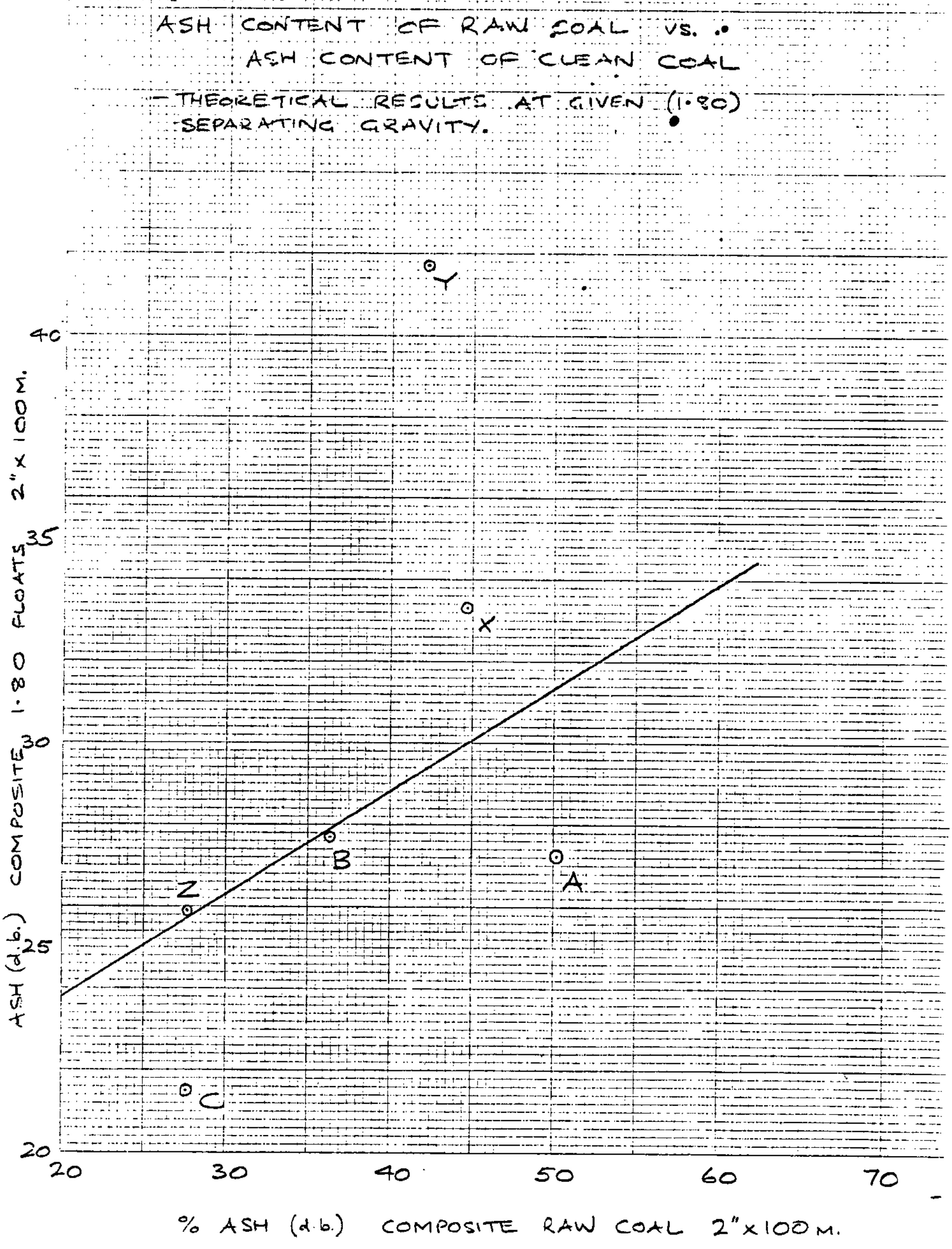

ASH CONTENT OF RAW COAL VS.
ASH CONTENT OF CLEAN COAL
- THEORETICAL RESULTS AT GIVEN (1.80)
SEPARATING GRAVITY.
Y
X
B
A
Z
C
20
25
30
35
40
20
30
40
50
60
70
ASH (d.b.) COMPOSITE 1.80 FLOATS 2" x 100 M.
% ASH (d.b.) COMPOSITE RAW COAL 2" x 100 M.

FIG. 3

THEORETICAL BENEFICIATION BY WASHING
TO 70% WT. YIELD

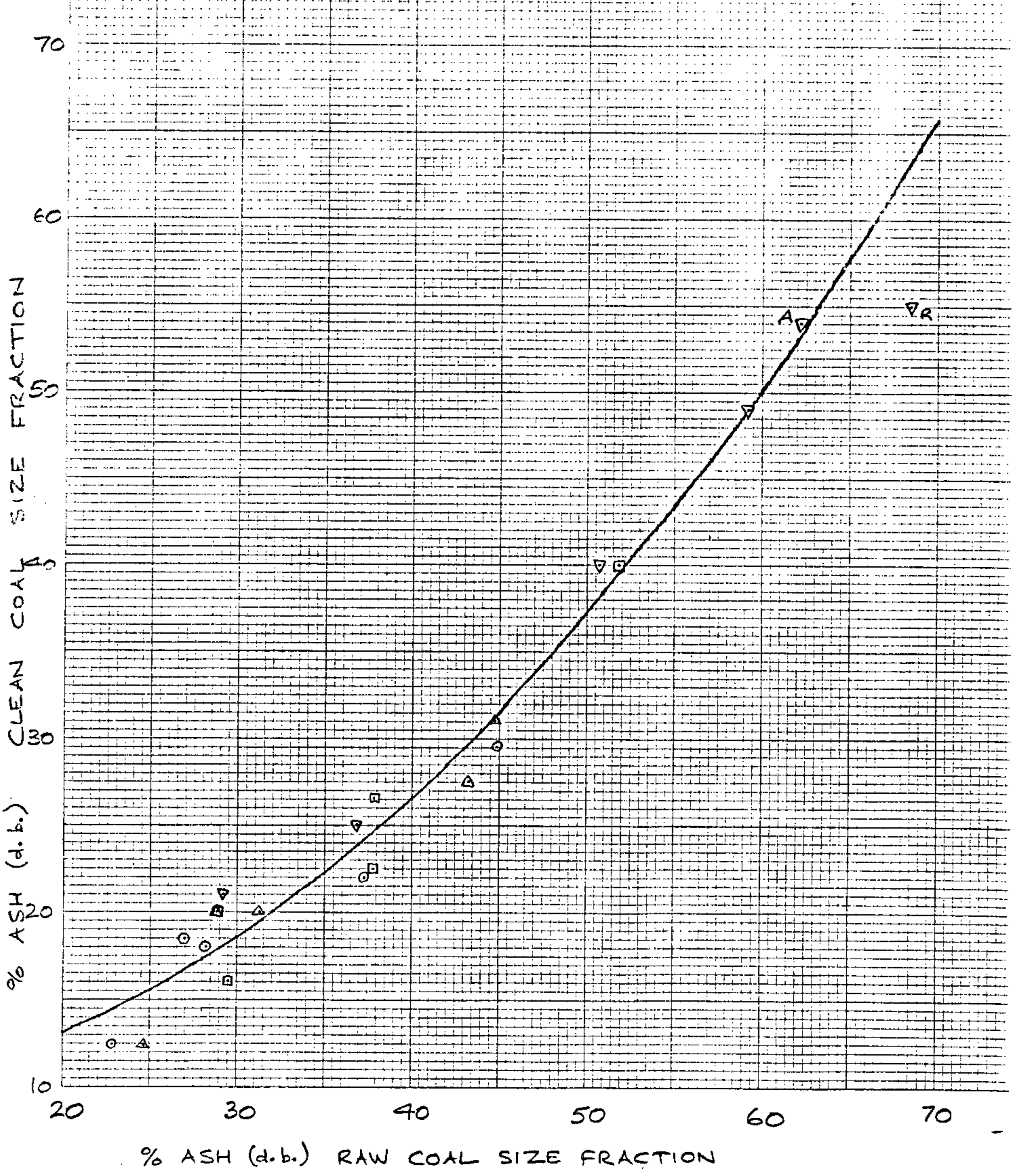
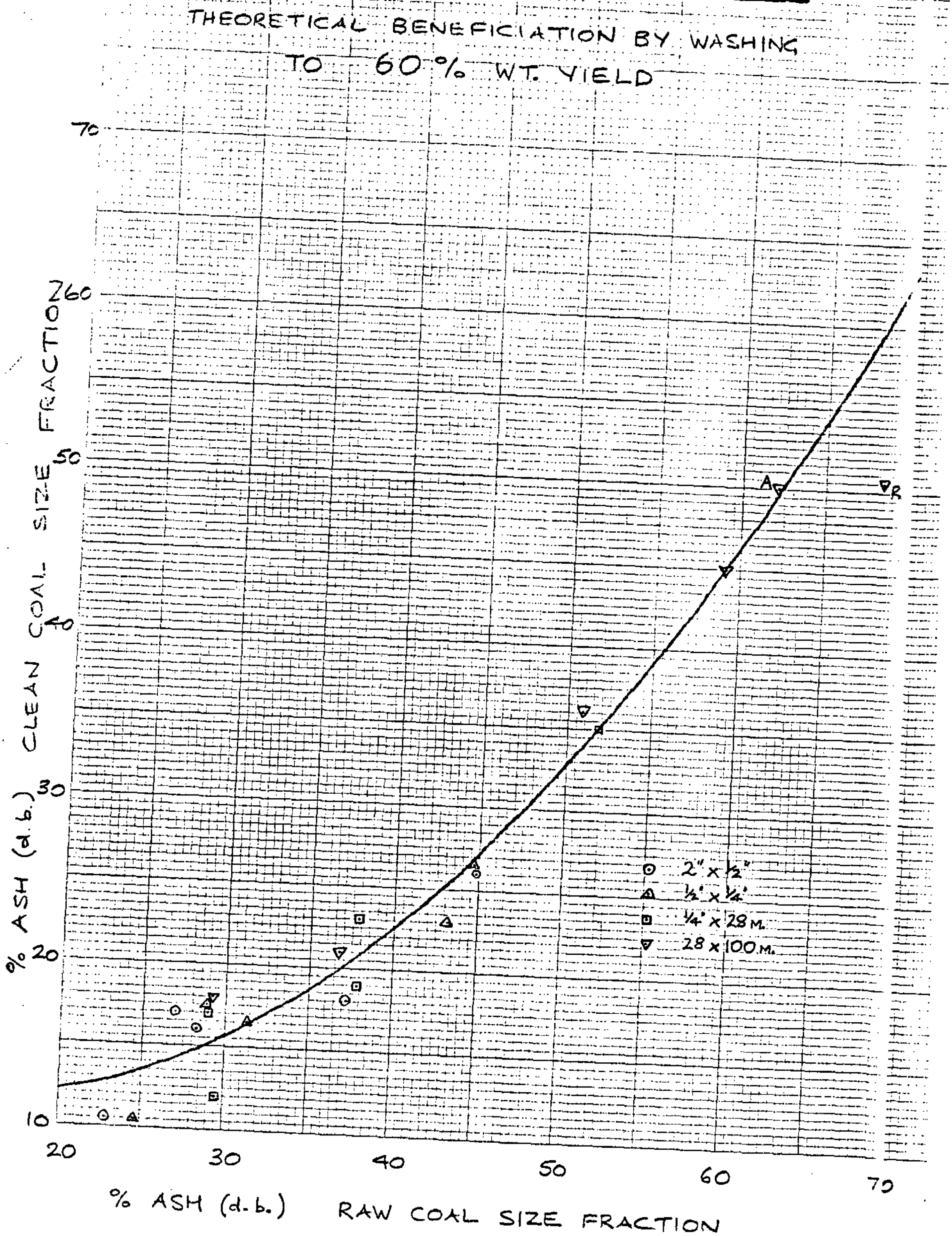


FIG. 4



THEORETICAL BENEFICIATION BY WASHING
TO 60% WT. YIELD
70
60
50
40
30
20
10
% ASH (d.b.) CLEAN COAL SIZE FRACTION
20
30
40
50
60
70
% ASH (d.b.) RAW COAL SIZE FRACTION
2" x ½"
½" x ¼"
¼" x 28 M.
28 x 100 M.
A
R

SECTION 4

BENEFICIATION CHARACTERISTICS

4.2 Beneficiation by Partial Washing - cont.

The results which could theoretically be obtained by partial washing of the Low Grade Coals are shown in Table 6 below. This assumes that the raw coal would be screened at 13mm and only the Screen Overflow passed to the washing process. This is thus an extension of Table 2.

4.2.1 The coal recovered from the low grade coals by rejection of the minus 13mm dry fines and washing the plus 13mm raw coal does have a usefully enhanced calorific value, e.g. a 5350 BTU/lb product from a 3000 BTU/lb raw coal. Thus in terms of coal recovery and total rejects ash content this scheme may be considered more acceptable than stockpiling the low grade coals in the 2000 - 4000 BTU/lb. range.

4.2.2 The washed coal thus recovered is all below the 7,000 BTU/lb average quality of the coal above a 4,000 BTU/lb Cut-Off Grade.

Thus the 18,798,350 tonnes of Screen Overflow would yield on washing an estimated 11.279,000 tonnes at 4794 BTU/lb.

The overall result would therefore be 372,069,600 tonnes at 6933 BTU/lb.

The reduction in quality is considerably less than achieved without washing - see paragraph 4.1.2.

The quantity to be mined would be reduced by 7.7 million tons, and there would be no stockpiling requirement other than to provide a uniform washery feed.

The costs are by no means insignificant - a first estimate would be $10 million Capital plus $1.00 per tonne run-of-mine (i.e. $38 million) Operating Costs.

4.2.3 Similarly the partial washing of the 4000 - 5000 BTU/lb material may be considered. As in section 4.1 the Dry Fines (minus 13mm) have a significant head content, and could not be discarded.

SECTION 4

BENEFICIATION CHARACTERISTICS

TABLE 7

Partial Washing of Low Grade Coals
(Plus 13mm Size Fraction Washed at 60% Yield)

Raw Coal		30% Yield as Washing Product		20% Yield as Washing Reject		50% Yield Dry Fines		80% Yield Part Washed Blended Smalls
CV BTU/lb	Ash d.b.%	CV BTU/lb	Ash d.b.%	CV BTU/lb	Ash d.b.%	CV BTU/lb	Ash d.b.%	CV BTU/lb
2000	73.2	3514	62.7	940	80.5	1507	76.6	2260
2500	69.7	4470	56.1	853	81.1	1978	73.3	2912
3000	66.3	5350	50.0	867	81.0	2436	70.2	3529
3500	62.8	6189	44.2	983	80.2	2894	67.0	4130
4000	59.3	6984	38.7	1200	78.7	3330	63.9	4700
4500	55.9	7693	33.8	1504	76.6	3780	60.9	5247
5000	52.4	8314	29.5	1952	73.5	4231	57.7	5762
(7000	38.6	10,093	17.2	4526	55.7	6131	44.6	7617)

Note: These results do not allow for material misplaced in any washing process, and are therefore, somewhat optimistic in terms of product yield/rejects ash content. The more detailed calculations to allow for this factor were not performed in view of the generally poor benefit obtained by this operation as discussed below. Similarly a more serious tailings problem would be anticipated when washing these lower grade coals.

SECTION 4

BENEFICIATION CHARACTERISTICS

4.2 Beneficiation by Partial Washing - cont.

4.2.3 By comparison with the average value, 7000 BTU/lb., in the bottom line of Table 7, it can be seen that there is a case, in terms of heat content recovery and the degree of beneficiation achieved for concentrating any partial beneficiation required on the material just above the cut-off grade.

4.2.4 The benefit of recovering the plus 13mm coal from below cut-off grade, as in 4.2.2, on mine yield (as compared with the estimated additional costs involved) does not appear to be of significance to the overall project.

4.2.5 Similarly the benefit of partial washing on overall quality is significant only in terms of its effect on quality variation. A requirement for partial washing of lower grade coals may occur in conjunction with some mining schemes.

4.3 Beneficiation by Total Washing

The washability tests and test washes show that the lower grade coals will produce a very high quantity of washery tailings if subjected to total washing. Thus the general approach has been to concentrate on the application of partial washing if this can achieve the necessary degree of beneficiation.

Table 5 in Section 4.2 above shows that the plus 13mm clean coal recovered is of a useful quality from the low grade coals, but the Part Washed Blended Smalls are of dubious quality. Some consideration must, therefore, be given to washing the minus 13mm low grade coals.

As the fines content increases and becomes dirtier the potential coal recovery from the finer sizes is very low. (See Table 4, page 4-6) It is not, therefore, necessary to consider any washing of the minus 28 mesh material. However, whilst in Table 7 we have, for simplicity ignored the yield error (i.e. difference between theoretical and actual yields due to misplaced material in the washing process) this cannot be ignored in even the simplest consideration of the treatment of finer coals - see Table 6: yield errors here are approaching 12%.

SECTION 4

BENEFICIATION CHARACTERISTICS

4.3 Beneficiation by Total Washing - cont.

The results in Table 7 (page 4-5) are for the 1/4" x 28 mesh size fraction - as for the Table 6 these results were also obtained using Water Only Cyclones and show a significant yield error. These results are used to predict the recovery and beneficiation of the 13mm x 28 mesh size fraction and combined with the results of washing the plus 13mm material from Table 5. The total washing prediction is thus summarized in Table 8.

The results in Table 8 represent values which could be achieved by a plant specifically designed to treat low grade coals. They are, however, the result of data projections in respect of size consist, washability characteristics and tailings production which can only be proven by specific testwork on "as mined" coals. The results are, therefore, an indication of the best which could be achieved: actual yields may well be somewhat lower.

4.3.1 The coal recovered from the low grade coals by total washing does have a usefully enhanced calorific value, e.g. 5243 BTU/lb product from a 3000 BTU/lb raw coal. By comparison with the results in Tables 2 and 5 we conclude that total washing rather than beneficiation by screening or partial washing is more likely to permit incorporation of these materials in the total product.

4.3.2 The washed coal is, however, all below the 7000 BTU/lb average quality of the coal above the 4000 BGU/lb Cut-Off Grade. Thus the 37,596,700 tonnes of low grade coal would yield an estimated 16,388,000 tonnes on total washing at 4,633 BTU/lb.

The overall result would, therefore be 377,178,600 tonnes at 6,897 BTU/lb. The quality to be mined, to provide the same heat input to the boiler plant is reduced by some 10.8 million tons, and ther would be no stockpiling requirement other than to provide a uniform washery feed:

The costs are by no menas insignificant - a first estimate would be $12 million Capital plus $1.50 per tonne run-of-mine (i.e. $56 million) Operating Costs.

SECTION 4

BENEFICIATION CHARACTERISTICS

TABLE 8

Total Washing Potential of Low Grade Coals

Raw Coal		+13mm Clean Coal		13mm x 28 Mesh Clean Coal		Total Washing Clean Coal			Rejects Including Tailings	
CV BTU/lb	Ash d.b.%	Yield Wt.%	Ash d.b.%	Yield Wt.%	Ash d.b.%	Yield Wt.%	Ash d.b.%	CV BTU/lb	Ash d.b.%	CV BTU/lb
2000	73.2	30.0	62.7	12.0	65.8	42.0	63.6	3383	80.1	999
2500	69.7	30.0	56.1	13.2	58.2	43.2	56.7	4381	79.6	1069
3000	66.3	30.0	50.0	14.4	52.4	44.4	50.8	5243	78.6	1209
3500	62.8	30.0	44.2	15.6	47.0	45.6	45.2	6044	77.5	1368
4000	59.3	30.0	38.7	16.8	42.6	46.8	40.1	6782	76.3	1553
4500	55.9	30.0	33.8	18.0	38.9	48.0	35.7	7418	74.5	1806
5000	52.4	30.0	29.5	19.2	35.0	49.2	31.6	8081	73.0	2016

NOTE: These results are optimistic in respect of the assumptions made as detailed in Table 5 for the plus 13mm coal fractions. The results may also be optimistic due to the simplified approach to the determination of tailings yield/quality. This will depend upon the type of plant/equipment found best suited to these coals.

SECTION 4

BENEFICIATION CHARACTERISTICS

4.3 Beneficiation by Total Washing - cont.

4.3.3 Similarly total washing of the 4000 - 5000 BTU/lb material may be considered. In this case it is noted that the product calorific value is significantly enhanced. It may therefore, be prudent to consider a compromise scheme, e.g. beneficiating the 2000 - 5000 BTU/lb material so as to take advantage of the useful coal available without reducing the average grade below the 7000 BTU/lb value. This would reduce product quality variations.

SECTION 5

PLANT REQUIREMENTS FOR LOW GRADE COAL

It must be noted that the partial beneficiation characteristics of the lower grade coals, as discussed in Section 4, are based purely as projections of the very limited data available for the higher grade coals. Investigations of the lower grade coals are therefore essential prior to making any specific plant proposals or preliminary designs.

The initial mine plans (e.g. A. Bell Revision 2 Ultimate Pit - January 3, 1978) shows that the bulk of the coal below Cut-Off Grade will be mined in the period years 15 to 25. If this remains the case for the Final Report Mine Plan then the work to obtain design data for any lower grade coal beneficiation can be based on appropriate "as mined" coal samples taken during the first decade of the mine operations.

For the first 15 years the relatively small quantities of low grade coal would be segregated and stockpiled - unless of course it proves practicable to blend them into the product.

5.1 Beneficiation by Screening

The Raw Coal handling system will of necessity have to incorporate screening facilities to permit crushing of the plus 40mm material. However, the 13mm screening plant for 4.1 would require substantially larger screen area per unit feed. It would probably not justify putting in this facility as part of the main coal handling plant when only 10% of the run-of-mine coal would be beneficiated in this way.

It would, at an appropriate stage, be necessary to test the breaking and screening characteristics of the low grade coals. Based on observations during the 1977 Trench A Mining Operations an extended breaker drum might be useful. This would make use of the soft characteristics of the high ash material with the hope of breaking off as minus 13mm rejects even more of the high ash material than anticipated in Table 2. After this operation a large area of screens - possibly with heated decks or rod decks - would be necessary.

As for the washing schemes considered below, the spasmodic production of low grade coals would necessitate a stockpiling facility to give a uniform sustained feed rate to any economically sized low grade coal beneficiation scheme.

SECTION 5

PLANT REQUIREMENTS FOR LOW GRADE COAL

5.2 Partial Washing

As a preliminary indication of plant requirements the Modular Coal Washery Scheme provides both of the "operating modes" required for the alternatives in paragraphs 4.2.2 and 4.2.3.

If 2,000,000 MTPA of low grade coal is to be partially cleaned the input is -

$$\frac{2,000,000}{350 \times 24 \times 0.7} = 340 \text{ MTPH at 70\% availability}$$

Thus provide for one 400 MTPH Module with a single thickener, and incorporate two tailings centrifuges (See Tailings Disposal Equipment Report). The fine coal washing section would not be required.

This plant could also provide cleaning for higher grade coals which are diluted beyond an acceptable quality in the mining and handling operations. The true low grade coals considered in this report represent the worst possible beneficiation problem. Diluted higher grade coals would give correspondingly better clean coal products. There may, therefore, ultimately be a need for a plant to treat various substandard mixtures of low grade and diluted high grade coals.

5.3 Total Washing

The Modular Coal Washery Scheme complete with somewhat extended fines washing section could provide the facilities for total washing low grade coal. A 400 MTPH Module with a larger thickener and four tailings centrifuges is envisaged in the costs quoted in paragraph 4.3.2.

It is, however, noted in Table 5 and paragraph 4.3 that facilities for the 28 x 100 mesh fines would not give a useful coal recovery. Simpler plant configurations may therefore be appropriate.

5.3.1 The two stage Water-Only Cyclone System (e.g. EMR Canmet) may be considered for washing the raw low grade coal crushed to 75mm. The main disadvantage of this system is that the multitude of cyclone operations: feed classifying, first washing, second washing and product thickening requires large volumes of water in circulation.

SECTION 5

PLANT REQUIREMENTS FOR LOW GRADE COAL

5.3 Total Washing - cont.

5.3.1 Operating costs for pumping are thus high and the several passes with circulating water will give a high tailings problem as found in the CSMT and EMR Test Washes and the Wet Attrition Tests. Large numbers of cyclones are required due to their relatively limited rejects capacity (25 to 30% of feed).

5.3.2 An alternative form of autogenous medium cyclone is available - the Simdex. The Simdex system was specifically developed for re-washing the rejects from older Baum Washeries - some five plants are in use in UK and Belgium re-processing old colliery waste dumps.

The Simdex uses the minus 28 mesh fine shale present to form a thick shale suspension in water which then acts in the cyclone as a dense medium for the 75mm x 28 mesh material. Since it was designed for waste coal treatment a Simdex Cyclone has some three times the rejects capacity of similar sized magnetite medium cyclone or water-only cyclone.

The minus 75mm raw coal is added to the shale suspension and is pumped to the Simdex Cyclones. The separation takes place as in a magnetite dense medium cyclone, and the products pass to drain and spray screens. From the drainage sections the circulating medium is recirculated to the feed sump. Note that medium losses are immediately made up by the minus 28 mesh fines contained in the feed. However, to permit control of medium gravity, the diluted medium from the spraying sections is passed through recovery cyclones. Cyclone underflow will be added to the feed sump if required to raise the separating gravity, and the excess is a thick slurry which may be dewatered without thickening for disposal with the discard. Cyclone overflow is used as primary spray water, and to lower the separating gravity if required, with the excess overflowing to the tailings thickener for water recovery.

SECTION 5

PLANT REQUIREMENTS FOR LOW GRADE COAL

5.3 Total Washing - cont.

5.3.2 Thus the Simdex plant is much simpler and cheaper to operate than other cyclone systems. It may be possible to think in terms of a low grade coal washery for Hat Creek at less than half the costs quoted in paragraph 4.3.2. The most significant benefit may well lie in the greatly reduced fine shale/water contact as compared with conventional plant, giving a reduced breakdown to tailings.

The process does have disadvantages. Its efficiency is similar to two-stage water only cyclones, and thus much lower than conventional magnetite medium cyclones. The separation gravities attainable depend on the characteristics of the minus 28 mesh shale particles. These factors have been used, so far as they can be presently evaluated, in making the predictions in Table 8.

The dependence of the process on the fine shale particles must be noted. Firstly the clay content of the Hat Creek rejects may give too viscous a medium: this would result in lower separation efficiencies and lower separation gravities. Results could, therefore, be far less promising than forcast in Table 8. Secondly the use of the plant is limited to washing "coals" with a significant fine shale content - thus it cannot be used for raw coals of below say 50% ash content.

Specific testwork is thus required.

5.3.3 A simpler form of "total washing" scheme may be purposely developed for low-grade Hat Creek coals based on the ready breakdown in water of the clayish rejects materials. For example the raw coal could be tumbled in a drum or mill with a quantity of water. The objective would be to recover the coal as screen overflow and the reject as a thick screen underflow.

Specific testwork would be required.

SECTION 5

PLANT REQUIREMENTS FOR LOW GRADE COAL

The concepts outlined in paragraphs 5.3.2 and 5.3.3 suggest that a viable scheme for recovery of useful coal from the low grade coals can be developed. Such a facility may not, however, be needed or viable in the first decade of the mine operations. This period can therefore be used to obtain the necessary design data.

The additional heating value recovered from the deposit by beneficiating and using the low grade coal is relatively small. The absence of any definite provisions within the mine scheme at this stage will not, therefore, alter the overall mine viability. The scheme should allow for such facilities to be added when proven.