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A COMPUTER METHOD FOR COAL WASHABILITY AND DEPENDENT PERFORMANCE CALCULATIONS

L.C. BIRD, M.W. MIKHAIL AND I.S. PARSONS

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A COMPUTER METHOD FOR COAL WASHABILITY AND DEPENDENT PERFORMANCE CALCULATIONS

by

L.C. Bird*, M.W. Mikhail** and I.S. Parsons***

ABSTRACT

A computer program is described for calculating and plotting coal washability data and calculating dependent performance data for a washing unit or plant. The dependent performance evaluation includes the determination of ash and yield errors, and organic efficiency values. The program is intended to help coal preparation, engineers and plant operators to interpret data and make decisions in adjusting operating conditions to meet changing feed washability characteristics and to achieve optimum plant performance.

The program was written in BASIC language for use with a Hewlett Packard 9845A desk-top computer. A program listing is available upon request from CANMET's Coal Research Laboratory, Edmonton.

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UN PROGRAMME DE CALCUL DE COURBES DE LAVABILITÉ ET DE DONNÉES CONNEXES

par

L.C. Bird*, M.W. Mikhail** et I.S. Parsons***

RÉSUMÉ

On décrit ici un programme en langage BASIC destiné à calculer et à tracer des courbes de lavabilité du charbon, et des données connexes pour une unité ou une installation de lavage. L'évaluation des données connexes comprend la détermination des erreurs de la teneur en cendre et de rendement, en plus des indexes de l'efficacité des valeurs organiques. Le programme vise à faciliter les travaux dans le domaine de la préparation du charbon, de même qu'à aider les ingénieurs et les opérateurs d'installations à interpréter les données et à prendre des décisions quant à l'ajustement des conditions d'opération pour se conformer aux caractéristiques changeantes de la lavabilité des produits d'alimentation. Il permet aussi aux installations d'atteindre une performance optimale.

Ce programme peut être utilisé sur un micro-ordinateur Hewlett Packard 9845A. Une liste du programme est disponible sur demande auprès du Laboratoire de recherche sur le charbon à Edmonton.

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INTRODUCTION

In Canadian coal preparation plants, samples are collected daily from feed and product streams for quality control. Ash content of the clean product is a prime interest since it is the criterion upon which the product price is based. Producers also want to maximize yield, i.e., the amount of clean product per tonne of run of mine (ROM) coal feed. Unfortunately, the clean product ash content increases with yield therefore to optimize his operation the producer must make a trade-off between these two criteria. In many plants, however, performance evaluation is based only on the ash content of the clean coal which in turn depends on the washability characteristics of the feed coal. Since these characteristics cannot be controlled except by blending, ash content alone is a poor basis upon which to judge performance.

To determine a more appropriate basis for judging and hence optimizing plant performance, three actual values must be known: relative density of separation (cutpoint), clean coal yield and its ash content. The yield and ash values are then compared with corresponding theoretical values to determine organic efficiency, ash and yield errors. Plant performance can then be judged in a manner that is not wholly dependent on feed washability. Performing these calculations manually every day are both tedious and subject to human error.

Other lengthy calculations are necessary when the plant feed is blended from different seams. The blending ratio varies from day to day depending on the mining operation and the conditions of different seams. The washability of the blended feed can be determined as a weighted average of washabilities from the different seams. Each time the blending ratio changes the washability of the new feed must be calculated. Desk-top or minicomputers can simplify the cumbersome calculations and save time for preparation engineers.

This report is the first in a series intended to help coal preparation engineers and plant operators interpret data and make decisions in adjusting their wash plants to perform smoothly and efficiently. A computer program is presented which is designed to calculate and plot feed washability characteristics from a blend of different seams, and to evaluate the plant's performance by calculating organic efficiency and ash and yield errors. A sample run and program user's manual are presented along with the necessary program instructions. The program language is BASIC, written for a Hewlett Packard 9845A desk-top computer. A listing is available on request from CANMET's Coal Research Laboratory, Edmonton.

PREPARATION CONCEPTS

WASHABILITY

Coal washability reflects and quantifies the theoretical limitations of beneficiation processes as they relate to coal's ash or sulphur components. To study washability, various size fractions of the coal are float-sink tested at pre-selected relative densities (specific gravities), using commercially available organic liquids of standardized relative densities to separate coal to required fractions. These fractions are then dried, weighed and analyzed for ash, if applicable sulphur and/or heat value (kJ/kg). The data are mathematically combined on a weighted basis and used to develop the washability curves that are characteristic of the coal (1). The following define various relationships determined from the washability data (Fig. 1):

(1) Cumulative float curve is the percentage of the feed material that will be recovered for any given clean product ash content, or conversely, the clean product ash content for any desired yield.

(2) Elementary ash curve indicates the ash content that the dirtiest particle in the clean product will have for any yield.

(3) Cumulative sink curve indicates the ash content of the reject product for any yield, or the yield at any ash content of the rejects.

(4) Relative density curve indicates the expected yield percentage at any desired cutpoint or,

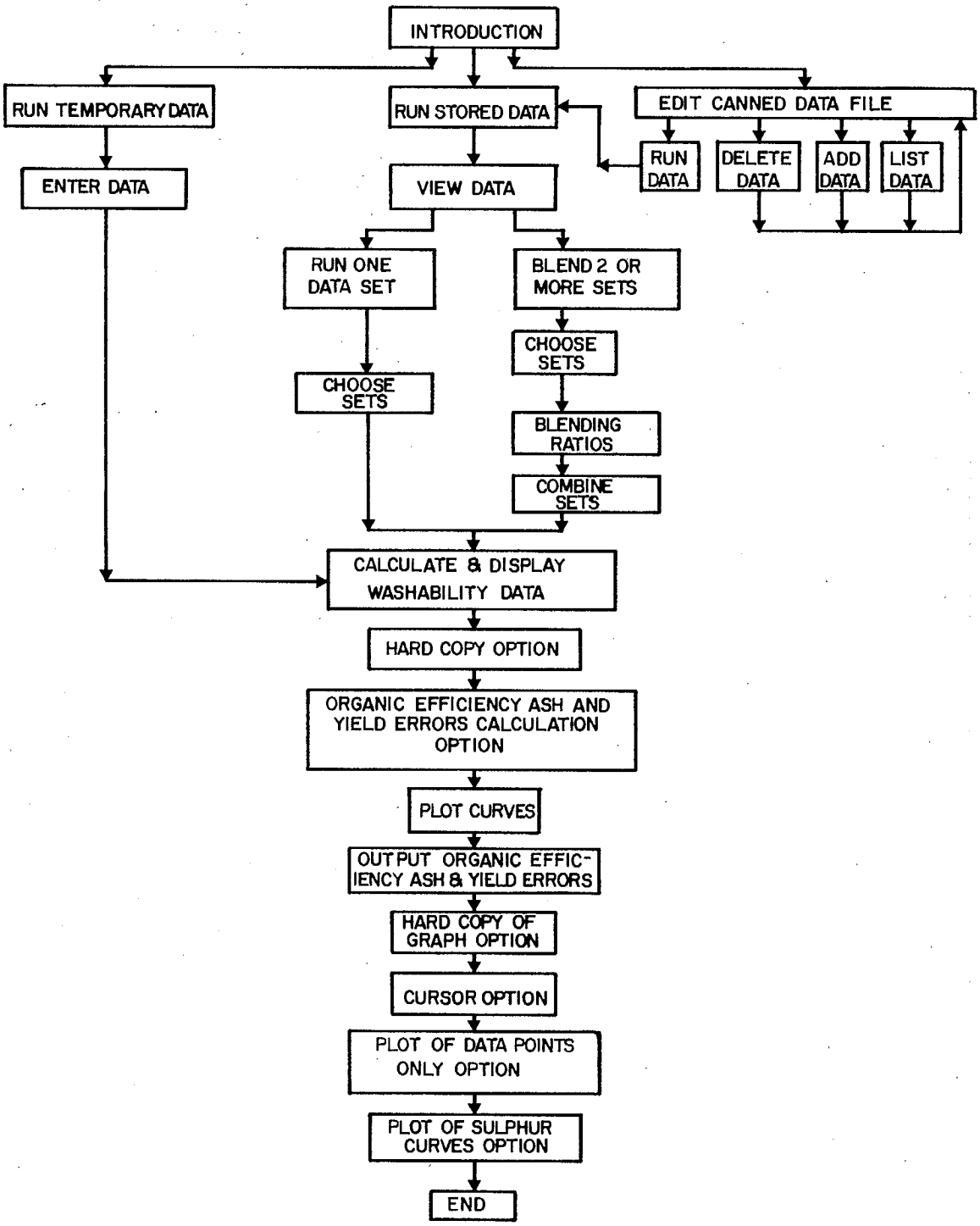

Fig. 1 - Decision making flowsheet

the cutpoint necessary for any pre-selected yield percentage.

(5) Near-density curve indicates the percentage of the feed material that lies within ±0.1 relative density units of the relative density of separation.

PERFORMANCE CRITERIA

Evaluating the performance of a wash plant or unit establishes the efficiency of the density separation. Performance criteria are, therefore valuable in determining whether better plant performance could be expected (2). Performance criteria can be classified according to their degree of dependence upon the relative density composition of the raw feed, although under certain circumstances some of the performance criteria are essentially independent. Some dependent criteria relating to daily operations, can be calculated easily with minimum analysis.

The yield and quality of a washed coal are of direct and practical interest in any washing operation. However, they depend on the washability characteristics of the raw coal thus are inadequate for routine day-to-day control. For example, if a wash plant's yield were lower than average, it would not necessarily mean that control action should be taken. Possibly, the plant was operating at optimum but the use of high-ash raw coal feed resulted in more reject material than usual.

To optimize plant performance, it would be useful to have a standard for comparison that does not depend directly on washability data. Three criteria, organic efficiency, ash and yield errors, are not directly dependent on feed washability, therefore they are more suitable for routine control purposes.

(1) Organic efficiency expresses the yield of washed coal from actual plant data as a percentage of the theoretical yield of coal of the same ash content as determined by float-sink analysis. Mathematically, it is written:

$$\text{Organic eff.} = \frac{\text{actual yield of washed coal}}{\text{theoretical yield}} \times 100$$

High organic efficiency alone does not necessarily indicate satisfactory performance. Ash reduction must be considered as well.

(2) Ash error is a direct measurement of the degree to which the ash content of the washed coal is increased by separation errors inherent in any process. It is the numerical difference between the actual and theoretical ash content (as determined by float-sink analysis) of the washed coal at the yield obtained.

Ash error = (% of clean coal ash) - (% of float coal ash at the recovery of clean coal obtained)

(3) Yield error is the difference between the yield of the coal actually obtained and the theoretical yield as determined by float-sink analysis at the ash content of the washed coal:

Yield error = (% of clean coal recovered) - (% of float coal recovered at the ash content of clean coal obtained)

The above criteria are directly related to impairment in yield and ash content caused by imperfect washing. It is cautioned that since they are influenced by the separation cutpoint, equipment treating coals having different washability characteristics or washing them at substantially different cutpoints cannot be compared solely on the basis of these dependent criteria.

PLANT OPTIMIZATION

A coal preparation plant operator should consider adjusting plant operating conditions to produce the required product:

(1) when feed washability characteristics change; and
(2) when there is a departure from optimum performance.

In the first case the operator can use the described program to determine approximately, from feed washability calculation, the theoretical separation cutpoint to produce the desired ash content. The method is only approximate because errors in separation lead to misplacement of material, and size fractions are washed at different cutpoints in various washing units. To accurately determine required cutpoints, the separation efficiency of each unit should first be determined in relation to its feed characteristics. However, by using feedback from products analysis to calculate ash and yield errors, the operator can closely estimate the required cutpoint and in turn readjust it. Prediction of performance for different washing units using mathematical models is the subject of a future report.

In the second case, organic efficiency and ash and yield errors would quantify deviation from optimum performance. This deviation could be caused by several conditions, including overloading certain sections of the plant, slime build-up, cyclone plugging, deviation from set cutpoints and various mechanical and maintenance problems. The computer program acts as a yardstick to evaluate actual performance, thus indicating necessary corrective action.

COMPUTER CALCULATIONS

DATA INPUT

Computer data input is composed primarily of the float-sink analysis of the feed to the wash plant or particular washing unit (Table 1). When seams are to be blended, the blending ratio and the washability analysis of each seam must be input. To calculate dependent performance criteria, the user must also supply the computer with the following data:

(a) number of seams to be blended;
(b) blending ratio of each;
(c) number of relative density ranges in the float-sink analysis;
(d) mass per cent of each relative density range in the feed, and ash per cent and sulphur per cent for each range (sulphur per cent may be replaced by thermal value, either kJ/kg or BTU/lb);
(e) yield, separation cutpoint and ash percentage in the clean coal, all determined during an actual test run of the plant or unit.

Note that the program is capable of storing permanently a large number of washability data sets (Fig. 1). The number is limited only by the available space on the storage medium. It is therefore possible to enter only once the washability data (c and d above) for a number of seams, after which they can be recalled and blended in any manner with minimum effort.

DATA OUTPUT

The initial computer data output contains the washability characteristics of the feed (Table 2). This includes, for each relative density fraction, the elementary (input) data, the cumulative float and sink data. The cumulative data indicate what product characteristics (yield, ash, sulphur and heat value) can be theoretically expected for any desired cutpoint.

The computer displays graphically the same data in five washability curves (Fig. 2):

Table 1 - Typical input of float-sink data to computer

Relative density fractions	Mass %	Ash %	Sulphur %
Float - 1.30	24.69	3.07	1.20
1.30 - 1.35	18.26	6.37	1.80
1.35 - 1.40	12.31	10.00	2.30
1.40 - 1.45	8.52	13.70	3.10
1.45 - 1.50	6.24	17.55	4.20
1.50 - 1.60	8.34	22.81	4.90
1.60 - 1.80	7.52	32.21	5.60
1.80 - 2.00	3.09	42.42	6.00
2.00 - Sink	11.03	68.28	7.20

Table 2 - Typical washability data output from computer

Relative density fractions	Elementary data			Cumulative data					
				Float			Sink		
	Mass %	Ash %	Sulphur %	Mass %	Ash %	Sulphur %	Mass %	Ash %	Sulphur %
Float - 1.30	24.69	3.07	1.20	24.69	3.07	1.20	100.00	18.58	3.24
1.30 - 1.35	18.26	6.37	1.80	42.95	4.47	1.46	75.31	23.67	3.91
1.35 - 1.40	12.31	10.00	2.30	55.26	5.70	1.64	57.05	29.20	4.59
1.40 - 1.45	8.52	13.70	3.10	63.78	6.77	1.84	44.74	34.49	5.22
1.45 - 1.50	6.24	17.55	4.20	70.02	7.73	2.05	36.22	39.38	5.72
1.50 - 1.60	8.34	22.81	4.90	78.36	9.34	2.35	29.98	43.92	6.04
1.60 - 1.80	7.52	32.21	5.60	85.88	11.34	2.64	21.64	52.05	6.47
1.80 - 2.00	3.09	42.42	6.00	88.97	12.42	2.75	14.12	62.62	6.94
2.00 - Sink	11.03	68.28	7.20	100.00	18.58	3.24	11.03	68.28	7.20

(a) cumulative float ash curve;
(b) elementary ash curve;
(c) cumulative sink ash curve;
(d) relative density distribution curve, and
(e) near density (±0.1 relative density units) distribution curve.

The computer then uses these curves to generate the theoretical yield and ash per cent in the clean coal, at the indicated values for cutpoint, yield and ash per cent. From the above curves and input values of cutpoint (dp), yield and ash per cent in clean coal it calculates and outputs the yield and ash errors and organic efficiency of the particular unit or wash plant. The final data output is also a graph of washability curves, this time indicating the washability characteristics of the sulphur in the feed, if applicable.

COMPUTER METHOD USED TO PLOT CURVES

To draw the curves from tabulated washability data, the computer first plots the discrete washability data points. For example, to plot the points in the relative density distribution curve (curve 4, Fig. 1) the computer plots the range end-points (x coordinates) versus the cumulative float mass per cent (y coordinates) on the computer screen (Table 2, Fig. 3). Next, it uses a cubic spline interpolation routine to locate points between those already plotted (3,4). The computer then joins each of these new points with a line. There are 30 such interpolated points between each discrete point. When joined, they give a smooth curvilinear appearance (Fig. 4).

The spline function determines a curve S(x) passing through the mass and ash percentages (or relative density) data points (x_1, y_1), (x_2, y_2) ... (x_n, y_n) where x_i are distinct and $x_1<x_2<....<x_n$ but need not be equally spaced (3,4). The fitted curve is a third degree spline function that is so named because it approximates the behaviour of a mechanical spline used by draftsmen to draw a smooth curve through a set of points. The curve has continuous first and second derivatives, and is the smoothest curve through the given points. In fact, the curve S(x) is a piece-wise function given by a different polynomial in each interval. The junction points x_i are smooth because the two polynomials that meet there have the same ordinate and the same first and second derivatives. The process to determine S(x) involves solving a set of simultaneous linear equations and is iteratively carried out by the method of successive over relaxation. The accuracy tolerance to which parameters of the second derivative are found in the subroutine is 0.01.

Notwithstanding that the spline routine can take a relatively long time (an average data set can take up to 15 s) to generate one curve,

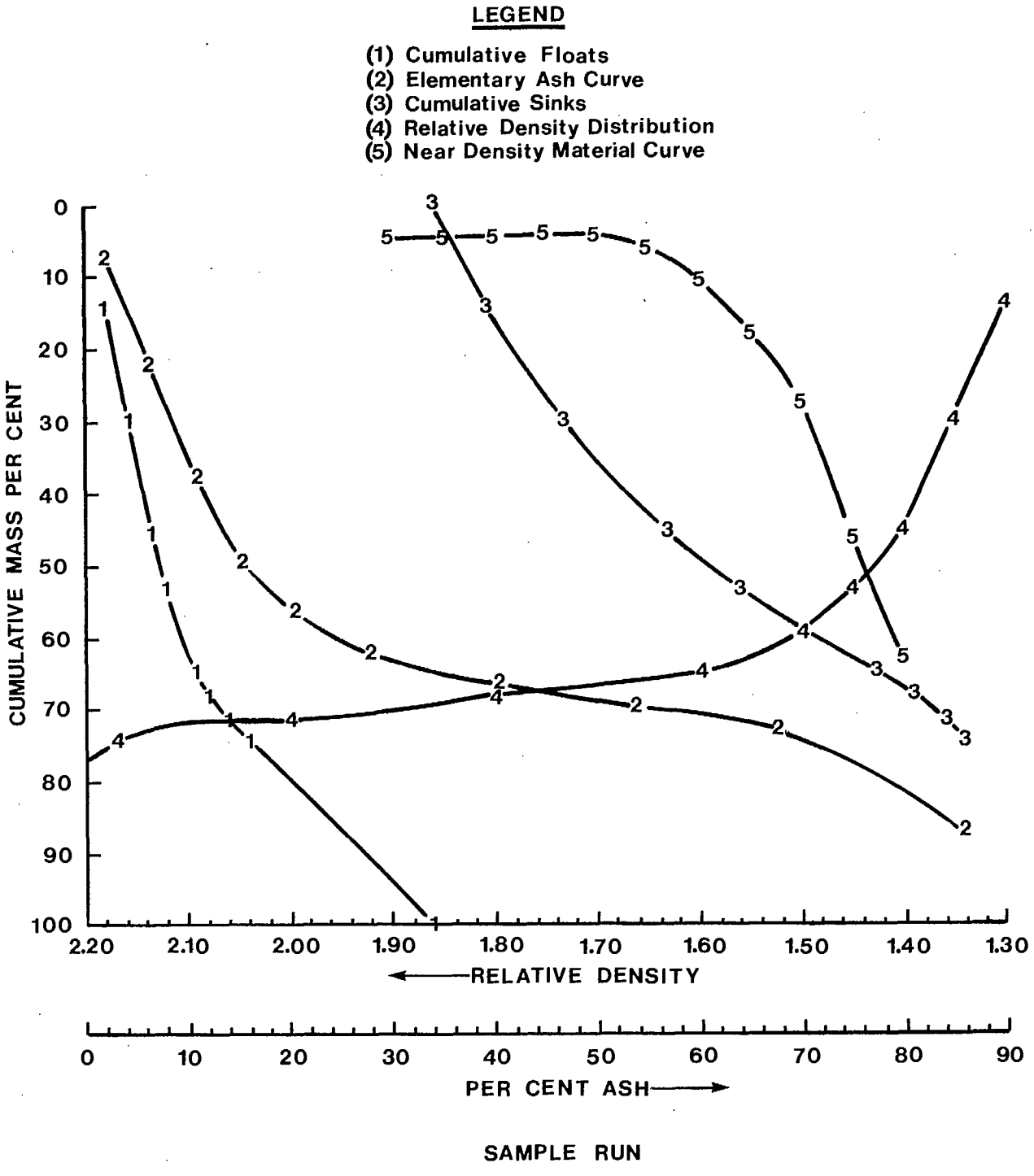

Fig. 2 - Washability curves as drawn by cubic spline

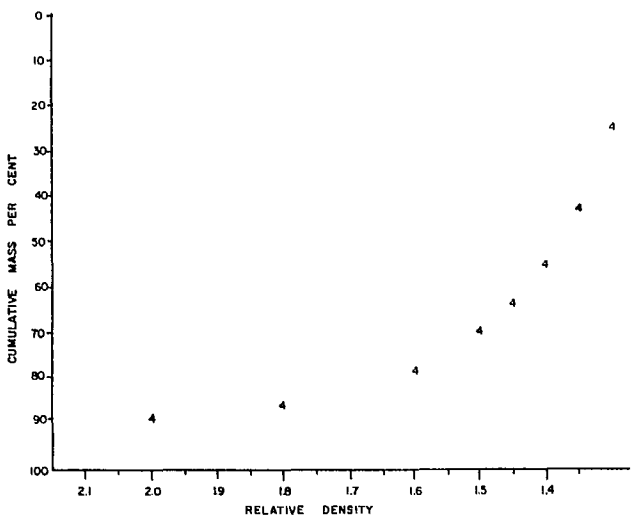

Fig. 3 - First step in plotting curves; locating discrete data points

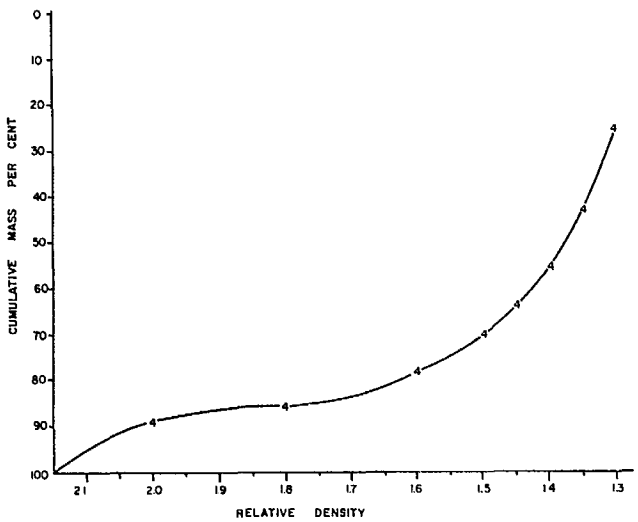

Fig. 4 - Completed relative density distribution curve

it has only one major problem. For data in which abscissa values are close and a relatively large difference exists in the corresponding ordinate values, the generated curve will oscillate above and below the obvious curve of best fit (Fig. 5). Nevertheless, this method still proves superior to using a least squares polynominal as the spline curve goes through all the discrete washability data points as required (Fig. 1,6). If the operator is not satisified with the shape of the spline curve, he can instruct the computer to print a copy of the graph indicating only the data points (see Sample Run, Appendix B). The user can then sketch his own curve to fit the points.

RUNNING THE PROGRAM

The program makes extensive use of prompts, enabling anyone to run the program with minimum instruction. In most cases the only instruction necessary can be obtained from the Program User's Manual (Appendix A). Whenever data sets are entered, the user has a chance to view them on the CRT screen and make any necessary correction before continuing.

As washability calculations are often performed on more than one float-sink data set using the same relative density ranges, a provision in the program overcomes the need to repeat data entries, by storing permanently a set of commonly used relative density ranges. Further provisions in the program permit storage of whole sets of washability data so that they may be recalled and used as needed.

Other options allow the user to avoid unnecessary calculations and data entries, thus reducing the time per run. Using all possible options, the total time for a complete run is about 10 min.

Data points can be read very accurately from the washability curves appearing on the CRT by placing the intersection of two cross hairs (cursor) on any curve, at any desired location and pressing the CONTINUE button on the computer's console. The computer will return the exact coordinate values.

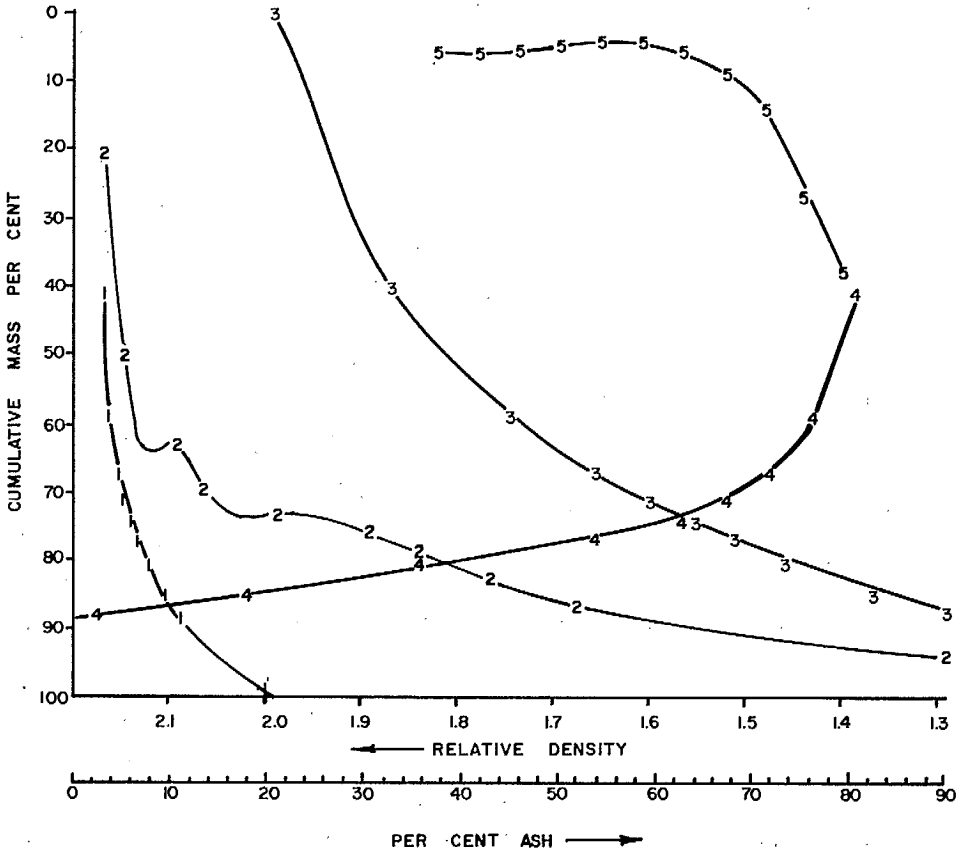

Fig. 5 - Limitations of the spline function (note the oscillations in curve 2)

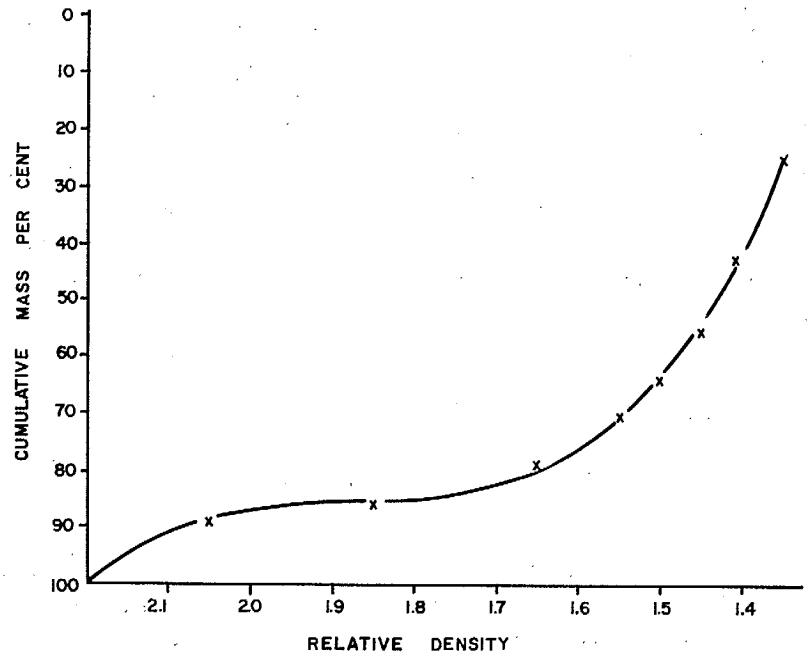

Fig. 6 - Cubic polynomial fitting of relative density distribution (curve does not go exactly through points)

CONCLUSION

A computer program has been developed for the calculation of washability data, blending, organic efficiency, and yield and ash errors. The program is simple in design to enable operators with little or no computer experience to use a desk-top computer to interpret data and make daily decisions in adjusting wash plants. Coal preparation terms are defined and briefly explained along with steps and options included in the program.

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APPENDIX A

PROGRAM USER'S MANUAL

PROGRAM USER'S MANUAL

WASHABILITY AND DEPENDENT PERFORMANCE CALCULATIONS

I. Object of Program

This program is intended to help coal preparation engineers and plant operators interpret data and make decisions in adjusting wash plants to attain maximum efficiency.

From various float-sink analyses, the program combines various seams or size fractions into one float-sink data set representing the plant or unit feed. It then generates a complete set of washability curves along with ash and yield errors and organic efficiency.

II. Special Considerations

1. This program is intended for use with a Hewlett Packard 9845A desk-top computer having the following options:
   (a) extended memory (64K)
   (b) graphics
   (c) internal thermal printer
   (d) right-hand tape drive.
2. The maximum number of seams or size fractions that may be combined is 15.
3. If the relative density ranges in the float-sink data do not go as high as 2.00, the adjusted near gravity material curve cannot be calculated.
4. If the float-sink analysis contains only mass and ash percentages, the user may enter zeros for either sulphur percentages or heat values. Note that in this case requesting a plot of the washability curves for sulphur removal will lead to ERROR 31.

III. Methods and Formulae

1. Methods for calculating washability data and plotting the curves are provided elsewhere (1).
2. Methods for determining ash and yield errors and organic efficiency are based on data collected during an actual run of the unit or wash plant. The data that must be collected are ash content and per cent clean coal recovery. The calculations are then made as follows:

   organic efficiency = (yield of clean coal obtained in the trial run) ÷ (theoretical yield of float coal of the same ash content) x 100

   ash error = (per cent of clean coal ash) - (per cent of float coal ash at the recovery of clean coal obtained)

   yield error = (per cent of clean coal recovered) - (per cent of float coal recovered at the ash content of clean coal obtained)

IV. User instructions

1. Load the program into memory:
   (a) with the power to the computer switched off, ensure that the AUTOST key is depressed, and that the proper tape cartridge is in place
   (b) turn the computer ON

   or:

   (a) turn the computer ON
   (b) Type LOAD "AUTOST"
   (c) press EXECUTE
   (d) press RUN

2. When "Enter Your Choice" is displayed:
   (a) enter 1 if you wish to run the program using data stored in computer memory during a previous run of this program
   (b) press CONT
   (c) go to 3

   or:

   (a) enter 2 if you wish to run the program using data not to be stored
   (b) press CONT
   (c) go to 15

   or:

   (a) enter 3 if you wish to store any number of data sets in computer memory, or if you wish to delete any data - the amount of data you may store depends on the available space on the storage medium (tape)

(b) press CONT
(c) go to 43

or:

(a) enter 4 if you wish to view any of the stored data
(b) press CONT
(c) go to 43

3. When "To see the data for any of the sets enter its number (enter 0 if none desired)" is displayed:
   (a) enter the number corresponding to the data set that you would like displayed on the CRT
   (b) press CONT

or:

   (a) enter 0 if you do not wish to view any of the stored data
   (b) press CONT
   (c) go to 5

4. When "Do you wish to see another data set? (Y/N)" is displayed:
   (a) type Y if you wish to view another stored data set
   (b) press CONT
   (c) go to 3

or:

   (a) type N if you do not wish to view another data set
   (b) press CONT

5. When "Do you wish to combine more than 1 data set? (Y/N)" is displayed:
   (a) if you wish to combine any 2 or more data sets, on a weighted basis, into one data set, type Y
   (b) press CONT

or:

   (a) if you wish to use only 1 data set in the washability calculations, type N
   (b) press CONT
   (c) go to 14

6. When "Enter the numbers of data sets that you would like to combine" is displayed:
   (a) enter the number of data sets that are to be combined into 1 data set
   (b) press CONT

7. When "From the list enter the number of the first data set that you would like to combine" is displayed:
   (a) enter the number corresponding to one of the data sets that is to be combined with another data set(s)
   (b) press CONT
   (c) go to 9

8. This step is repeated for each remaining data set that you wish combined when "Enter the number of the next set you would like to combine" is displayed:
   (a) enter the number corresponding to another data set that is to be combined
   (b) press CONT

9. This step is repeated for each of the data sets to be combined. When "Enter the blending ratio of this data set" is displayed:
   (a) enter the mass per cent of all of the combined data sets that this data set represents
   (b) press CONT
   (c) if there are more data sets to be combined, go to 8

10. When "Is the above data correct? (Y/N)" is displayed:
   (a) enter Y if the data sets and blending ratios are correct as indicated. Note that if the blending ratios are less than 100 when added, the computer will automatically recalculate them in such a manner that each data set is combined in the correct proportion yet the total of the blending ratios will be 100
   (b) press CONT

or:

   (a) enter N if the data sets and blend-

ing ratios are not correct as displayed
(b) press CONT
(c) go to 6

11. When "Enter the name that you would like to give the combined data" is displayed:
(a) enter the name that you would like the final, combined data set to have
(b) press CONT

12. When "Do you want a copy of the data? (Y/N)" is displayed:
(a) enter Y if you would like a hard copy printout on the thermal printer of the individual data sets
(b) press CONT

or:

(a) enter N if you do not want a hard copy of the input data
(b) press CONT

13. When "Would you like a hard copy printout of this data? (Y/N)" is displayed:
(a) enter Y if you would like a hard copy of the combined data printed out on the thermal printer
(b) press CONT
(c) go to 49

or:

(a) enter N if you do not want a hard copy of the combined data
(b) press CONT
(c) go to 49

14. When "Enter the data set number that you wish to do washability calculations for" is displayed:
(a) enter the number corresponding to the data set that you wish to use as input data
(b) press CONT
(c) go to 49

15. When "Are these ranges okay? (Y/N)" is displayed:
(a) enter Y if the displayed relative density ranges are the same as the ones in your data set
(b) press CONT
(c) go to 23

16. When "Please enter the number of relative density ranges you wish to use" is displayed:
(a) enter the number of relative density ranges you have in your float

17. When "Please enter float cutpoint" is displayed:
(a) enter the relative density of the lightest solution used in the float-sink analysis
(b) press CONT

18. When "Please enter the upper bound of the next relative density range" is displayed:
(a) enter the relative density of the next heaviest solution used in the float-sink analysis
(b) press CONT
(c) repeat this step until "Do you want to correct any of the above data? (Y/N)" is displayed

19. When "Do you want to correct any of the above data that are displayed? (Y/N)" is displayed:
(a) enter N if the displayed data are correct
(b) press CONT
(c) go to 23

or:

(a) enter Y if the displayed data are incorrect
(b) press CONT

20. When "Enter the range No. of the ERROR" is displayed:
(a) enter the number corresponding to the incorrect range
(b) press CONT
(c) note that if the first (float) range is incorrect you should enter range

2 as being incorrect and if the last (sink) range is incorrect you should enter the second last range number

21. When "Enter the corrected range (lower bound, upper bound)" is displayed:
    (a) enter the correct lower and upper bounds of the range with a comma between each
    (b) press CONT

22. When "More corrections? (Y/N)" is displayed:
    (a) enter Y if there are more corrections to be made
    (b) press CONT
    (c) go to 20

or:

    (a) enter N if there are no more corrections to be made
    (b) press CONT

23. When "Please enter mass per cent in relative density range 1" is displayed:
    (a) enter the mass per cent of the feed material that is contained in the lightest relative density
    (b) press CONT

24. When "Please enter mass per cent in next relative density range" is displayed:
    (a) enter the mass per cent of the feed material that is contained in the next heaviest relative density fraction
    (b) press CONT
    (c) repeat this step until the computer beeps

25. When "Do you want to correct any of the above data? (Y/N)" is displayed:
    (a) enter Y if a mistake was made in entering the data
    (b) press CONT

or:

    (a) enter N if all of the data on the CRT are correct
    (b) press CONT
    (c) go to 29

26. When "Enter the relative density range # which has an incorrect value of Mass %" is displayed:
    (a) enter the relative density range number (as indicated on the CRT) that has an erroneous value for mass per cent
    (b) press CONT

27. When "Enter the new value of Mass %" is displayed:
    (a) enter the correct value of mass per cent in the relative density range under consideration
    (b) press CONT

28. When "More corrections? (Y/N)" is displayed:
    (a) enter Y if any further erroneous values for mass per cent are indicated
    (b) press CONT
    (c) go to 26

or:

    (a) enter N if all of the errors have been corrected
    (b) press CONT

29. When "Please enter ash content in relative density range 1" is displayed:
    (a) enter the ash content of the feed sample in the lightest relative density range in the float-sink analysis
    (b) press CONT

30. When "Please enter ash content in next relative density range" is displayed:
    (a) enter the ash content of the feed sample in the next heaviest relative density range in the float-sink analysis
    (b) press CONT
    (c) repeat this step until the computer beeps

31. When "Do you want to correct any of the above data? (Y/N)" is displayed:

(a) enter Y if the data displayed are erroneous
(b) press CONT

or:

(a) enter N if the displayed data contain no errors
(b) press CONT
(c) go to 35

32. When "Enter the relative density range # which has an incorrect value of ash content" is displayed:
    (a) enter the relative density range number (as indicated on the CRT) which has an erroneous value for ash content
    (b) press CONT

33. When "Enter the new value for ash content" is displayed:
    (a) enter the correct value of ash content in the relative density range under consideration
    (b) press CONT

34. When "More corrections" is displayed:
    (a) enter Y if further erroneous values of ash content are indicated
    (b) press CONT
    (c) go to 32

35. When "Do you want to enter sulphur %, BTU/lb, or kJ/kg? (S, BTU, K)" is displayed:
    (a) enter S if you want the washability data for sulphur content to be calculated
    (b) press CONT
    (c) go to 37

or:

(a) enter BTU if you want the washability data for heat value to be calculated in Imperial units
(b) press CONT

or:

(a) enter K if you want the washability data for heat value to be calculated in metric units. (Note this requires input of heat value in metric units)
(b) press CONT
(c) go to 37

36. When "Do you want BTU/lb converted to kJ/kg? (Y/N) (1 BTU/lb = 2.326 kJ/kg)" is displayed:
    (a) enter Y if you would like to have the washability analysis for heat value carried out in metric units
    (b) press CONT

or:

(a) enter N if you would like the washability analysis for heat value carried out in Imperial units
(b) press CONT

37. When "Enter the % sulphur content (BTU content or kJ/kg content) in relative density range 1" is displayed:
    (a) enter the value of the displayed parameter (either % sulphur, BTU/lb or kJ/kg) in the lightest relative density range in the float-sink data
    (b) press CONT

38. When "Please enter % sulphur content (BTU content or kJ/kg content) in the next relative density range" is displayed:
    (a) enter the value of the displayed parameter (either % sulphur, BTU/lb or kJ/kg) in the next heaviest relative density range in these float-sink data
    (b) press CONT
    (c) repeat this step until the computer beeps

39. When "Do you want to correct any of the above data? (Y/N)" is displayed:
    (a) enter Y if erroneous values are indicated
    (b) press CONT

or:

(a) enter N if no erroneous values are indicated
(b) press CONT

(c) go to 49 if you answered 2 in step 2
(d) go to 43 if you answered 3 or 4 in step 2

40. When "Enter the relative density range # which has an incorrect value" is displayed:
(a) enter the relative density range number (as indicated on the CRT) which has an incorrect value
(b) press CONT

41. When "Enter the correct value" is displayed:
(a) enter the correct value of the parameter for the relative density range in question
(b) press CONT

42. When "More corrections? (Y/N)" is displayed:
(a) enter Y if more incorrect values are indicated
(b) press CONT
(c) go to 40

or:

(a) enter N if no more incorrect values are indicated
(b) press CONT
(c) go to 49 if you answered 2 in step 2. Go to 43 if you answered 3 or 4 in step 2

43. When "Enter your choice from the above options" is displayed:
(a) enter 1 if you wish to add a data set to the list
(b) press CONT

or:

(a) enter 2 if you wish to delete a data set from the list
(b) press CONT
(c) go to 45

or:

(a) enter 3 if you wish to list the data sets stored on the CRT
(b) press CONT
(c) go to 47

or:

(a) enter 4 if you wish to calculate washability data and curves
(b) press CONT
(c) go to 3 Note: all you can use is stored data to draw curves from this point

44. When "Enter the name you wish to give the data set (< = 50 characters)" is displayed:
(a) using no more than 50 characters (including blanks) type in a name for your data set
(b) press CONT
(c) go to 15

45. When "Enter the number of the data set that you wish deleted" is displayed:
(a) enter the number corresponding to the data set that you wish to delete
(b) press CONT

46. When "Is this information correct? (Y/N)" is displayed:
(a) enter Y if the data set to be deleted is correctly identified
(b) press CONT
(c) go to 43

or:

(a) enter N if the data set indicated is not to be deleted
(b) press CONT
(c) go to 43

47. When "Enter your choice" is displayed:
(a) enter 1 if you wish to view all of the data sets on the CRT at once
(b) press CONT
(c) go to 43

or:

(a) enter 2 if you wish to view only 1 specific data set
(b) press CONT

48. When "Enter the number of the data set that you wish to view" is displayed:
(a) enter the number corresponding to the data set that you wish to view on the CRT
(b) press CONT
(c) go to 43

49. When "Enter the mid-point of the sink range" is displayed:
    (a) enter the average relative density of all of the coal that sank in the heaviest relative density solution in the float-sink test
    (b) press CONT

50. When "Would you like a hard copy of the above data? (Y/N)" is displayed:
    (a) enter Y if you would like a copy of the washability data printed out on the thermal printer
    (b) press CONT
    (c) go to 56 if in step 66, Y was entered

or:

    (a) enter N if you do not want a copy of the washability data printed out on the thermal printer
    (b) press CONT

51. When "Do you want the organic efficiency etc. calculated (Y/N)" is displayed:
    (a) enter Y if you want the computer to calculate organic efficiency, ash error, yield error and per cent near density material
    (b) press CONT

or:

    (a) enter N if you do not want the dependent performance calculation performed
    (b) press CONT
    (c) go to 56

52. When "Enter the actual yield" is displayed:
    (a) enter the wash plant or unit's yield observed during an actual run using the feed whose float-sink data were input
    (b) press CONT

53. When "Enter the actual ash" is displayed:
    (a) enter the ash percentage observed in the clean coal during an actual run of the wash plant or unit using the feed whose float-sink data were input
    (b) press CONT

54. When "Enter the cutpoint (enter 0 if near density material calcs not desired)" is displayed:
    (a) enter the cutpoint used in the actual run that resulted in the yield and ash percentages entered in steps 52 and 53. If you do not wish to know the per cent of near density material in the run, enter 0. The dependent performance data will still be calculated and output
    (b) press CONT

or:

    (a) enter 0 if you do not want to know the per cent near density material or, if the cutpoint is not at least 0.1 relative density units greater than the relative density of the lightest cut in the float-sink data
    (b) press CONT

55. When "Do you want to correct these values? (Y/N)" is displayed:
    (a) enter Y if any of the data indicated are in error
    (b) press CONT
    (c) go to 52

or:

    (a) enter N if all of the data are correct
    (b) press CONT

56. When "Please enter the title that you wish to give your plot, use no more than 40 characters" is displayed:
    (a) enter the title of the washability curves using no more than 40 characters
    (b) press CONT

57. When "Please press 'CONT' when you are finished viewing the plots" is displayed:
    (a) wait for the computer to beep

(b) press CONT

58. When "Would you like to use the cursor on the plot? (Y/N)" is displayed:
    (a) enter Y if you would like a copy of the washability curves printed out on the thermal printer
    (b) press CONT

59. When "Would you like to use the cursor on the plot? (Y/N)" is displayed:
    (a) enter Y if you would like to use computer generated cross hairs on the CRT to accurately read data points off the washability curves
    (b) press CONT

or:

    (a) enter N if it is not desired to accurately read data from the washability curves
    (b) press CONT
    (c) go to 64

60. When "Please answer relative density or % ash (% S)" is displayed:
    (a) enter RD if the cross hairs are to read the abscissa value of the data point from the relative density scale on the graph
    (b) press CONT

or:

    (a) enter % ash (% S) if the cross hairs are to read the abscissa value of the data point from the ash per cent (sulphur per cent) scale on the graph
    (b) press CONT

61. When the washability curves plot is returned to the CRT:
    (a) using the up, down, left and right arrow keys (under the heading DISPLAY on the keyboard) and the SHIFT key, place the cross hairs on the data point for which it is desired to find the coordinate values
    (b) press CONT

62. When "Do you want to use the cursor again? (Y/N)" is displayed:
    (a) enter Y if more data points are to be located
    (b) press CONT

or:

    (a) enter N if no more data points are to be located
    (b) press CONT
    (c) go to 64

63. When "Do you want to change the axes it is lined up with? (Y/N)" is displayed:
    (a) enter Y if the abscissa value of the next data point is to be read using the other horizontal scale
    (b) press CONT
    (c) go to 60

or:

    (a) enter N if the abscissa value for the next data point is to be read using the same horizontal scale
    (b) press CONT
    (c) go to 61

64. When "Answer?" is displayed:
    (a) enter Y if you would like a copy of the washability data points plotted on the graph without the curve joining them
    (b) press CONT

or:

    (a) enter N if you do not want a copy of the washability data points only
    (b) press CONT

65. If heat values were entered from the float-sink data rather than sulphur percentage or if the response to step 67 was Y:
    (a) go to 67

66. When "Do you want to see the sulphur curves for your data? (Y/N)" is displayed:
    (a) enter Y if it is desired to see the washability curves for sulphur

(b) press CONT

(c) go to 50

or:

(a) enter N if it is not desired to see the sulphur washability curves

(b) press CONT

67. End of Program

APPENDIX B

SAMPLE RUN

WASHABILITY CURVES PROGRAM
****

To run this program using previously stored data press 1
To run this program using data you do not wish stored press 2
To store data for use now and in future press .. 3
To view the stored data press 4
Enter your choice
1
GETTING CANNED

*** CANNED DATA ROUTINE ***

Float - Sink data sets are stored permanently in memory for the following:

(1) Seam A
(2) Seam B
(3) Seam C
(4) Seam D
(5) Seam E
(6) Seam F

To see the data for any of the sets enter it's number (enter 0 if none desired)
2
(2) Float - Sink data for Seam B

Rel. Density	Mass %	Ash %	BTU/lb
Float - 1.30	23.60	2.00	12000
1.30 - 1.35	26.30	6.25	11000
1.35 - 1.40	25.60	10.88	10000
1.40 - 1.45	12.50	15.17	9000
1.45 - 1.50	7.50	19.47	8000
1.50 - 1.60	3.80	25.08	7000
1.60 - 1.80	0.20	35.41	6000
1.80 - 2.00	0.00	47.91	5000
2.00 - 2.17	0.00	60.42	4000
2.17 - Sink	0.50	83.79	3000

Do you wish to see another data set? (Y/N)
Y
To see the data for any of the sets enter it's number (enter 0 if none desired)
3
(3) Float - Sink data for Seam C

Rel. Density	Mass %	Ash %	kJ/kg
Float - 1.30	0.00	3.20	26832
1.30 - 1.35	0.11	8.81	24596
1.35 - 1.40	0.27	14.76	22360
1.40 - 1.45	1.25	18.75	20124
1.45 - 1.50	3.49	23.23	17888
1.50 - 1.60	8.57	29.83	15652
1.60 - 1.80	7.55	40.74	13416
1.80 - 2.00	8.18	53.91	11180
2.00 - 2.17	7.33	67.41	8944
2.17 - Sink	63.25	85.94	6708

Do you wish to see another data set? (Y/N)
N

Float - Sink data for the following data sets is stored in memory:

(1) Seam A
(2) Seam B
(3) Seam C
(4) Seam D
(5) Seam E
(6) Seam F

Do you wish to combine more than 1 data set? (Y/N)
Y
Enter the number of data sets that you would like to combine
2
From the list enter the number of the first data set you would like to combine.
2
Enter the blending ratio per cent of this data set
60
Enter the number of the next set you would like to combine
3
Enter the blending ratio of this data set
40
The sets will be combined as follows:

(1) Seam B at 60.00%
(2) Seam C at 40.00%

Is the above data correct? (Y/N)
Y
LOADING DATA (SEAM B)
LOADING DATA (SEAM C)

ONLY MASS AND ASH WILL BE COMBINED AS OPTIONAL VALUES ARE INCONSISTENT
Enter the name that you would like to give to the combined data
Seam B and Seam C

*** Seam B and Seam C ***

Seam B at 60.0% of TOTAL WEIGHT

	Mass %	Ash %	Sulphur %
Float - 1.30	23.60	2.00	0.00
1.30 - 1.35	26.30	6.25	0.00
1.35 - 1.40	25.60	10.88	0.00
1.40 - 1.45	12.50	15.17	0.00
1.45 - 1.50	7.50	19.47	0.00
1.50 - 1.60	3.80	25.08	0.00
1.60 - 1.80	0.20	35.41	0.00
1.80 - 2.00	0.00	47.91	0.00
2.00 - 2.17	0.00	60.42	0.00
2.17 - Sink	0.50	83.79	0.00

Seam C at 40.0% of TOTAL WEIGHT

	Mass %	Ash %	Sulphur %
Float - 1.30	0.00	3.20	0.00
1.30 - 1.35	0.11	8.81	0.00
1.35 - 1.40	0.27	14.76	0.00
1.40 - 1.45	1.25	18.75	0.00
1.45 - 1.50	3.49	23.23	0.00
1.50 - 1.60	8.57	29.83	0.00
1.60 - 1.80	7.55	40.74	0.00
1.80 - 2.00	8.18	53.91	0.00
2.00 - 2.17	7.33	67.41	0.00
2.17 - Sink	63.25	85.94	0.00

Do you want a copy of the data? (Y/N)
N

***** RECONSTITUTED WASHABILITY DATA OF SEAM A AND SEAM B *****

Rel. Density	COMBINED MASS AND ASH PERCENT		
	Mass	Ash	Sulphur
Float - 1.30	14.16	2.00	0.00
1.30 - 1.35	15.82	6.26	0.00
1.35 - 1.40	15.47	10.91	0.00
1.40 - 1.45	8.00	15.39	0.00
1.45 - 1.50	5.90	20.36	0.00
1.50 - 1.60	5.71	27.93	0.00
1.60 - 1.80	3.14	40.54	0.00
1.80 - 2.00	3.27	53.91	0.00
2.00 - 2.17	2.93	67.41	0.00
2.17 - Sink	25.60	85.91	0.00
	100.00	34.00	0.00

Would you like a hard copy printout of this data? (Y/N)
N
LOADING COMP

The relative density ranges to be used in this calculation are:

Float - 1.30
1.30 - 1.35
1.35 - 1.40
1.40 - 1.45
1.45 - 1.50
1.50 - 1.60
1.60 - 1.80
1.80 - 2.00
2.00 - 2.17
2.17 - Sink

Enter the mid point of the sink range
2.35

WASHABILITY DATA

****

REL. DENSITY	INDIV. FRACT. Mass %	Ash %	% S	CUM. FLT. Mass %	Ash %	% S	CUM. SINK Mass %	Ash %	% S
Float - 1.30	14.16	2.00	0.00	14.16	2.00	0.00	100.00	34.00	0.00
1.30 - 1.35	15.82	6.26	0.00	29.98	4.25	0.00	85.84	39.27	0.00
1.35 - 1.40	15.47	10.91	0.00	45.45	6.51	0.00	70.02	46.73	0.00
1.40 - 1.45	8.00	15.39	0.00	53.45	7.84	0.00	54.55	56.89	0.00
1.45 - 1.50	5.90	20.36	0.00	59.35	9.09	0.00	46.55	64.03	0.00
1.50 - 1.60	5.71	27.93	0.00	65.06	10.74	0.00	40.65	70.36	0.00
1.60 - 1.80	3.14	40.54	0.00	68.20	12.11	0.00	34.94	77.29	0.00
1.80 - 2.00	3.27	53.91	0.00	71.47	14.03	0.00	31.80	80.92	0.00
2.00 - 2.17	2.93	67.41	0.00	74.40	16.13	0.00	28.53	84.02	0.00
2.17 - Sink	25.60	85.91	0.00	100.00	33.99	0.00	25.60	85.92	0.00

Would you like a hard copy of the above data?
(Y/N)
N
DO YOU WANT THE ORGANIC EFFICIENCY ETC. CALCULATED? (Y/N)
Y
ENTER THE ACTUAL YIELD
49.8
ENTER THE ACTUAL ASH
10.5
ENTER THE CUTPOINT (ENTER 0 IF NEAR DENS. MATL. CALCS NOT DESIRED)
1.45
DO YOU WANT TO CORRECT THESE VALUES? (Y/N)
N

PLEASE ENTER THE TITLE THAT YOU WISH TO GIVE YOUR PLOT, USE NO MORE THAN 40 CHARACTERS
?
SAMPLE RUN
THE COMPUTER WILL BEEP WHEN IT IS FINISHED PLOTTING, DO NOT TOUCH ANYTHING UNTIL IT DOES.
PLEASE PRESS 'CONT' WHEN YOU ARE FINISHED VIEWING THE PLOTS.

ACTUAL YIELD = 49.80
ACTUAL ASH = 10.50
THEORETICAL YIELD = 64.37
THEORETICAL ASH = 7.21
CUTPOINT = 1.45
YIELD ERROR = 14.57
ASH ERROR = 3.29
ORGANIC EFFICIENCY = 77.36%
NEAR DENSITY = 33.11%
CORRECTED NEAR DENSITY = 46.34%

WOULD YOU LIKE A HARD COPY OF THE PLOT? (Y/N)
Y
WOULD YOU LIKE TO USE THE CURSOR ON THE PLOT? (Y/N)
Y
ON THE X AXIS, DO YOU WANT THE CURSOR TO LINE UP WITH THE RD SCALE OR THE PER CENT ASH SCALE?

PLEASE ANSWER RD OR %ASH
RD
CURSOR WILL LINE UP WITH THE RD SCALE ON THE X AXIS
FOR RD = 1.45, ORDINATE VALUE = 53.24

DO YOU WANT TO USE THE CURSOR AGAIN? (Y/N)
Y
DO YOU WANT TO CHANGE THE AXIS IT IS LINED UP WITH? (Y/N)
Y
ON THE X AXIS, DO YOU WANT THE CURSOR TO LINE UP WITH THE RD SCALE OR THE PER CENT ASH SCALE?

PLEASE ANSWER RD OR %ASH
%ASH
CURSOR WILL LINE UP WITH THE % ASH SCALE ON THE X AXIS

FOR % ASH = 7.84, ORDINATE VALUE = 53.24

DO YOU WANT TO USE THE CURSOR AGAIN? (Y/N)
N
WOULD YOU LIKE A PLOT OF THE DATA POINTS ONLY? (Y/N)
Y (See Fig. B-1)
DO YOU WANT TO SEE THE SULPHUR CURVES FOR YOUR DATA? (Y/N)
N
REWINDING

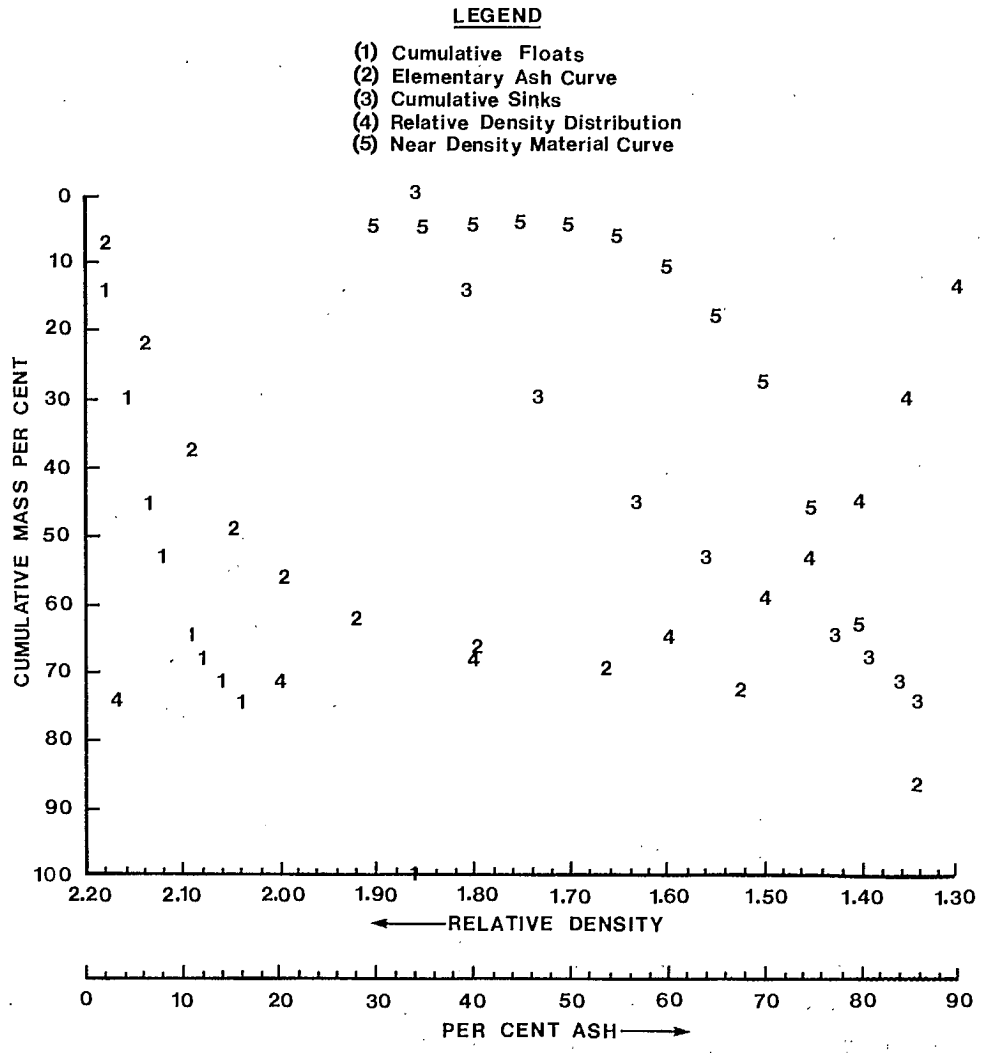

Fig. B-1 - Data points for the washability curves

***** END OF PROGRAM *****

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