INSTITUTE OF GAS TECHNOLOGY
IIT CENTER
CHICAGO, ILLINOIS 60616

PREPARATION OF A COAL CONVERSION SYSTEMS TECHNICAL DATA BOOK

ERDA Contract No. E (49-18)-1730
Report No. 7
May 1975

Project 8964 Status Report

for

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

INSTITUTE OF GAS TECHNOLOGY - IIT CENTER - CHICAGO 60616

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Report for

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Project Title: Preparation of a Coal Conversion Systems Technical Data Book

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I. Project Objective

The objective of this work is to provide a single, comprehensive source of data on coal conversion systems. This compilation shall be entitled The Coal Conversion Systems Technical Data Book and shall provide up-to-date data and information for the research, development, design, engineering, and construction of coal conversion processes and/or plants. Other concurrent objectives are to identify those areas where data are required and to suggest research programs that will provide the required data.

II. Summary

Liquefaction

More experimental coal liquefaction data were examined using the method described in the Project 8964 March 1975 Status Report. The "cut end point" for the liquefied residue (vacuum bottoms) of catalytic operations was determined to be 1200° to 1300°F. For noncatalytic operations, it was 2900° to 3600°F. A procedure is given to estimate yields of all intermediate cuts, given the total oil yield and hydrocarbon gas yield.

It was also found that coal liquefaction operations, in which less than 50 weight % of MAF coal fed is converted to oil, do not exhibit normal product distribution.

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Gasification

Conversion versus solids residence time charts are presented for a steam-char gasification system. In this system, the heat is supplied by some external source, such as electricity, instead of by char-oxygen reaction as in the case of steam-oxygen gasification, which was described in earlier reports.

All other assumptions for this system are the same as those for the steam-oxygen-char system.

Fluidization

A new correlation for estimating the bed-expansion ratio is proposed, which predicts about 95% of the evaluated data within ±12%. Further work is in progress to express the correlation in pertinent dimensionless groups to facilitate reliable extrapolation beyond the operating range of the data considered.

Published correlations to predict transport disengagement height (TDH), entrainment, and elutriation are compiled.

Combustion

Low-Temperature (Fluidized-Bed)

The data-correlation approach described in last month's report was applied to an earlier set of data developed by Argonne National Laboratory (Illinois coal and limestone No. 1359 system).

Coal, Char, and Oil Shale Properties

Analytical and other related data on 50 coal deposits, which were received from Penn State are presented in a tabular compilation form deemed suitable for the Data Book.

Notice to Readers of Open File

Any comments about the material presented in this report or suggestions about the format and the content of the Data Book as well as the priorities of the needed data are most welcome. Please direct any communications to Mr. Bipin Almaula of ERDA (202/634-6643) or to Dr. Al Talwalkar of the Institute of Gas Technology (312/225-9600, Ext. 869).

III. Work Accomplished

A. LIQUEFACTION

1. Correlation of Coal Liquefaction Yield Structure

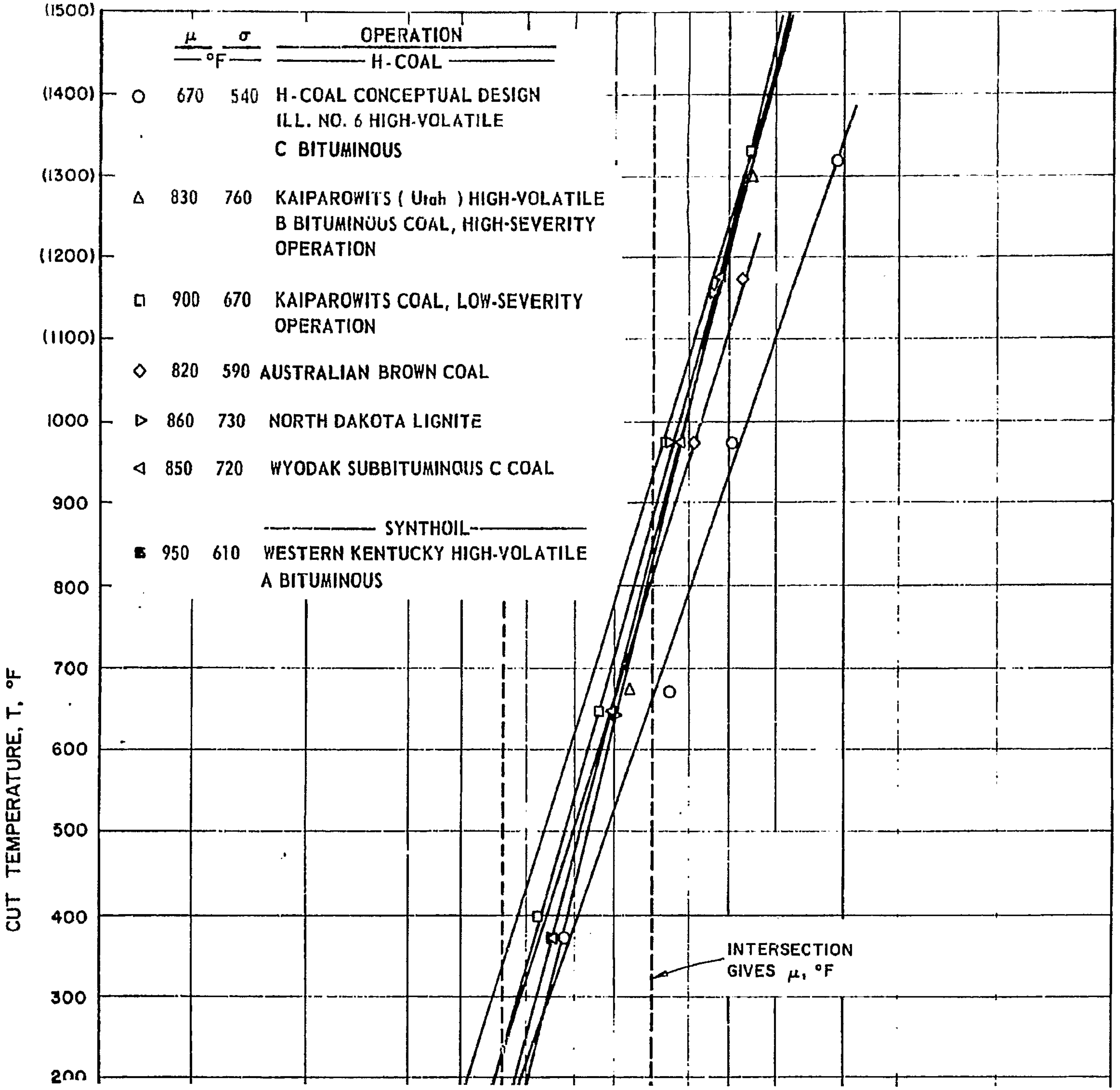
We have examined more experimental coal liquefaction data using the method described in the Project 8964 March 1975 Status Report. The "cut end point" for the liquefied residue (vacuum bottoms) of catalytic operations was determined to be 1200° to 1300°F. For noncatalytic operations, it was 2900° to 3600°F. By assigning a nominal cut end point temperature for vacuum bottoms of 1250°F for catalytic operations at 3250°F for noncatalytic operations, the point for total oil yield, which is often the only figure reported, can be plotted on a graph similar to Figure 1 or 2. If, in addition, one other yield temperature point is available, an estimate is then available of the complete yield structure for the operation.

We also found that coal liquefaction operations in which less than 50 wt % of MAF coal fed was converted to oil do not exhibit normal product distributions.

Experimental data for the H-COAL operation,[2,3] the Synthoil Process,[1] and the SRC Process[4] show normal product distribution. Figure 1 shows experimental data for several H-COAL operations and for the Synthoil operation using various types of catalysts. Figure 2 shows autoclave data for the SRC operation and for a noncatalytic run made in the H-COAL reactor. The data were plotted as follows:

> First, the cumulative yields of products up to but not including vacuum bottoms were plotted. Then, a line was drawn through the points and the added yield of vacuum bottoms was plotted on that line. Thus, the "cut end point" for the residue (vacuum bottoms) was determined.

It should be noted that the vacuum bottoms cut end point is not an actual temperature corrected to atmospheric pressure at which all the vacuum bottoms would be distilled off. It is merely a way of adding the residue yield data to the product distribution curve determined from yields of lighter fractions. Residue oils for catalytic operations all show nominal cut end points of 1200° to 1300°F. Considering experimental difficulties, this agreement is quite good. Residue oil for noncatalytic operations generally has a nominal end point of 2900° to 3600°F, a considerably wider spread. This is probably due in part to the considerable experimental difficulties associated with quanti-


μ σ
°F
OPERATION
H-COAL
○ 670 540 H-COAL CONCEPTUAL DESIGN ILL. NO. 6 HIGH-VOLATILE C BITUMINOUS
△ 830 760 KAIPAROWITS (Utah) HIGH-VOLATILE B BITUMINOUS COAL, HIGH-SEVERITY OPERATION
□ 900 670 KAIPAROWITS COAL, LOW-SEVERITY OPERATION
◇ 820 590 AUSTRALIAN BROWN COAL
▷ 860 730 NORTH DAKOTA LIGNITE
◁ 850 720 WYODAK SUBBITUMINOUS C COAL
SYNTHOIL
■ 950 610 WESTERN KENTUCKY HIGH-VOLATILE A BITUMINOUS
(1500)
(1400)
(1300)
(1200)
(1100)
1000
900
800
700
600
500
400
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200
CUT TEMPERATURE, T, °F
INTERSECTION GIVES μ, °F

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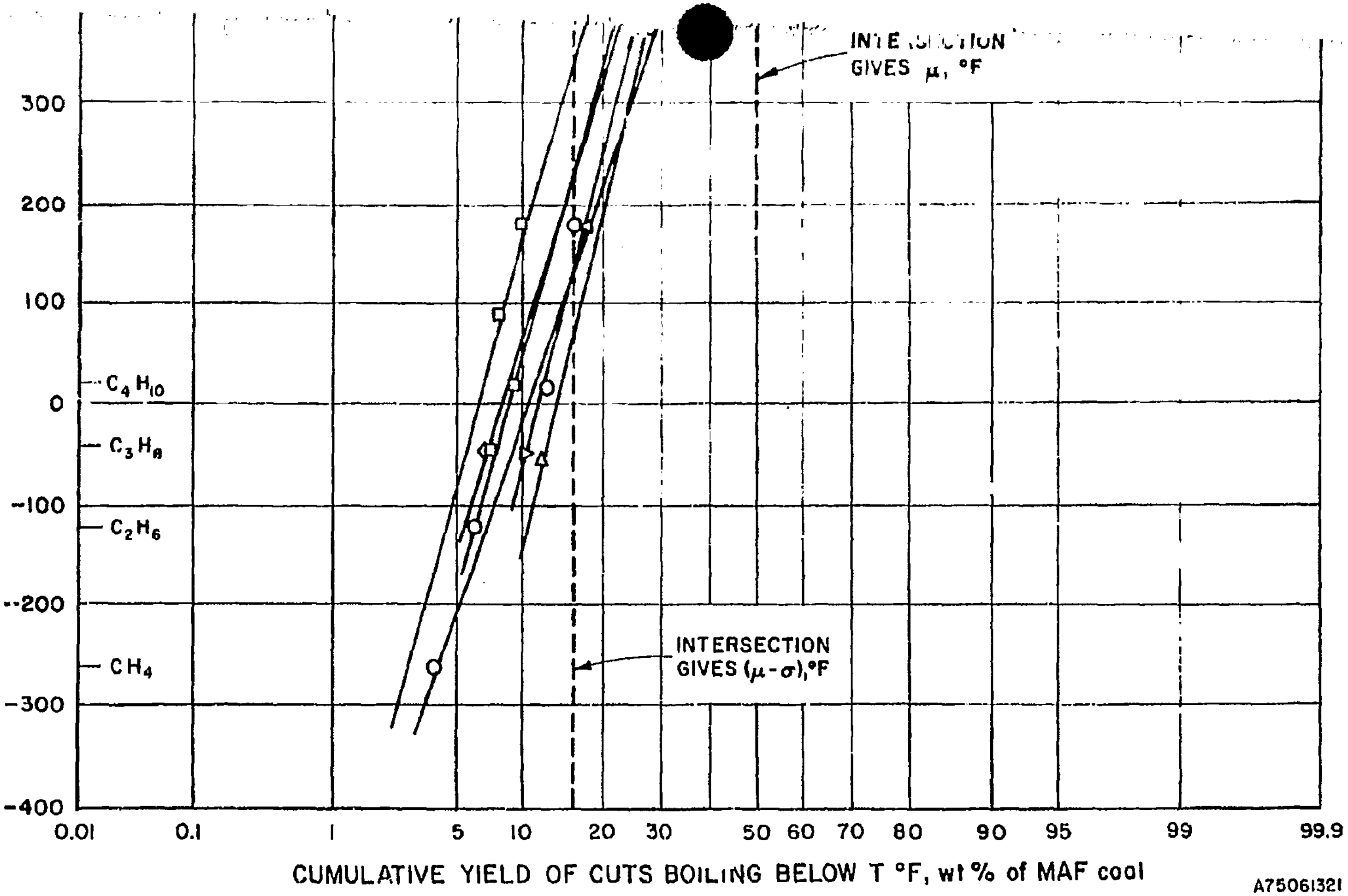

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Figure 1. CATALYTIC COAL LIQUEFACTION PROCESSES

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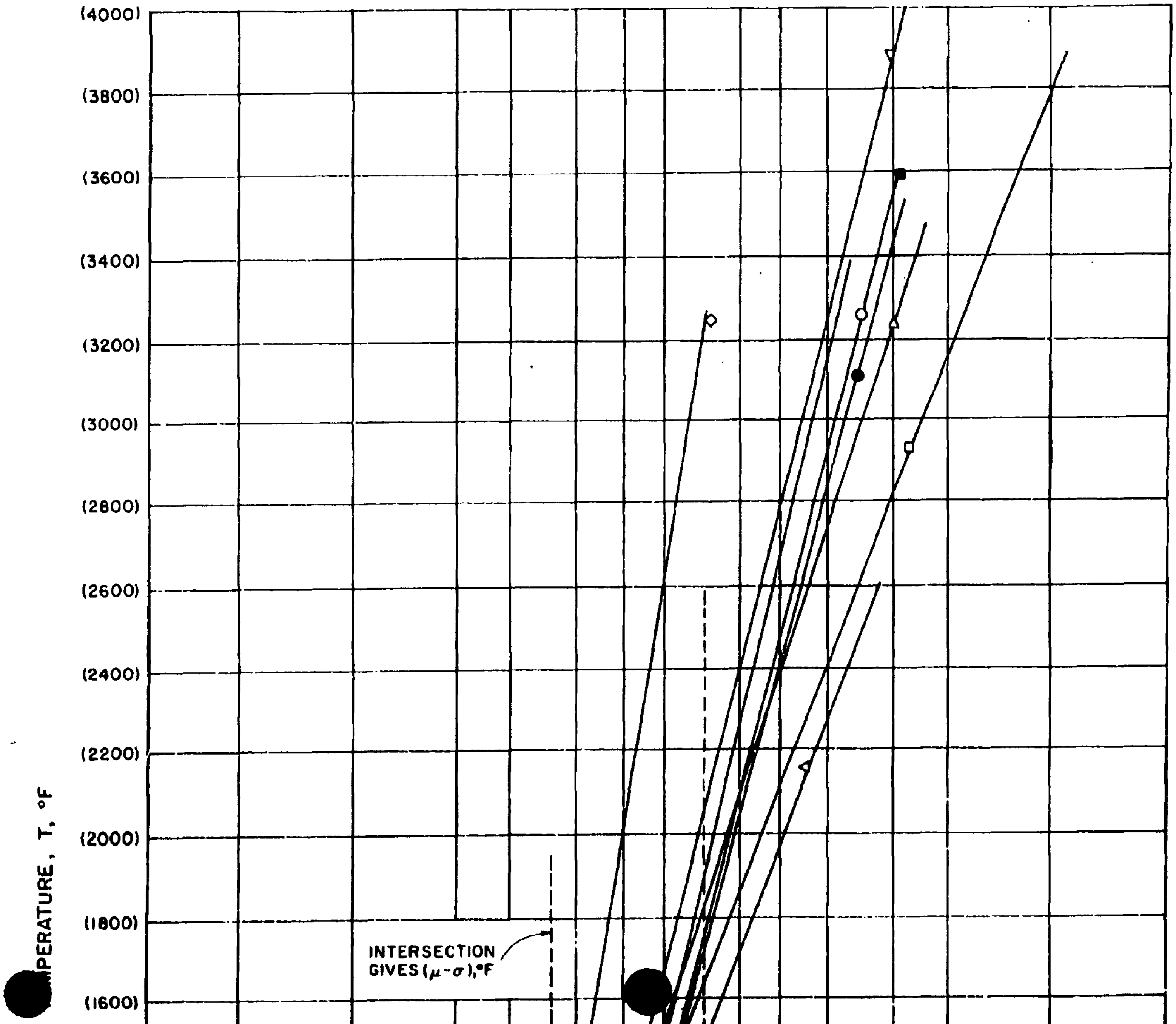
(4000)
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(1800)
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PERATURE, T, °F
INTERSECTION GIVES (μ-σ),°F

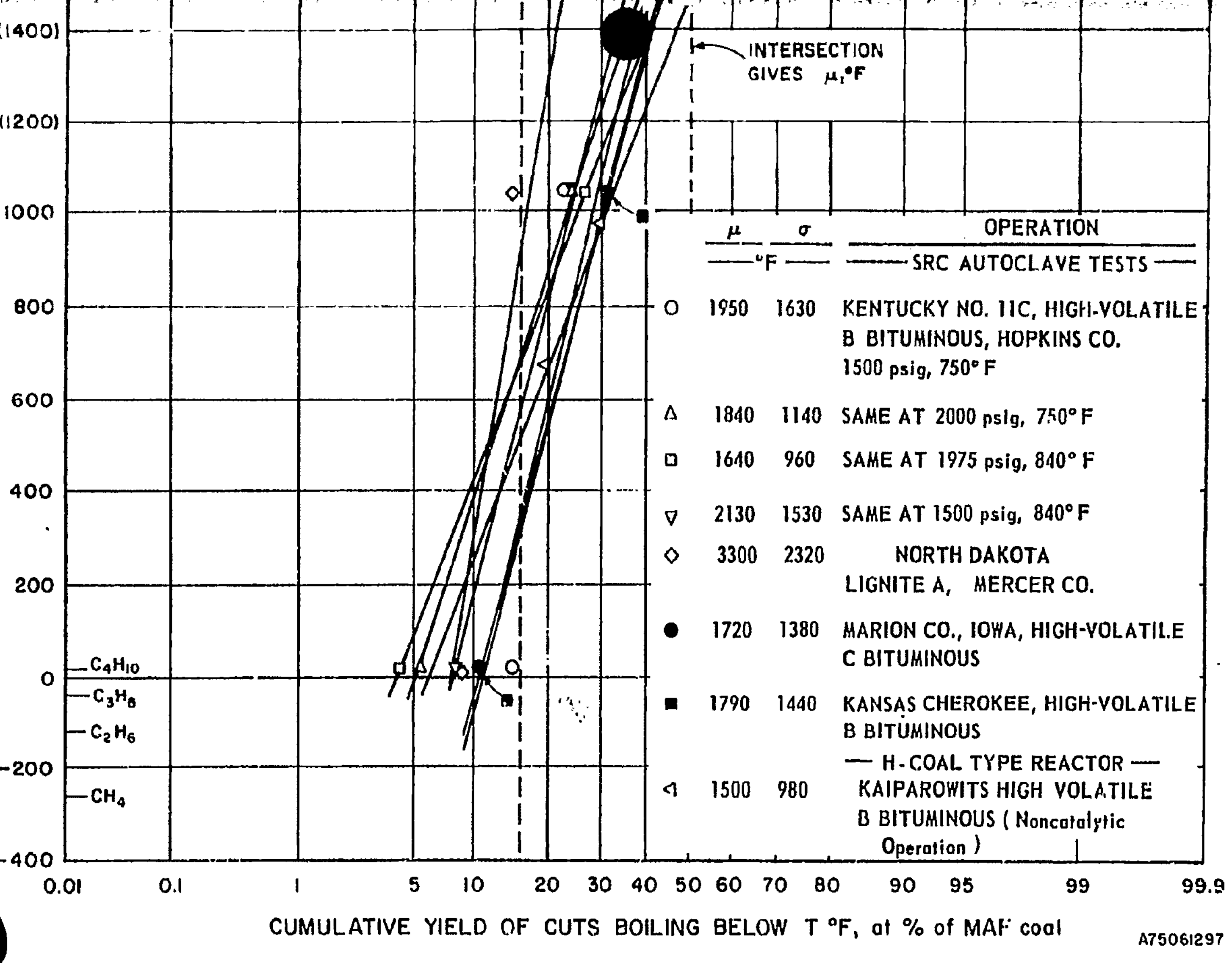

Figure 2. NONCATALYTIC COAL LIQUEFACTION PROCESSES

tative separation of the solvent in batch tests. Data for batch autoclave tests in which total oil yield (including vacuum bottoms) were less than 50 wt % of MAF coal fed are not shown because operations with less than 50 wt % total oil yield do not exhibit normally distributed product slates.

Example*

Correlation of experimental data has shown that a particular catalytic process operating on a specific coal gives a yield structure with mean temperature $\mu = 800°F$ and a spread temperature $\sigma = 700°F$. Determine the yield of 1000°F + residue that can be expected.

The nominal cut end point temperature for the residue cut for a catalytic operation is 1250°F. Therefore,

$$X_1 = \frac{1000 - 800}{700} = 0.2857$$

$$X_2 = \frac{1250 - 800}{700} = 0.6429$$

$$N(X_1) = N(0.2857) = 0.6124^{\dagger}$$

$$N(X_2) = N(0.6429) = 0.7399^{\dagger}$$

$$N(X_2) - N(X_1) = 0.1275$$

The yield of residual oil (vacuum bottoms) boiling above 1000°F would be approximately 12.75% by weight of the MAF coal fed.

Note that the total oil yield, about 74 % for this case, is not equal to 100% minus the percentage of unconverted MAF coal. Some of the coal reacts to form H_2O and carbon oxides, which are not included in the oil yield.

2. References Cited

1. Akhtar, S. et al., "The Synthoil Process — Material Balance and Thermal Efficiency." Paper No. 35B presented at 67th Annual A.I.Ch.E. Meeting, December 1-5, 1974, Washington, D. C.
2. Hydrocarbon Research, "Liquefaction of Kaiporowits Coal," EPRI 123-2, Palo Alto, Calif.: Electric Power Research Institute, October 1974.

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[*] Nomenclature is as given in the Project 8964 March 1975 Status Report.

[†] Values of N corresponding to X_1 and X_2 were determined from a table of normal distribution.

3. Hydrocarbon Research, "Project H-COAL Report on Process Development," OCR R& D Rep. No. 26. Washington, D. C.: Office of Coal Research, n. d.

4. Wright, C. H. et al., "Development of a Process for Producing an Ashless, Low-Sulfur Fuel From Coal," Vol II, Part 1 — Autoclave Experiments, OCR R&D Rep. No. 53, Int. Rep. No. 6. Washington, D. C.: Office of Coal Research, n. d.

B. GASIFICATION

1. Steam-Char Gasification in Fluidized Bed

The design charts presented up to now have been for the steam-oxygen-char gasification system in which the heat requirement for the steam-char reaction was supplied within the system by combustion of a part of the feed char with oxygen. In this monthly report, we begin presenting information on a different system — the gasification of char with steam only. Since there is no oxygen feed into this system, all the feed carbon converted is by the steam-char reaction. To operate at a constant temperature, such a system requires an external source of heat. The amount of heat required to maintain a given temperature is shown by lines of constant heat inputs in Figures 3 to 6.

Besides the exceptions just noted, the assumption and the basis for the present system are the same as those in the steam-oxygen-char system. The charts presented here are also for the base case conditions — fluidized-bed model with both gases and solids in backmixed flow and the base carbon conversion fraction in the feed char, $X_o = 0$. Additionally, the same correction charts for adjustments for variations from the base case can be applied to the present system.

For a given gasification temperature and 70-atm pressure, Figures 3 to 6 present curves that give the residence time required to achieve a specified feed carbon conversion at different steam feeds to the gasifier. The figures also have the constant heat input lines that show the amount of heat input required by the gasifier in order to maintain the specified operating temperature. In contrast to the charts for the steam-oxygen-char system, the time required to achieve specified feed carbon conversion is relatively higher because none of the feed carbon is being combusted with oxygen.

2. Erratum

In the Project 8964 April Status Report, the following correction is to be noted. In the calculation of C_b (p. 9), the first quantity should be 0. 078 lb ash/lb raw coal instead of 0. 78.

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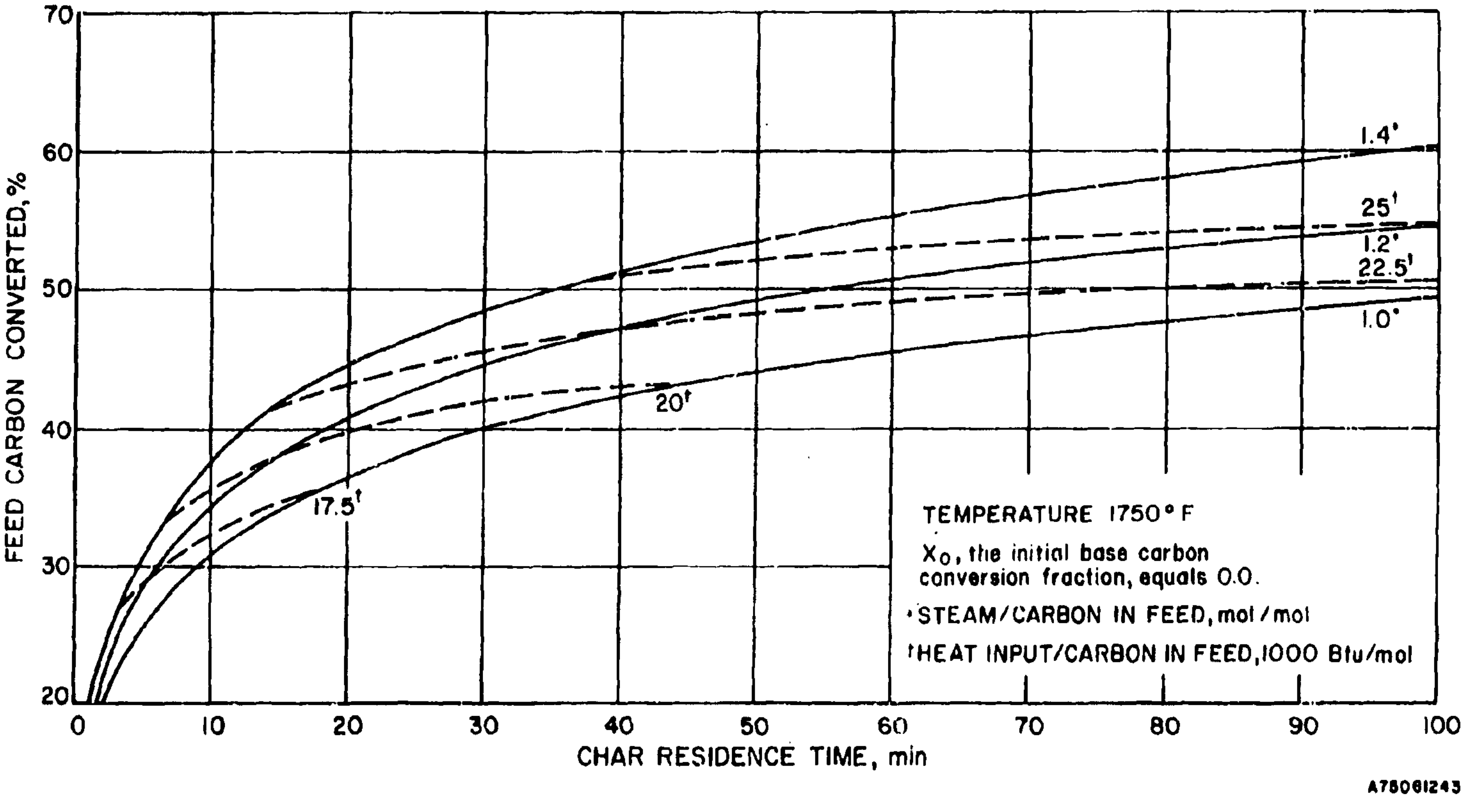

Figure 3. STEAM GASIFICATION OF DEVOLATILIZED IRELAND MINE BITUMINOUS CHAR AT 1750°F AND 70-atm PRESSURE

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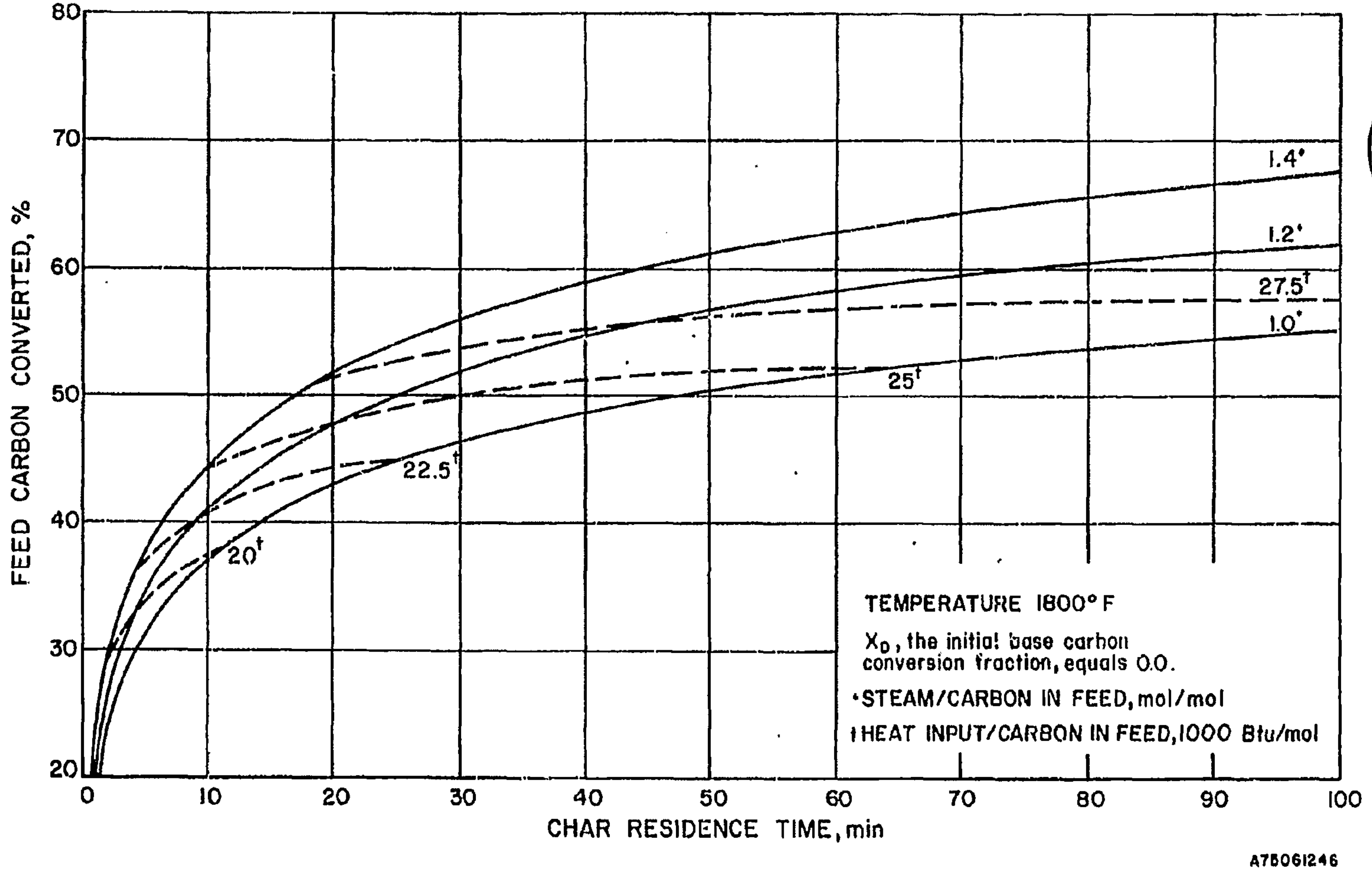

Figure 4. STEAM GASIFICATION OF DEVOLATILIZED IRELAND MINE BITUMINOUS CHAR AT 1800°F AND 70-atm PRESSURE

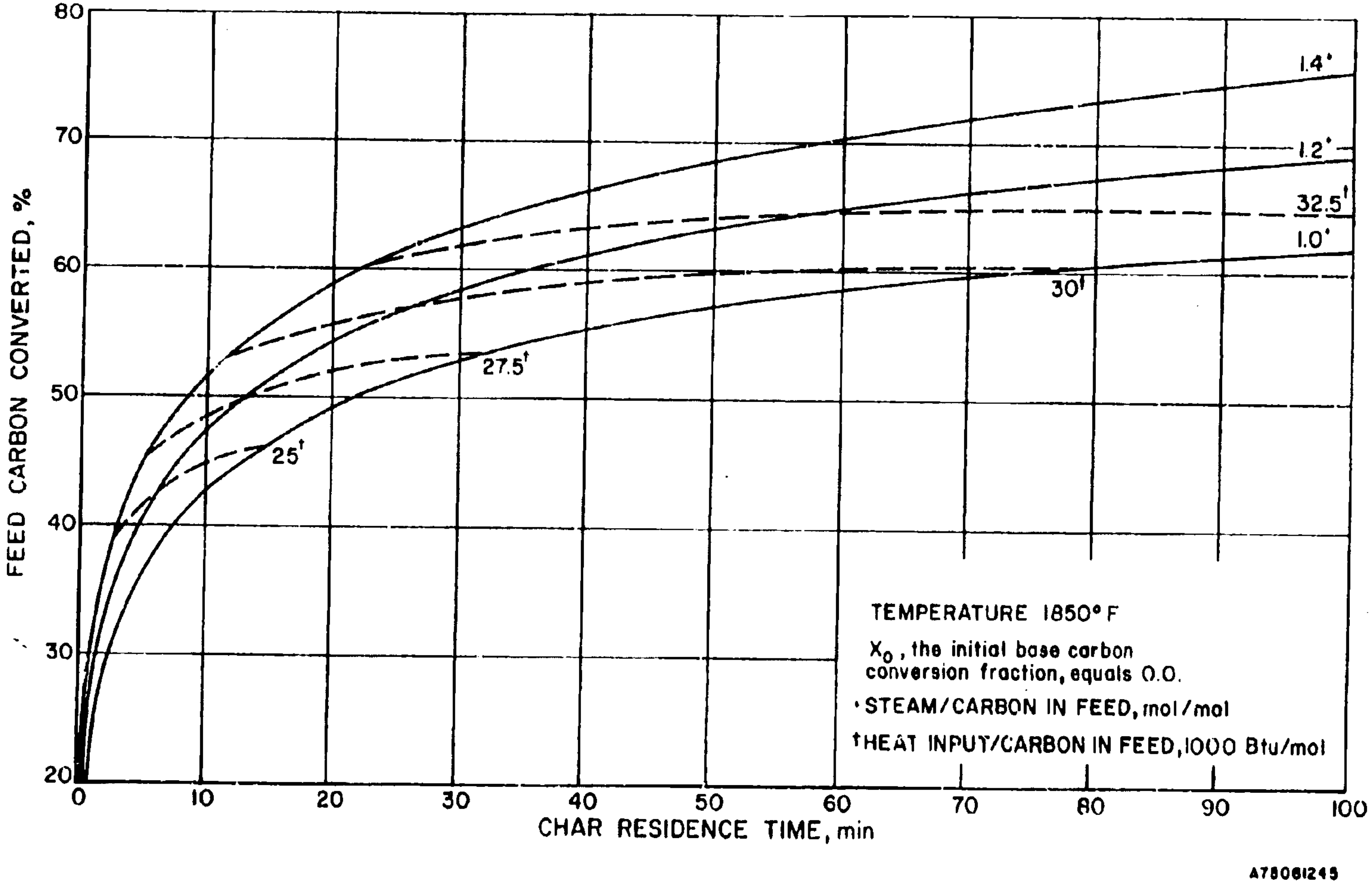

Figure 5. STEAM GASIFICATION OF DEVOLATILIZED IRELAND MINE BITUMINOUS CHAR AT 1850°F AND 70-atm PRESSURE

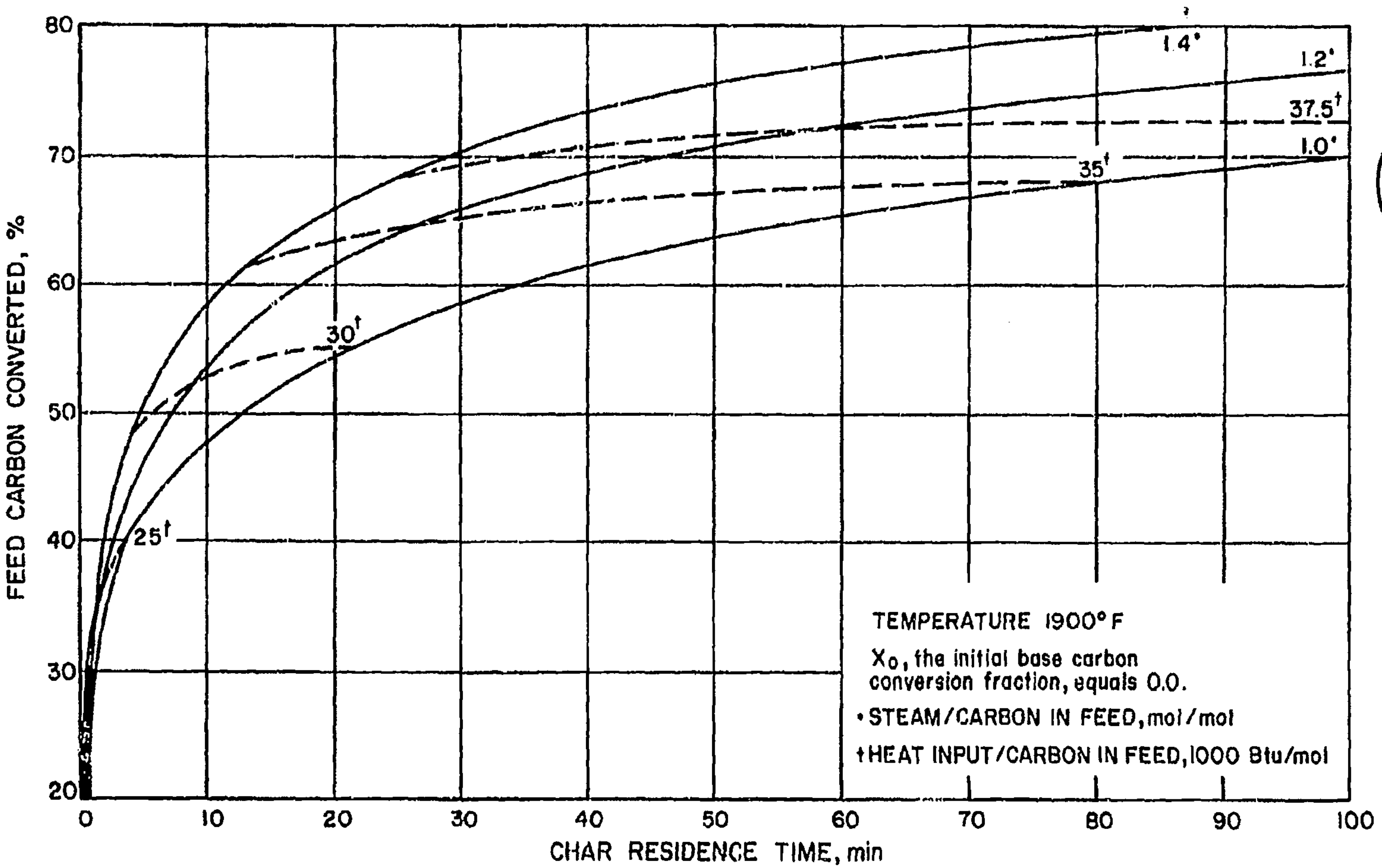

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Figure 6. STEAM GASIFICATION OF DEVOLATILIZED IRELAND MINE BITUMINOUS CHAR AT 1900°F AND 70-atm PRESSURE

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C. FLUIDIZATION

1. Bed Expansion on Fluidization

During the past month, more data on the expansion of fluidized beds were collected. A complete list of the published data used to evaluate the fluidized-bed expansion correlations is shown in Table 1.

An interesting correlation in the literature, developed by Furukawa and Ohmae,[8] assumes the principle of corresponding states and in particular states that the expansion characteristics of a fluidized bed are analogous to the thermal expansion of liquids. The relationship between the fluidized-bed expansion ratio and the superficial gas velocity is given by,

$$U^{0.5} \ \alpha \left[1 - \left(\frac{L_{mf}}{L_f}\right)^{1/3}\right] \qquad (1)$$

for low fluidization gas velocities. Furukawa and Ohmae note that Equation 1 is valid only for the linear part of the bed expansion ratio versus the superficial gas velocity plot. Because the published data used in this investigation cover both the linear and nonlinear parts of the bed expansion plots, the comparison of these data with the Furukawa-Ohmae correlations was not attempted.

The evaluations of the Lewis et al.[15] and the Shen-Johnstone[19] correlations reported in the Project 8964 April 1975 Status Report were repeated to check their comparison with the additional data by Tarman et al.[20] and Knowlton.[10] These comparisons are shown in Figure 7 and 8, and it is apparent that more than 90% of the data falls within ±20% of the calculated values of bed expansion ratios.

To explore the possibility of verifying whether a modified version of the Shen-Johnstone correlation will show a greater than 20% deviation, the published data were plotted in terms of L_f/L_{mf} versus $(U - U_{mf})/D_p^{0.5}$, as shown in Figure 9. The data fall into distinctly different groups, permitting the drawing of a straight line through each set of data points. It is, therefore, possible to deduce empirical correlations of the form –

$$\frac{L_f}{L_{mf}} = 1 + \alpha\left(\frac{U - U_{mf}}{D_p^{0.5}}\right) \qquad (2)$$

for each set of data, by determining the slope of the linear plots.

Table 1. SOURCES OF FLUIDIZED-BED EXPANSION DATA FOR COALS AND RELATED MATERIALS (at 70° to 80°F)

Investigators	Bed Diameter, inches	Fluidized Solids	Particle Diameter, inch	Particle Density, lb/cu ft	Fluidizing Medium	Operating Pressure, psig	Range of U/U_{mf}	Range of L_f/L_{mf}
Curran and Gorin[3]	1 and 2	Lignite, char, dolomite, periclase	0.0028-0.0173	51-222	N_2, H_2, CO_2	0	1-20.5	1-2
Feldmann *et al.*[5]	2	Char	0.0052	23	CO_2	0	1-12.0	1-1.53
Tarman *et al.*[20]	2.5 5.5 11.5	Siderite	0.00269-0.0141	245	Air, freon, N_2	0-1000	1-10.5	1-1.49
Knowlton[10]	11.5	Lignite, FMC char, Illinois No. 6 siderite	0.0096-0.0114	73.0-244	N_2	0-1000	1-2.637	1-1.12

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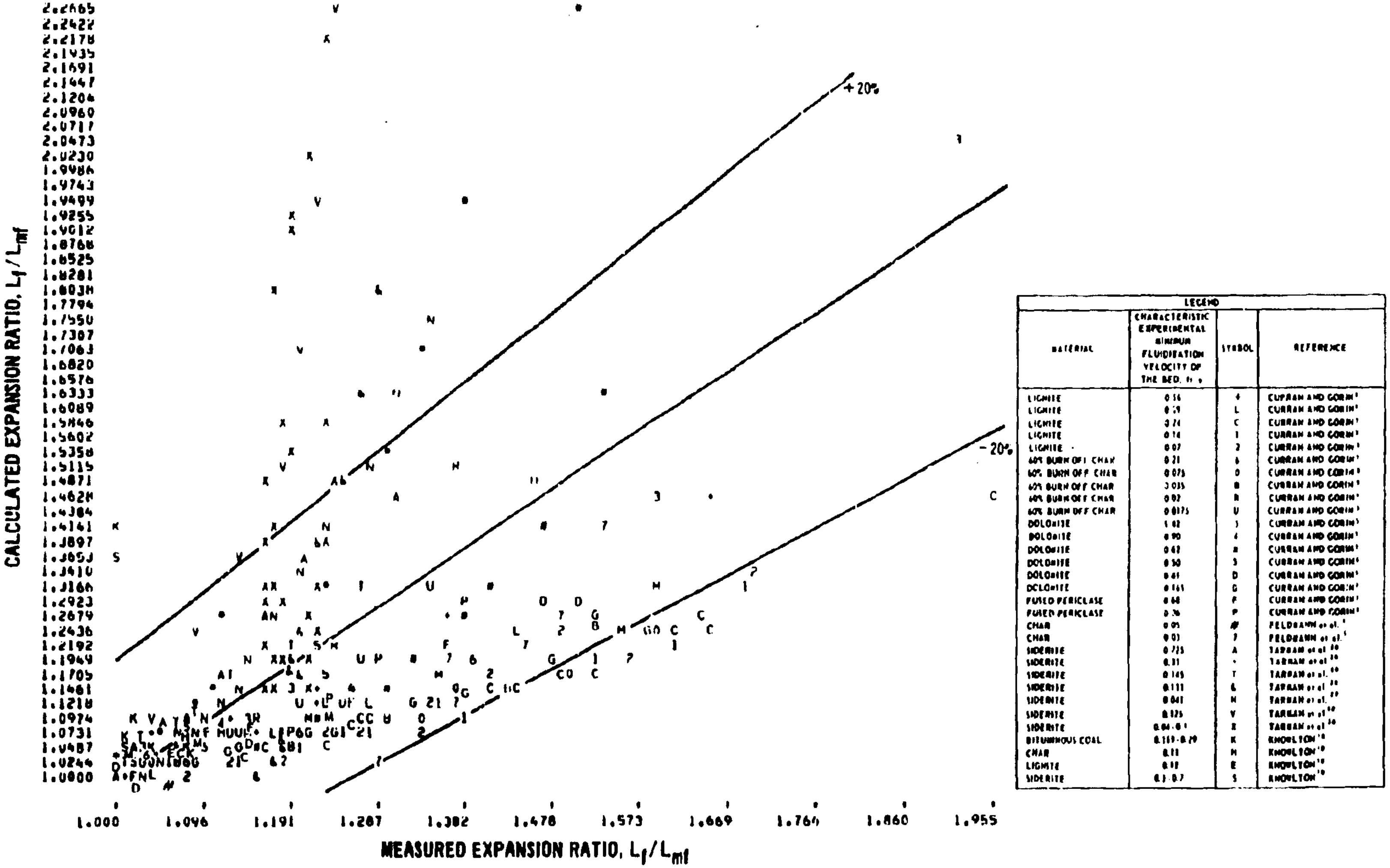

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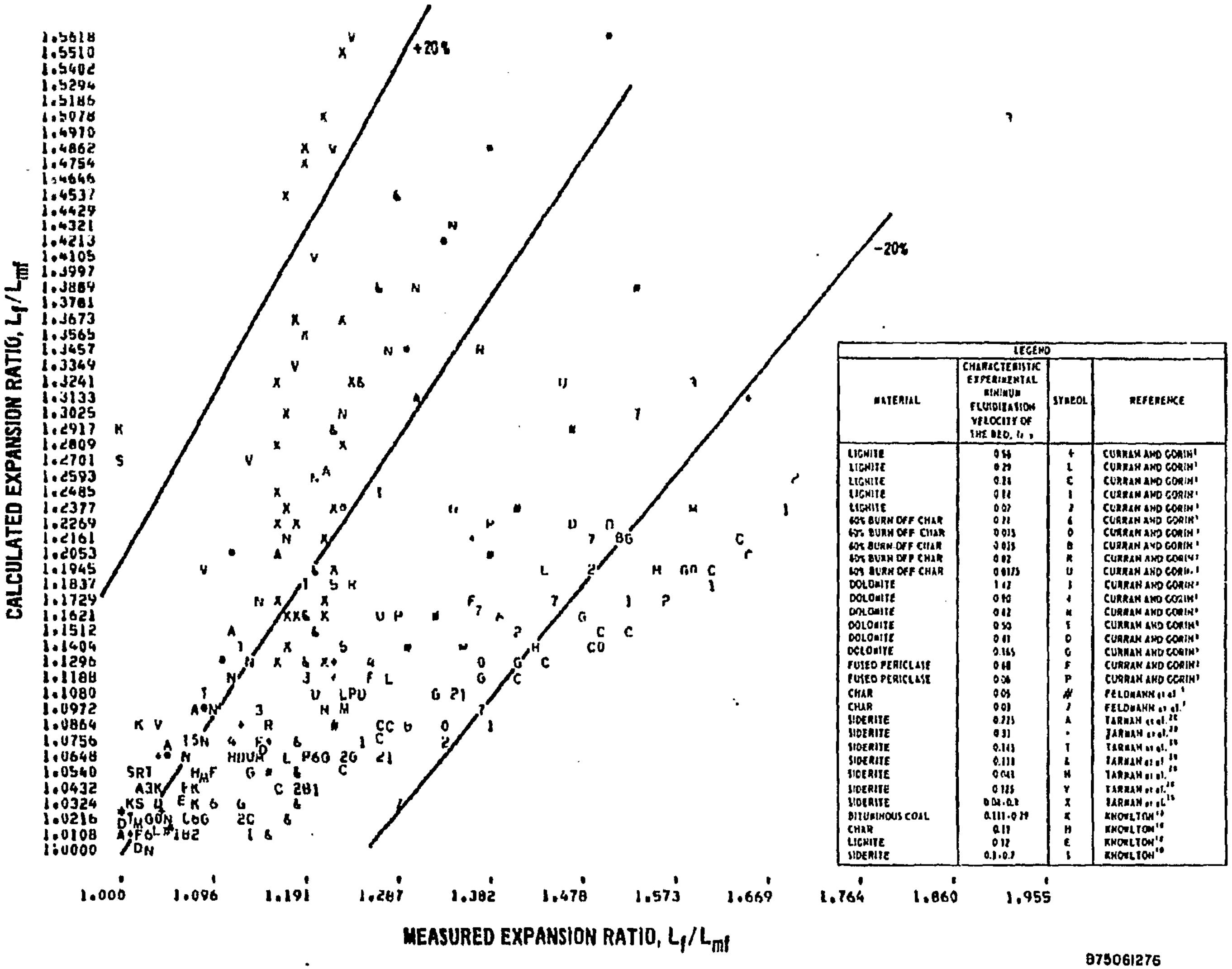
Figure 7. COMPARISON OF THE LEWIS et al. CORRELATION WITH MEASURED FLUIDIZED-BED EXPANSION RATIOS



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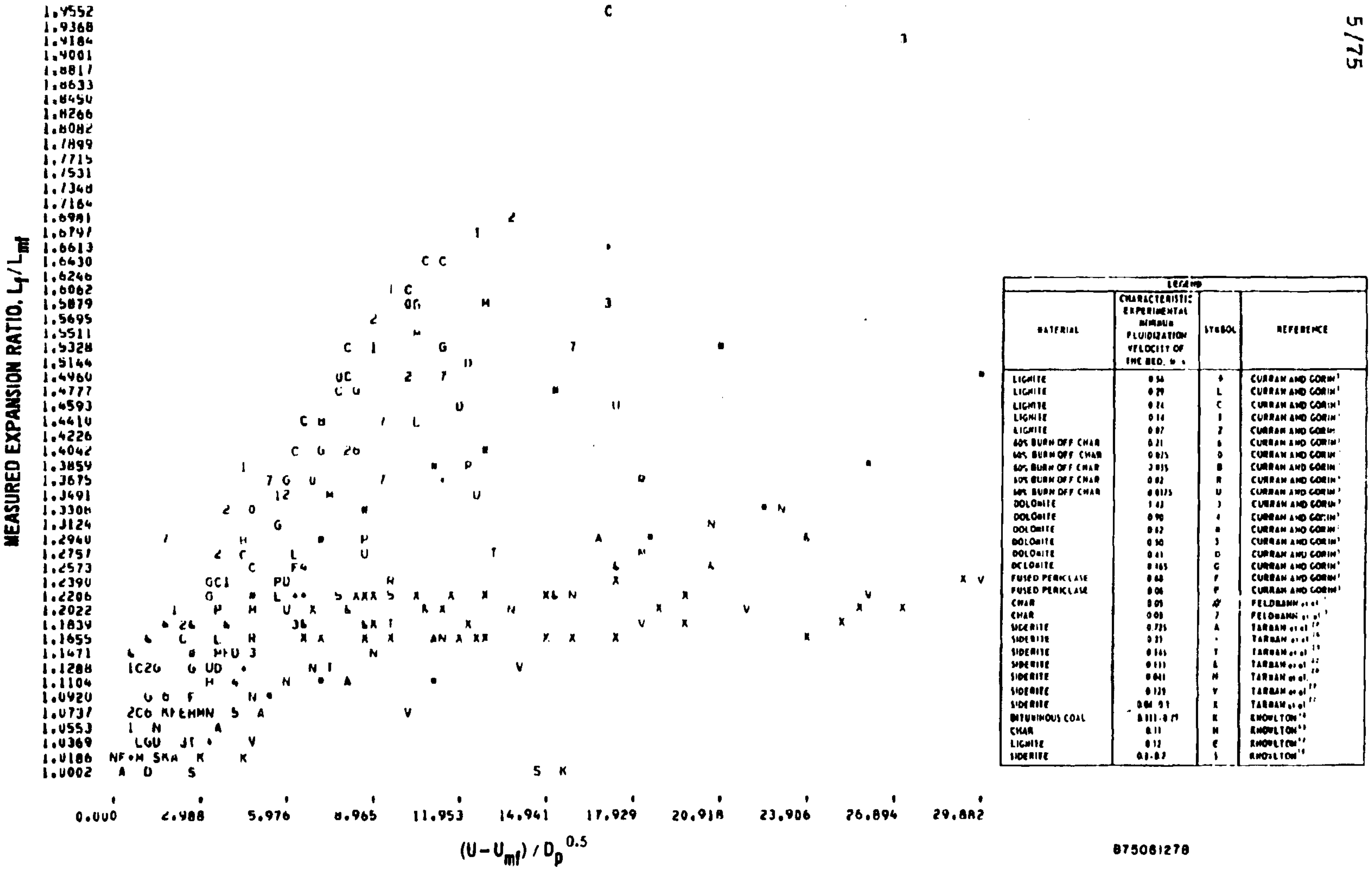
MATERIAL	CHARACTERISTIC EXPERIMENTAL MINIMUM FLUIDIZATION VELOCITY OF THE BED, ft/s	SYMBOL	REFERENCE
LIGNITE	0.56	+	CURRAN AND GORIN[7]
LIGNITE	0.29	L	CURRAN AND GORIN[7]
LIGNITE	0.26	C	CURRAN AND GORIN[7]
LIGNITE	0.12	1	CURRAN AND GORIN[7]
LIGNITE	0.07	2	CURRAN AND GORIN[7]
60% BURN OFF CHAR	0.21	6	CURRAN AND GORIN[7]
60% BURN OFF CHAR	0.015	O	CURRAN AND GORIN[7]
60% BURN-OFF CHAR	0.015	B	CURRAN AND GORIN[7]
60% BURN OFF CHAR	0.02	R	CURRAN AND GORIN[7]
60% BURN OFF CHAR	0.0175	U	CURRAN AND GORIN[7]
DOLOMITE	1.42	3	CURRAN AND GORIN[7]
DOLOMITE	0.10	4	CURRAN AND GORIN[7]
DOLOMITE	0.42	M	CURRAN AND GORIN[7]
DOLOMITE	0.50	5	CURRAN AND GORIN[7]
DOLOMITE	0.41	D	CURRAN AND GORIN[7]
DOLOMITE	0.165	G	CURRAN AND GORIN[7]
FUSED PERICLASE	0.68	F	CURRAN AND GORIN[7]
FUSED PERICLASE	0.36	P	CURRAN AND GORIN[7]
CHAR	0.05	#	FELDMANN et al.[5]
CHAR	0.03	7	FELDMANN et al.[7]
SIDERITE	0.225	A	TARMAN et al.[22]
SIDERITE	0.31	•	TARMAN et al.[20]
SIDERITE	0.143	T	TARMAN et al.[19]
SIDERITE	0.118	&	TARMAN et al.[19]
SIDERITE	0.043	N	TARMAN et al.[20]
SIDERITE	0.125	V	TARMAN et al.[20]
SIDERITE	0.02-0.2	X	TARMAN et al.[15]
BITUMINOUS COAL	0.111-0.29	K	KNOWLTON[13]
CHAR	0.17	H	KNOWLTON[13]
LIGNITE	0.12	E	KNOWLTON[13]
SIDERITE	0.1-0.3	S	KNOWLTON[13]

Figure 8. COMPARISON OF THE SHEN-JOHNSTONE CORRELATION WITH MEASURED FLUIDIZED-BED EXPANSION RATIOS



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MATERIAL	CHARACTERISTIC EXPERIMENTAL MINIMUM FLUIDIZATION VELOCITY OF THE BED, ft/s	SYMBOL	REFERENCE
LIGNITE	0.56	+	CURRAN AND GORIN[1]
LIGNITE	0.29	L	CURRAN AND GORIN[1]
LIGNITE	0.24	C	CURRAN AND GORIN[1]
LIGNITE	0.14	I	CURRAN AND GORIN[1]
LIGNITE	0.07	7	CURRAN AND GORIN[1]
60% BURN OFF CHAR	0.21	6	CURRAN AND GORIN[1]
60% BURN OFF CHAR	0.075	D	CURRAN AND GORIN[1]
60% BURN OFF CHAR	0.035	B	CURRAN AND GORIN[1]
60% BURN OFF CHAR	0.02	R	CURRAN AND GORIN[1]
60% BURN OFF CHAR	0.0175	U	CURRAN AND GORIN[1]
DOLOMITE	1.43	)	CURRAN AND GORIN[1]
DOLOMITE	0.90	4	CURRAN AND GORIN[1]
DOLOMITE	0.62	■	CURRAN AND GORIN[1]
DOLOMITE	0.50	3	CURRAN AND GORIN[1]
DOLOMITE	0.41	O	CURRAN AND GORIN[1]
DOLOMITE	0.165	G	CURRAN AND GORIN[1]
FUSED PERICLASE	0.48	/	CURRAN AND GORIN[1]
FUSED PERICLASE	0.06	P	CURRAN AND GORIN[1]
CHAR	0.05	#	FELDMANN et al.[7]
CHAR	0.03	J	FELDMANN et al.[7]
SIDERITE	0.725	A	TARMAN et al.[12]
SIDERITE	0.31	·	TARMAN et al.[16]
SIDERITE	0.165	T	TARMAN et al.[13]
SIDERITE	0.111	&	TARMAN et al.[12]
SIDERITE	0.041	H	TARMAN et al.[19]
SIDERITE	0.129	V	TARMAN et al.[17]
SIDERITE	0.04-0.1	X	TARMAN et al.[17]
BITUMINOUS COAL	0.111-0.27	K	KNOWLTON[19]
CHAR	0.11	N	KNOWLTON[19]
LIGNITE	0.12	E	KNOWLTON[19]
SIDERITE	0.1-0.7	S	KNOWLTON[19]

Figure 9. PLOT OF EXPANSION RATIO VERSUS $(U - U_{mf}) / D_p^{0.5}$

However, a single correlation is desirable that could adequately describe the entire data shown in Table 1. To arrive at such a correlation, a very fundamental approach was followed and the bed expansion ratio was related to some of the pertinent and varied parameters by the following equation:

$$\frac{L_f}{L_{mf}} - 1 = \alpha \ (U - U_{mf})^a \ (U_{mf})^b \ (D_p)^c \ (D_T)^d \ (\rho_s)^e \ (\rho_g)^f \qquad (3)$$

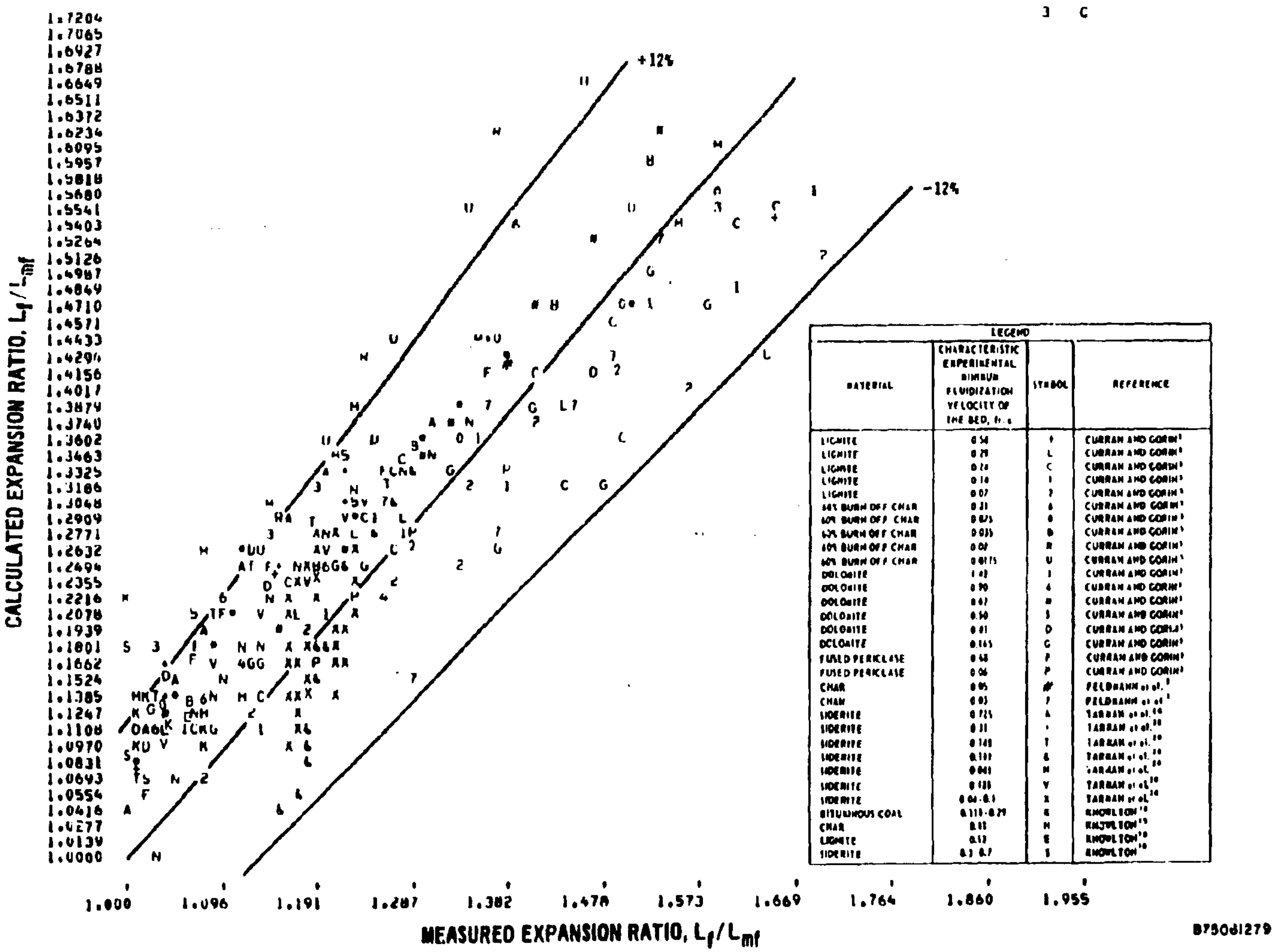
The constant α and the exponents a through f can be estimated by converting Equation 3 to a linear form and into its logarithmic form and by using linear regression analysis. The linear regression analysis was carried out assuming that the relative precision of L_f / L_{mf} is constant. Using the appropriate weighing factor for the linear form of Equation 3 as determined by propagation of variance to be $\left[(L_f - L_{mf})/L_f\right]^2$, the regression analysis of the data shown in Table 1 resulted in the following empirical correlation:

$$\frac{L_f}{L_{mf}} = 1 + \frac{0.748 \ (U - U_{mf})^{0.571} \ \rho_g^{0.089}}{U_{mf}^{0.033} \ \rho_s^{0.182} \ D_p^{0.030} \ D_T^{0.405}} \qquad (4)$$

A comparison of the calculated fluidized-bed expansion ratios, using Equation 4, with the published data is shown in Figure 10.

It is recognized that the regression analysis used above is constrained because all the parameters in Equation 3 were forcibly fitted to the data used in this investigation. To circumvent this problem, the linear regression analysis was expanded to use the t-test with 95% confidence limit to determine the relative statistical significance of the chosen parameters; as a result the following correlation was obtained:

$$\frac{L_f}{L_{mf}} = 1 + \frac{0.855 \ (U - U_{mf})^{0.569} \ \rho_g^{0.084}}{U_{mf}^{0.049} \ \rho_s^{0.173} \ D_T^{0.403}} \qquad (5)$$



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MATERIAL	CHARACTERISTIC EXPERIMENTAL MINIMUM FLUIDIZATION VELOCITY OF THE BED, ft/s	SYMBOL	REFERENCE
LIGNITE	0.58	+	CURRAN AND GORIN[3]
LIGNITE	0.79	L	CURRAN AND GORIN[3]
LIGNITE	0.24	C	CURRAN AND GORIN[3]
LIGNITE	0.14	1	CURRAN AND GORIN[3]
LIGNITE	0.07	7	CURRAN AND GORIN[3]
64% BURN OFF CHAR	0.31	6	CURRAN AND GORIN[3]
60% BURN OFF CHAR	0.075	0	CURRAN AND GORIN[3]
63% BURN OFF CHAR	0.035	B	CURRAN AND GORIN[3]
40% BURN OFF CHAR	0.07	R	CURRAN AND GORIN[3]
60% BURN OFF CHAR	0.0175	U	CURRAN AND GORIN[3]
DOLOMITE	1.43	J	CURRAN AND GORIN[3]
DOLOMITE	0.90	4	CURRAN AND GORIN[3]
DOLOMITE	0.67	#	CURRAN AND GORIN[3]
DOLOMITE	0.50	3	CURRAN AND GORIN[3]
DOLOMITE	0.81	D	CURRAN AND GORIN[3]
DOLOMITE	0.165	G	CURRAN AND GORIN[3]
FUSED PERICLASE	0.68	F	CURRAN AND GORIN[3]
FUSED PERICLASE	0.06	P	CURRAN AND GORIN[3]
CHAR	0.05	#	FELDMANN et al.[8]
CHAR	0.03	7	FELDMANN et al.[8]
SIDERITE	0.725	A	TARRAN et al.[10]
SIDERITE	0.31	•	TARRAN et al.[10]
SIDERITE	0.149	T	TARRAN et al.[10]
SIDERITE	0.111	&	TARRAN et al.[10]
SIDERITE	0.041	N	TARRAN et al.[10]
SIDERITE	0.131	V	TARRAN et al.[10]
SIDERITE	0.04-0.3	X	TARRAN et al.[10]
BITUMINOUS COAL	0.111-0.29	K	KNOWLTON[10]
CHAR	0.11	H	KNOWLTON[10]
LIGNITE	0.12	E	KNOWLTON[10]
SIDERITE	0.3-0.7	S	KNOWLTON[10]

Figure 10. COMPARISON OF THE EMPIRICAL CORRELATION GIVEN BY EQUATION 4 WITH MEASURED FLUIDIZED-BED EXPANSION RATIOS

A comparison of the calculated expansion ratios using this correlation with the published data related to coal gasification is shown in Figure 11. Figures 10 and 11 appear to predict about 95% of the data within ±12% of the measured values. This is a considerable improvement over the correlations shown in Figures 7 and 8. Most of the data with the higher expansion ratios and greater than 12% deviation are seen to be light char materials of particle sizes less than 0.0043 inch (about 150 mesh) fluidized at U/U_{mf} values ranging from 16 to 20. Even though Curran and Gorin[3] did not report any difficulty in measuring bed heights, it is conceivable that possible slugging or the inability to measure bed heights with accuracy at high superficial velocities could account for the deviations of these data. The difficulty of measuring precisely the expansion ratios of dense materials at low bed expansions is the reason for the calculated values being higher than the experimental data reported by Tarman et al., Curran and Gorin, and Knowlton.

By comparing Equations 4 and 5, a strong correlation appears to exist between U_{mf} and D_p for the data considered. Further work is in progress to modify the correlations given by Equations 4 and 5 to express the fluidized-bed expansion ratio in terms of physically pertinent dimensionless groups to facilitate reliable extrapolation beyond the range of operating conditions of the data shown in Table 1. Following this effort, the rationale will be developed for recommending specific correlations to estimate the fluidized-bed expansion characteristics.

2. Transport Disengagement Height

Fluidized beds are usually operated with a wide size distribution of solids, containing a substantial portion of fines. More fines are also created by attrition and by virtue of reacting solids, and the exiting gases conceivably exceed the terminal velocity of many of these fine particles, thereby carrying them out of the reactor. In addition to the entrainment of fines, solids are carried into the freeboard by erupting bubbles. However, as the particles lose their kinetic energy while ascending the freeboard space, some particles will return to the bed depending on the particle size and particle density. As a result, the particle loading in the escaping freeboard gas drops rapidly to a certain point beyond which it attains a constant value at which the terminal velocity of the accompanying particles are equal to or less than the velocity of the exiting gas stream.

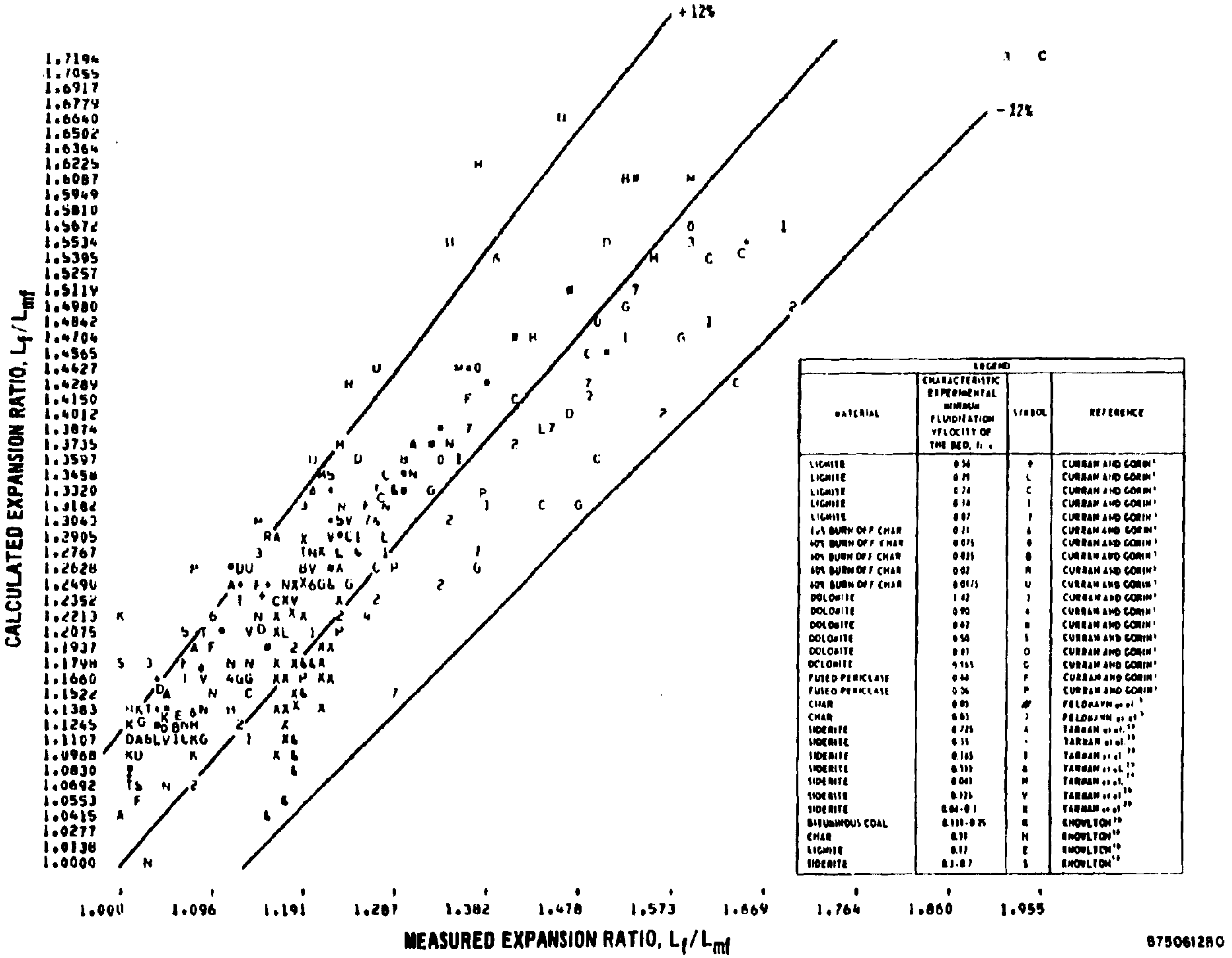

Figure 11. COMPARISON OF THE EMPIRICAL CORRELATION GIVEN BY EQUATION 5 WITH MEASURED FLUIDIZED-BED EXPANSION RATIOS

The freeboard height corresponding to the constant entrainment rate is known as the transport disengagement height (TDH), which determines the optimum location for gas exit ports in a fluidized bed.

The published correlations and empirical procedures to estimate TDH are summarized in Table 2. Attempts to evaluate the suitability of these correlations with the published data will be initiated during the subsequent months.

3. Entrainment and Elutriation

By definition, "entrainment" refers to the carry-over of solids in the exiting fluid stream from a fluidized bed. The particle-size distribution in the entrained-gas stream changes with freeboard height and remains constant beyond the TDH. The phenomenon of separation or classification of particles, either based on their size or particle density, during entrainment irrespective of the freeboard height is known as "elutriation."

The estimation of entrainment and the extent of accompanied elutriation are vital to the satisfactory operation of a fluidized-bed reactor. These quantities will determine the solids inventory in the fluidized bed and the extent of off-gas cleanup, and will be the basis for the design of dust removal equipment.

The published correlations to estimate entrainment are listed in Table 3. The suitability of these correlations to the entrainment and elutriation data of materials related to coal gasification will be tested and published in the future status reports.

4. Nomenclature

A_t = cross-sectional area of fluidized bed, sq ft

d_b = bed-particle diameter, ft

d_f = particle diameter of fines, ft

d_{fm} = maximum diameter of entrained fine particles, ft

d_p = particle diameter, ft

Table 2. SOME PUBLISHED CORRELATIONS TO PREDICT TRANSPORT DISENGAGEMENT HEIGHT (TDH)

Investigators	Bed Diameter, inches	Fluidized Solids	Fluidizing Medium	Proposed Correlation	Remarks
Zenz and Weil[21]	2, 3, 8, 12, 24, and 192	--	--	$TDH = \frac{\rho_s d_p^2}{28,1\mu}\left[V_o + (U_t - U)\cdot\ln\left(1 - \frac{V_o}{U_t - U}\right)\right]$	Theoretical model
				A plot of TDH versus superficial velocity, U, with tube diameter, D_T, as a parameter.	Empirical correlation
Amitin et al.[1]	·5, 67	Catalyst	Air	$TDH = 19,016\sqrt{D_T}/(U_t - U)$ where U_t is the terminal velocity based on the average diameter of coarser particles.	
Leva and Wen[14]	--	--	--	$TDH = \frac{\rho_s \cdot d_p^2}{18\mu}\left[V_o - (U_t - U)\cdot\ln\left(1 + \frac{V_o}{U_t - U}\right)\right]$	Theoretical model
Do et al.[4]	22 ft × 0, 4 in.	Glass beads	Air	--	Theoretical model; requires the numerical integration of a differential equation.
Frantz and Juhl[7]	1, 2, 6, 12	Catalyst, sand	H_2, N_2, Natural gas, air, argon, CO_2	$TDH = 8,4 \times 10^4 D_p\ \rho_g^{0,33}\ \mu^{0,79}\ D_T^{2,16}\ U^m$ $m = D_T^{-0,11}$	--
Fournol et al.[6]	24	FCC catalyst	Air	$TDH = \frac{1000\ U^2}{8}$	--

Table 3. SOME PUBLISHED CORRELATIONS TO PREDICT ENTRAINMENT RATES AND ELUTRIATION RATES

Investigators	Bed Diameter, Inches	Fluidized Solids	Fluidizing Medium	Proposed Correlation	Remarks
Leva[13]	1.32	Sand, Fischer-Tropsch catalyst	Air	$X_f = X_{fo}\, e^{-2.303 k\theta}, \quad k \propto U^{4.5}$	$H > TDH$
Osberg and Charlesworth[18]	3	Scotchlite glass beads	Air	$X_f = X_{fo}\, e^{-2.303 k\theta}, \quad k \propto \frac{(U-U_t)^{1.7}\, d_b^{0.7}}{d_f^{2}\, L_s^{1.4}}$	$H > TDH$ Low fines concentration
Yagi and Aochi[12]	--	--	--	$X_f = X_{fo}\, e^{\frac{-KA_t\theta}{W}}$ Graphical correlation of $\frac{Kd_f}{\mu}, \frac{gd_f}{(U-U_t)^2}$ versus $d_f U_t \rho_g/\mu$	$H > TDH$
Zenz and Weil[43]	--	--	--	Numerical calculation procedure based on a theoretical model Empirical approach by graphical correlation	$H < TDH$ and $H > TDH$
Wen and Hashinger[41]	4, 2	Scotchlite glass beads, bituminous coal powder	Air, helium	$X_f = X_{fo}\, e^{\frac{-KA_t\theta}{W}}$ $\frac{K}{\rho_g(U-U_t)} = 1.52\times10^{-5}\left[\frac{(U-U_t)^2}{gd_f}\right]^{0.5}\cdot\left[\frac{d_f U_t \rho_g}{\mu}\right]^{0.725}\cdot\left[\frac{\rho_s-\rho_g}{\rho_g}\right]^{1.15}$ for $X_f < 0.25$ $K_{X_f>0.25} = K_{X_f<0.25}\left(\frac{X_f}{0.25}\right)^{-0.48}$	$H > TDH$ for binary and multiparticle system
Andrews[1]	3.8, 1.2	Catalyst	Air, N_2	$F(d_f) = -\frac{\lambda A_t \rho_B \beta}{6}(2g)^{1/2}\, m_p g \int_H^{\infty}\sqrt{x}\; e^{-\beta m_p g x}\,dx$ $F = \Sigma X_f\, F(d_f)$	Theoretical model
Fridland and Skoblo[22]	--	Natural and synthetic microspherical aluminosilicate catalyst	Air	$\frac{F}{A_t U \rho_g}(10^2) = \frac{A\, U^3 X_f^{0.5} L_f^{p}\, m_v^{1}}{d_{av}^{1.51} H^{n} f}$ $d_{av} = \Sigma X_i d_f$ m_v is a correction factor and can be determined by graphical correlation; values of A, n, and p are tabulated by the investigators.	$H < TDH$ and $H > TDH$

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Table 3, Cont. SOME PUBLISHED CORRELATIONS TO PREDICT ENTRAINMENT RATES AND ELUTRIATION RATES

Investigators	Bed Diameter, inches	Fluidized Solids	Fluidizing Medium	Proposed Correlation	Remarks
Razumov and Larionova[24]	7.5	Microspheres of natural clay catalyst	Air	$\frac{F}{A_t U \rho_g} = 5.95 \left[F_r \cdot \frac{\rho_g}{\rho_s} \cdot X_f \right]^{1.85}$ $F_r = U^2/g d_{fm}$	$H > TDH$
Lewis et al.[16]	3/4, 1-1/4, 2, 3, 5-3/4	Glass, polystyrene, iron, cracking catalyst	Air	$\frac{F}{A_t U} = C \exp\left[(-b_o + A H U)/U^4\right]$ $b_o = 1.26 \times 10^4 \rho_s d_p^2$ C and A are constants and depend upon the column diameter and fluidized solids.	$H < TDH$ and $H \geq TDH$ for single particle size solids
Hanesian and Rankell[9]	3	Glass beads	Air	$\frac{X_f}{X_{fo}} = b e^{-k_1 \theta} + (1 - b) e^{-k_2 \theta}$ Constants k_1, k_2, and b are tabulated for various gas velocities and particle-size distributions	$H > TDH$
Kunii and Levenspiel[11]	--	--	--	$F = F_o e^{-aH}$ and $a = \frac{K^*}{U_l}$ where F_o = rate of solids projected from bed surface, lb/sq ft-s K^* = rate coefficient for transfer from agglomerates moving up to agglomerates and dispersed phase moving down, s^{-1} U_l = velocity of agglomerates moving up, ft/s	Theoretical model $H < TDH$ and $H \geq TDH$
Leva and Wen[15]				Graphical correlation of $F/A_t J$ versus $\left(\frac{U - U_L}{U_t}\right)^1 U_{mf}^4$ based on the theoretical model and data of single-size glass spheres.	
Merrick and Highley[17]	36 x 36	Coal and ash	--	$\frac{K}{U \rho_g} = A + 130 \exp\left[-10.4 \left(\frac{U_t}{U}\right)^{0.5} \left(\frac{U_{mf}}{U - U_{mf}}\right)^{0.25}\right]$ A is constant A = 0.0001 for 36 x 36-inch combustor unit with 11-ft freeboard A = 0.0015 for 48 x 24-inch BCURA unit with 6-ft freeboard	--

D_f = particle diameter of a sieved fraction, ft

D_p = average particle diameter, ft = $\frac{1}{\Sigma(X/D_f)}$

D_T = tube diameter, ft

E = total energy of fluidized system, ft-lb

f = free area of gas distributing grid (fraction of total), sq ft/sq ft

F = total entrainment rate, lb/s

$F(d_f)$ = entrainment rate of particles of diameter d_f, lb/s

g = acceleration of gravity, ft/s^2

H = distance between bed surface and gas outlet, ft

J = rate of solids carried up by wake of bubbles per unit time per unit surface area of bed, lb/sq ft-s

k = elutriation rate constant, s^{-1}

K = elutriation rate constant, lb/sq ft-s

L_{mf} = height of minimum fluidized bed, ft

L_f = height of fluidized bed, ft

L_s = settled bed height, ft

m_p = mass of entraining particle, lb

N = total number of particles in fluidized system

U = superficial gas velocity, ft/s

U_{mf} = minimum fluidization velocity, ft/s

U_t = terminal velocity, ft/s

V_o = particle velocity leaving bed surface, ft/s

W = weight of solids in fluidized bed, lb

X = weight fraction of sieved particles

X_f = weight fraction of fines in the fluidized bed at any time, θ

X_{fo} = weight fraction of fines in the fluidized bed at $\theta = 0$

X_i = weight fraction of ith size fraction with respect to total weight of fines

ρ_g = density of fluidizing gas, lb/CF

ρ_s = particle density of fluidizing solids, lb/CF

ρ_B = fluidized-bed density, lb/CF

μ = viscosity of fluidizing gas, lb/ft-s

β = entrainment rate constant = N/E

λ = constant coefficient of conductance

θ = time, s

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D. COMBUSTION

In the Project 8964 April 1975 Status Report, it was proposed that sulfur recovery data in FBC experiments be organized on the basis of a comparatively simple reactor model. The equations presented were applied to Argonne National Laboratory (ANL) data for a Pittsburgh coal-Tymochtee Dolomite system, and a completely backmixed reactor model appeared to give a reasonable characterization of the reported results. Therefore, the same approach was applied to an earlier but not quite as extensive set of data developed by ANL.[1] The system was of Illinois coal-limestone No. 1359 with the material properties and operating conditions shown in Tables 4 and 5. Unlike the previously analyzed data set, this one does not report directly measured bed compositions in most runs. Therefore, for this analysis, bed compositions have been calculated using material balance considerations as described in the April Report, with the assumption that there was no significant preferential elutriation.

Table 4. MATERIAL PROPERTIES

	Seam 6, Mine 10 Peabody Coal Co. Christian Co., Ill.	Limestone No. 1359	
	wt %		
Analysis			
Moisture	10.12	Ca	37.9
Ash	10.85	CO_2	42.2
Sulfur	3.72	Ash	56.2
Carbon	61.54		
Hydrogen	4.47		
Mean Particle Size, mm	490	550-1000	

As has been reported in many FBC studies at atmospheric pressure, the reaction rate appears to go through a maximum at about 1500°F, an effect not observed at higher (8-atm) pressures. Also, for this limestone, at these conditions, only a fraction of the CaO appears to be effective. Simultaneous allowance for these peculiarities makes data correlation difficult. Koppel[1] in his analysis of these (or similar) data implies that only 50% of the CaO is effective. With this value, the reaction rate constants, k_o, are plotted as a function of temperature. They are calculated from the ANL data and defined by —

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[1] Jonke, A. A. et al., Reduction of Atmospheric Pollution by the Application of Fluidized-Bed Combustion, Annual Report July 1970-June 1971, ANL ES-CEN-1004. Argonne National Laboratory, U. S. Environmental Protection Agency, 1971.

Table 5. OPERATING RANGES*

Temperature, °F	1400-1600
Pressure, atm	1
Dry Flue Gas/Coal, SCF/lb	105-130
Bed Diameter, ft	0.5
Bed Weight, lb	14-45
Ca/S Mole Ratio	1.0-5.5
Ca Conversion (Estimated)	0.16-0.38
Ca Bed Weight Fraction (Estimated)	0.22-0.45
Sulfur Recovery Fraction	0.38-0.96

---

* Not all the ANL tabulated results have been used in this analysis in view of the caveat concerning tabulation errors.

$$\text{Reaction rate (moles of S/min)} = k_o\, X_{SO_2}\,(X_{Ca,\,m} - X_{Ca})\, Ca_{bed}\, W_{bed}$$

where

X_{SO_2} = mole fraction of SO_2 in actual flue gas

$Ca_{bed} W_{bed}$ = weight of calcium in the bed, lb

X_{Ca} = fraction of calcium sulfated

$(X_{Ca})_m$ = maximum possible fraction of calcium sulfated.

Figure 12 shows the results. Each point is shown as a range corresponding (quite arbitrarily) to ±5% of the fraction of sulfur recovered as the sulfate. It is seen that the maximum rate near 1500°F is not very reproducible. There are, however, other systems that have indicated this maximum so its existence cannot be rejected. But one can entertain the thought that operation at this peak condition is unstable and not always achievable. Because of the uncertainty in the peak value, the curve shown was drawn on the basis of engineering conservatism. The observed value at 1500°F is 3.7 times the value on the curve, but, if one substitutes the lower value (at the conditions of the run), the fraction of sulfur recovered would be estimated as 0.81 rather than the 0.92 observed. Other data in this set imply such discrepancies are encountered. A similar calculation for the high value at 1550° would result in an estimation of 0.85 rather than the 0.92 sulfur recovery observed.

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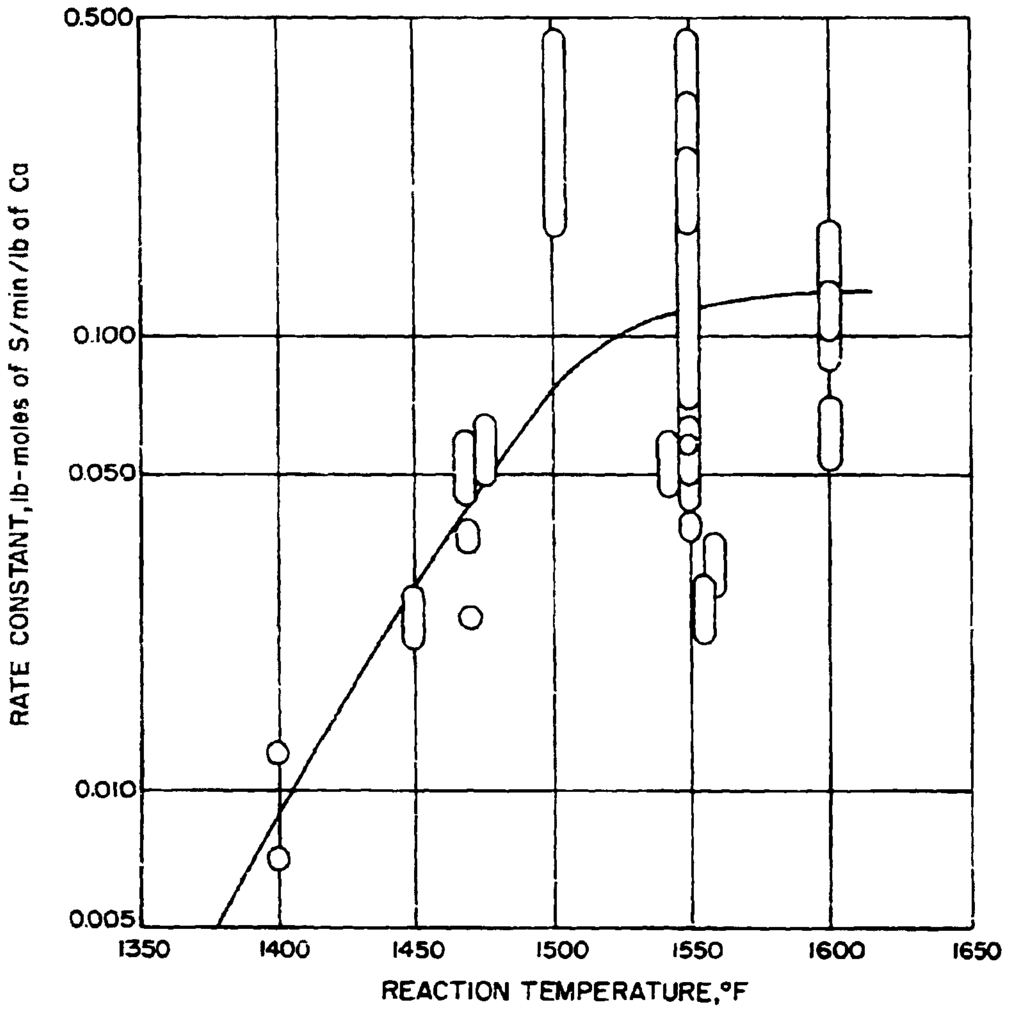

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Figure 12. RATE CONSTANTS FOR THE REACTION OF SULFUR IN ILLINOIS COAL WITH LIMESTONE 1359

E. COAL, CHAR, AND OIL SHALE PROPERTIES

1. Specific Heat of Coal, Char, and Ash

Work on the specific heat of coals, chars, and related materials was continued. Comparisons of Kirov's correlation (the Project 8964 March 1975 Status Report) with experimental data at elevated temperatures (300° and 600°C) were prepared in graphical form. Then we learned that apparent specific heat data on 20 American coals have just become available from P. L. Walker at Pennsylvania State University, via a paper to be presented at the ACS Fuels Division Meeting at Chicago in August. Next month, if the paper is received in time, we will present correlations incorporating these data as well as previous data.

2. Penn State Data

Data on 50 coal samples from Penn State have been tabulated (Table 6). About one-third of the samples are from deposits too small to be included in our table of large-size deposits (Table 4, Project 8964 April 1975 Status Report). However, they are being retained in the data table for the time being, at least.

Table 6. PROPERTIES OF SEL

STATE	COUNTY AND SEAM	MINE (OR OTHER IDENTIFICATION)	RANK	PROXIMATE ANALYSIS, wt %	DRY BASIS			ULTIMATE ANALYSIS, wt % DRY BASIS							
				MOISTURE	VOLATILE	FIXED CARBON	ASH	CARBON	HYDROGEN	NITROGEN	CHLORINE	SULFUR	ASH	OXYGEN (DIFFERENCE)	VITRINITE
AL	Jefferson, American	Maxine	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
AL	Walker, Mary Lee	Mary Lee No. 1	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	74.4
AR	Johnson, Lower Spadra	Hilton Coal Co. Strip	lvb	[illegible]	17.57	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.71	[illegible]	[illegible]	57.7
AZ	Navajo, Red	Black Mesa	subA	10.70	[illegible]	50.24	[illegible]	72.56	5.36	[illegible]	[illegible]	0.57	[illegible]	[illegible]	[illegible]
CO	Weld, Laramie 3	Eagle	subB	[illegible]	[illegible]	[illegible]	5.40	72.00	4.75	[illegible]	[illegible]	[illegible]	5.40	[illegible]	[illegible]
CC	Routt, Wadge	Edna	hvCb	[illegible]	[illegible]	[illegible]	[illegible]	64.20	[illegible]	1.77	0.02	0.65	[illegible]	[illegible]	[illegible]
CO	Pitkin, Coal Basin B	Dutch Creek	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.44	[illegible]	[illegible]	[illegible]
IL	Fulton, Colchester No. 2	Sunspot	--	[illegible]	[illegible]	[illegible]	[illegible]	70.80	[illegible]	0.44	0.04	[illegible]	[illegible]	[illegible]	[illegible]
IL	Saline, Herrin No. 6	Sahara No. [illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]	56.92	5.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IL	Gallatin, Illinois No. 5	Eagle No. 2	--	[illegible]	[illegible]	[illegible]	[illegible]	69.55	4.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IL	Williamson, Davis	Will Scarlet	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	67.76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IN	Owen, Indiana Block 1	Old Glory	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	71.13	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IN	Sullivan, Indiana No. 6	Dugger	hvCb	[illegible]	[illegible]	[illegible]	[illegible]	66.72	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IN	Sullivan, Indiana No. 7	Minnehaha	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	74.47	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
IC	Wapello, Lower Cherokee	[illegible] Coal Co. Strip	hvCb	[illegible]	[illegible]	[illegible]	[illegible]	60.74	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KS	Cherokee, Mineral	P&M No. 19	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	67.61	[illegible]	[illegible]	0.27	[illegible]	[illegible]	[illegible]	[illegible]
KY	Letcher, Elkhorn No. 3	No. [illegible]	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KY	Muhlenburg, Ky. No. 9	Sinclair Strip	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	72.41	5.06	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
KY	Muhlenburg, Ky. No. 11	Sinclair Strip	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	64.14	[illegible]	1.67	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MC	Henry, Tebo	Power	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.17	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MC	Macon, Bevier	Bee [illegible]	hvBb	[illegible]	[illegible]	[illegible]	[illegible]	59.76	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MT	Rosebud, Rosebud	Colstrip	subB	[illegible]	[illegible]	[illegible]	[illegible]	66.39	[illegible]	0.99	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
ND	Mercer, Coteau	Glenharold	lig	34.12	[illegible]	[illegible]	[illegible]	64.09	4.42	1.40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NM	McKinley, Lower Split of Blue	McKinley	--	[illegible]	[illegible]	[illegible]	[illegible]	73.63	[illegible]	1.17	0.00	[illegible]	5.14	[illegible]	[illegible]
NM	Colfax, York Canyon	York Canyon	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	74.61	5.14	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NM	San Juan, No. 6	Navaho	hvCb	[illegible]	[illegible]	[illegible]	[illegible]	61.65	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OH	Harrison, Lower Freeport	Nelms No. 1 Shaft	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	76.30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
OH	Harrison, Ohio No. 6	Georgetown [illegible] Strip	hvAb	[illegible]	[illegible]	[illegible]	[illegible]	72.19	[illegible]	[illegible]	[illegible]	3.47	[illegible]	[illegible]	[illegible]
OH	Morgan, Meigs Creek No. 9	Muskingham	hvAb	[illegible]	40.12	[illegible]	[illegible]	62.19	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TED COAL SAMPLES

PETROGRAPHIC DATA					FORMS OF SULFUR, %			RANK DATA			MISCELLANEOUS			ASH-SOFTENING TEMP, °F		
ERAL ANALYSIS, vol %					DRY BASIS											
SEMI-FUSINITE	MICRINITE	EXINITE	RESINITE	REFLECTANCE OF VITRINITE, %	PYRITIC	SULFATE	ORGANIC	FIXED CARBON, %, dry, mm free	EQUILIBRIUM MOISTURE, %	CALORIFIC VALUE, Btu/lb, moist, mm free	CALORIFIC VALUE, Btu/lb, dry basis	HARDGROVE GRINDABILITY INDEX	FREE-SWELLING INDEX	OXIDIZING ATMOS	REDUCING ATMOS	CODE NO.
4.8	[illegible]	3.6	0.8	0.48	0.02	0.04	2.25	64.25	--	15,341	12,885	[illegible]	[illegible]	--	--	PSC C-[illegible]
5.7	[illegible]	3.8	0.4	0.44	0.45	0.00	0.45	64.6	--	14,679	11,887	90.2	[illegible]	--	--	PSC C-[illegible]
10.6	7.1	0.0	0.0	2.47	[illegible]	0.11	0.47	80.82	--	--	12,830	[illegible]	--	--	--	PSC C-[illegible]
4.8	2.2	2.2	0.2	0.44	0.07	0.01	0.29	54.19	18.2	11,072	12,741	[illegible]	[illegible]	--	--	PSC C-[illegible]
6.1	[illegible]	1.7	1.7	0.56	0.00	0.00	0.15	60.14	--	10,455	12,404	[illegible]	--	--	--	PSC C-[illegible]
3.7	1.1	2.1	2.1	0.80	0.25	0.01	0.51	57.96	--	12,545	12,215	49.0	--	--	-	PSC C-[illegible]
2.0	1.7	0.0	0.0	1.44	0.04	0.00	0.46	75.62	--	--	14,625	[illegible]	--	-	--	PSC C-[illegible]
1.2	4.8	[illegible]	0.0	0.70	1.44	0.04	1.64	59.53	--	--	12,525	[illegible]	--	[illegible]	[illegible]	PSC C-[illegible]
[illegible]	[illegible]	8.4	1.0	0.84	[illegible]	0.35	2.05	56.07	--	--	12,775	[illegible]	--	--	--	PSC C-[illegible]
[illegible]	[illegible]	2.9	0.4	[illegible]	2.52	0.06	1.84	58.35	--	--	12,652	70.1	--	--	--	PSC C-[illegible]
[illegible]	[illegible]	4.8	1.0	[illegible]	3.30	0.03	0.71	55.81	--	14,022	[illegible]	77.7	4.0	--	--	PSC C-[illegible]
2.8	[illegible]	22.0	[illegible]	[illegible]	1.24	0.05	0.42	62.24	--	[illegible]	[illegible]	[illegible]	[illegible]	--	--	PSC C-[illegible]
3.1	[illegible]	2.1	0.7	[illegible]	2.69	0.09	1.93	59.71	--	12,774	[illegible]	67.4	[illegible]	--	--	PSC C-[illegible]
3.7	2.4	[illegible]	[illegible]	[illegible]	0.26	0.02	0.55	[illegible]	--	[illegible]	[illegible]	[illegible]	[illegible]	--	-	PSC C-[illegible]
4.7	[illegible]	4.0	0.2	0.80	2.76	0.31	1.07	53.12	--	12,986	11,227	[illegible]	--	--	--	PSC C-[illegible]
1.1	[illegible]	[illegible]	[illegible]	[illegible]	4.07	0.19	2.11	[illegible]	--	[illegible]	[illegible]	[illegible]	--	--	--	PSC C-[illegible]
4.8	[illegible]	[illegible]	[illegible]	[illegible]	0.1	0.00	0.82	62.14	--	14,836	13,434	[illegible]	--	--	--	PSC C-[illegible]
2.8	[illegible]	2.4	0.1	[illegible]	2.35	0.14	1.61	[illegible]	--	13,677	[illegible]	[illegible]	[illegible]	--	--	PSC C-[illegible]
1.7	[illegible]	2.8	[illegible]	[illegible]	2.21	0.15	2.00	[illegible]	--	[illegible]	[illegible]	57.4	[illegible]	--	--	PSC C-[illegible]
[illegible]	9.7	2.1	0.1	[illegible]	4.25	0.05	1.65	54.32	--	13,734	[illegible]	[illegible]	[illegible]	--	--	PSC C-[illegible]
9.9	[illegible]	1.8	[illegible]	[illegible]	4.71	0.05	1.09	56.27	--	[illegible]	[illegible]	73.0	[illegible]	--	--	PSC C-[illegible]
2.7	[illegible]	2.4	[illegible]	[illegible]	0.33	0.04	0.42	[illegible]	--	10,177	[illegible]	50.4	--	--	--	PSC C-[illegible]
13.5	[illegible]	[illegible]	[illegible]	[illegible]	0.03	0.06	0.56	51.0	--	7,494	[illegible]	62.9	--	--	--	PSC C-[illegible]
12.3	[illegible]	2.0	[illegible]	0.40	0.05	[illegible]	0.40	54.58	--	--	13,009	51.5	0.5	--	--	PSC C-[illegible]
14.9	[illegible]	2.3	0.1	0.52	0.53	0.00	0.36	60.08	--	15,081	[illegible]	63.6	--	--	--	PSC C-[illegible]
11.0	[illegible]	1.4	0.4	0.49	[illegible]	0.00	0.47	54.04	--	[illegible]	10,982	47.7	[illegible]	--	--	PSC C-[illegible]
14.4	[illegible]	5.9	0.7	0.77	1.41	0.09	0.73	59.21	--	14,541	[illegible]	[illegible]	[illegible]	--	--	PSC C-[illegible]
4.7	[illegible]	3.1	0.6	0.65	2.28	0.02	1.17	56.27	--	14,215	[illegible]	44.0	4.5	--	--	PSC C-[illegible]
5.4	[illegible]	1.8	0.6	0.56	[illegible]	0.05	2.05	[illegible]	--	14,144	11,679	55.2	5.0	--	--	PSC C-[illegible]

2

Table 6, Cont. PROPERTIES OF

STATE	COUNTY AND SEAM	MINE (OR OTHER IDENTIFICATION)	RANK	PROXIMATE ANALYSIS, wt %				ULTIMATE ANALYSIS, wt %							
					DRY BASIS			DRY BASIS							
				MOISTURE	VOLATILE	FIXED CARBON	ASH	CARBON	HYDROGEN	NITROGEN	CHLORINE	SULFUR	ASH	OXYGEN (DIFFERENCE)	VITRINITE
OH	Mahoning, No. 5, Lower Kittanning	Five Points	hvAb	4.16	36.21	45.60	18.19	67.16	4.66	2.14	0.11	0.96	18.19	6.78	43.0
OH	Belmont, Ohio No. 12	No. 36	hvAb	3.57	31.97	38.77	29.26	56.42	4.21	1.26	0.06	2.05	29.26	6.74	61.9
OK	Le Flore, Hart Shorne	Howe	mvb	0.44	20.85	68.97	10.18	79.96	4.01	0.18	0.01	1.05	10.18	4.59	90.5
PA	Schuylkill, Buck Mountain	Renninger	an	2.51	5.77	80.29	13.94	78.18	2.25	0.66	0.0	0.55	13.94	4.42	90.3
PA	Somerset, Lower Kittanning	Bird No. 3	lvb	0.51	18.10	71.28	10.62	78.92	4.17	1.05	0.12	3.10	10.62	2.03	86.9
PA	Cambria, Lower Freeport	Pennsylvania No. 8	lvb	1.14	20.59	66.49	12.92	74.27	4.33	1.11	0.11	4.04	12.92	3.22	85.8
PA	Cambria, Lower Kittanning	Cambria No. 33	lvb	0.64	18.62	74.37	7.01	82.90	4.46	0.85	0.04	1.09	7.01	3.64	59.0
PA	Washington, Pittsburgh	Mathies	hvAb	1.62	38.78	54.52	6.70	78.00	4.71	2.09	0.09	1.95	6.70	6.46	80.2
TE	Campbell, Peewee	Long Pit Mining Co.	hvAb	2.77	36.66	56.11	7.23	77.34	5.24	1.84	0.14	1.29	7.23	6.92	73.60
TX	Harrison, Lignite *	Darco	--	24.52	42.28	47.44	10.28	66.66	4.45	0.38	0.03	0.65	10.28	17.55	[illegible]
VA	Wise, Jawbone or Shannon	Dal Strip Job	hvAb	1.16	31.66	52.79	15.54	71.69	4.64	2.03	0.02	0.58	15.54	5.5	[illegible]
VA	Wise, Imboden	Prescott No. 2	hvAb	1.26	33.63	59.16	7.21	79.95	5.05	2.23	0.01	0.54	7.21	5.01	[illegible]
VA	Dickenson, Lower Banner	Camp Branch No. 1	hvAb	0.95	32.86	58.63	8.51	80.10	4.97	1.75	0.04	0.71	8.51	3.93	59.2
UT	Emery, Lower Sunnyside	Geneva	hvBb	4.29	39.55	55.30	5.15	77.15	5.44	1.39	0.02	0.85	5.15	10.0	81.3
UT	Carbon, Seam A	King	--	3.60	41.73	48.81	9.46	71.89	5.55	1.52	0.04	1.76	9.46	9.77	65.2
UT	Carbon, Hiawatha	Plateau	hvBb	6.32	39.27	44.66	16.07	66.55	5.15	1.51	0.05	0.61	16.07	10.06	79.9
WA	Lewis, Big D	Centralia	subB	18.22	39.12	38.39	22.48	56.27	4.49	1.09	0.02	1.01	22.48	14.64	78.9
WV	Nicholas, Tioga	Tioga No. 1	hvAb	1.92	30.71	53.93	15.36	71.11	4.26	0.97	0.06	1.10	15.36	7.14	68.1
WV	Mcdowell, Pocahontas 3	No. 14	--	1.82	21.54	72.07	6.39	84.6	4.02	1.05	0.01	0.52	6.39	3.41	78.5
WY	Sheridan, Monarch	Big Horn	subB	17.60	40.92	52.09	6.99	67.99	4.93	1.33	0.04	0.84	6.99	17.88	85.7
WY	Lincoln, Adaville 1	Elkol	subA	19.17	42.50	54.57	2.93	72.96	5.00	1.68	0.04	0.64	2.93	16.75	76.3

* Includes 0.1 of sclerotinite.

CTED COAL SAMPLES

PETROGRAPHIC DATA					FORMS OF SULFUR, %			RANK DATA			MISCELLANEOUS			ASH-SOFTENING TEMP, °F		
ERAL ANALYSIS, vol %					DRY BASIS											
SEMI-FUSINITE	MICRINITE	EXINITE	RESINITE	REFLECTANCE OF VITRINITE, %	PYRITIC	SULFATE	ORGANIC	FIXED CARBON, %, dry, mm free	EQUILIBRIUM MOISTURE, %	CALORIFIC VALUE, Btu/lb, moist, mm free	CALORIFIC VALUE, Btu/lb, dry basis	HARDGROVE GRINDABILITY INDEX	FREE-SWELLING INDEX	OXIDIZING ATMOS	REDUCING ATMOS	CODE NO.
8.2	16.8	21.2	2.2	0.74	0.91	0.0	0.07	56.95	--	14,384	12,157	40.7	1.5	--	--	PSCC-296
8.6	9.0	7.3	0.2	0.7	1.21	0.01	0.83	57.17	--	14,346	10,243	50.4	1.5	--	--	PSCC-306
1.0	3.8	0.0	0.0	1.43	0.42	0.00	0.63	77.81	--	--	13,541	115.6	--	--	--	PSOC-142
1.7	0.0	0.0	0.0	4.17	0.02	0.00	0.53	94.76	--	--	12,603	28.9	--	--	--	PSOC-60
3.9	6.4	0.0	0.0	1.80	2.03	0.16	0.91	61.56	--	--	13,745	--	--	--	--	PSCC-113
3.5	6.8	0.0	0.0	1.47	2.69	0.20	1.16	78.60	--	--	13,233	--	--	--	--	PSCC-116
1.8	9.8	0.0	0.0	1.68	0.63	0.02	0.44	80.81	--	--	14,603	122.5	--	--	--	PSCC-126
2.6	7.9	4.2	0.3	0.81	1.29	0.01	0.65	60.57	--	14,577	13,743	59.4	8.5	--	--	PSCC-293
1.9	9.0	9.3	0.8	0.66	0.53	0.06	0.70	61.12	--	14,057	13,801	49.0	3.5	--	--	PSCC-300
[illegible]	11.9	2.8	2.7	0.32	0.18	0.03	0.46	53.46	--	--	11,467	66.4	0.5	--	--	PSCC-135
[illegible]	14.3	6.3	1.4	0.96	0.02	0.00	0.56	63.59	--	15,132	12,754	53.9	7.5	--	--	PSCC-265
[illegible]	4.2	3.2	0.9	1.03	0.02	0.00	0.52	64.27	--	15,250	14,239	63.6	8.0	--	--	PSCC-269
9.0	12.2	5.2	2.2	--	0.16	0.01	0.54	65.16	--	15,626	14,266	67.1	5.5	--	--	PSCC-302
4.2	2.4	2.8	0.6	0.69	0.27	0.06	0.52	58.72	--	13,930	13,757	48.3	--	--	--	PSCC-068
3.5	3.8	2.4	0.5	0.58	0.74	0.01	1.03	54.66	--	--	13,061	53.2	--	--	--	PSCC-238
2.8	1.0	9.0	1.8	0.57	0.13	0.00	0.48	54.15	--	13,326	11,698	49.0	1.0	--	--	PSOC-313
10.9	4.7*	1.5	2.9	0.46	0.33	0.00	0.69	50.69	--	10,163	9,952	45.6	--	--	--	PSOC-240
4.9	10.2	5.8	0.0	0.89	0.51	0.00	0.59	64.93	--	14,761	12,567	56.7	--	--	--	PSCC-118
4.6	12.0	0.3	0.0	1.42	0.04	0.00	0.48	77.57	--	--	14,533	114.2	--	--	--	PSCC-130
2.6	2.2	1.4	0.4	0.48	0.46	0.01	0.37	56.49	--	10,357	11,762	45.6	--	--	--	PSCC-241
11.6	9.5	1.2	0.4	0.47	0.03	0.00	0.61	55.42	--	10,507	12,661	49.7	--	--	--	PSCC-248

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2

F. MISCELLANEOUS

Advisory Committee

Letters were sent out inviting eminent people in various areas of coal conversion technology to serve on an Advisory Committee for the Data Book Project. The purpose of an advisory committee is to obtain reviews and comments on –

- Organization of the total work (Data Book Index)
- Selection of subjects to be covered in priority schedule
- Scope of work to be covered for selected subjects
- General plan for implementing the work
- Progress reports
- Final data presentations.

The list of the people to whom the letters were sent is given in Table 7. We have received eight responses so far; seven of them accepting our invitation. One declined because of lack of time to spare for serving on the committee, although he too was in favor of the idea.

IV. Patent Status

The work performed during May is not considered patentable.

V. Future Work

The data collection and evaluation work will be continued in the selected areas of coal conversion technology.

Approved W. W. Bodle
W. W. Bodle, Director
Process Analysis

Signed A. Talwalkar
A. Talwalkar, Coordinator
Process Data

Table 7. PERSONS INVITED TO SERVE ON THE DATA BOOK ADVISORY COMMITTEE

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