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THE G-VALUE: APPLICATION TO WESTERN CANADIAN COALS

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THE G-VALUE: APPLICATION TO WESTERN CANADIAN COALS

by

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ABSTRACT

The G-value is an index of the caking power of a coal used extensively in Germany as an aid in the blending of coals for cokemaking. In this report the G-values of western Canadian coals are examined to determine whether this method of predicting coke quality is applicable.

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CONTENTS

FIGURES

INTRODUCTION

The decline in the availability of prime coking coals has necessitated the increased use of coal blends for carbonization. A knowledge of the relationship between coke quality and coal properties facilitates the formulation of coal blends designed to yield high-quality coke. The use of such predictive relationships becomes particularly necessary for blends containing three or more component coals. Clearly, the required amount of experimental work (e.g. 500 lb capacity oven tests) to optimize the composition of such blends would become unmanageably large.

Current practice in North America is to predict coke strength from a knowledge of the petrographic composition of the component coals and their proportions in the blend (1). In Japan, coking coals are characterized in terms of their measured mean vitrinite reflectance and maximum fluidity in the plastic zone (2). Coke of maximum strength is produced from blends with reflectance and fluidity values which are within defined upper and lower limits. A predictive method developed in Germany is based on a knowledge of blend volatile content and caking capacity (G-value) (3,4). The latter is calculated from the measured plastic zone swelling characteristics of the blend (Ruhr dilatometer). More recently, the method has been applied (with success) in predicting the strength (stability) of cokes made from American coals (5).

The purpose of this report is to assess the G-value for a range of western Canadian coals which have been used in test-oven carbonization studies in this laboratory. Results are examined in order to demonstrate whether or not the G-value is a relevant variable in the relationship between coal properties and coke quality.

BACKGROUND

Calculation of G-value from Dilatometer Data

Dilation (swelling) measurements are commonly made using a Rhur dilatometer (of standardized design) in which a compressed pencil of fine coal is heated at a steady rate in a cylindrical tube. Changes in pencil height with temperature are determined from the recorded displacement of a piston located on the top of the pencil. Dilation is attributed to the evolution of gas bubbles (volatile matter) within the plastic mass. The effect is preceded by an initial contraction during which the softened coal is deformed under its own weight together with that of the piston. The dilation characterics of a strongly caking coal are shown in Figure 1. Relevant features are (i) the softening temperature (θ_s) denoting the onset of deformation (ii) the temperature (θ_c) at which the contraction (c) is a maximum; at this temperature, the rate of contraction of the coal pencil is balanced by the rate of dilation (iii) the temperature (θ_d) at which dilation (d) is a maximum.

Simonis (3) introduced the G-value (defined as a caking capacity) as a means of characterizing the contraction/dilation behaviour in terms of a single dimensionless parameter. The G-value is expressed as:

$$G = \frac{\theta_s + \theta_d}{2} \quad \frac{(c + d)}{(c\theta_d + d\theta_s)}$$

were c, d are the maximum contraction and dilation, respectively. Hence, G represents a ratio of two mean temperatures. The first is the arithimetic mean of the temperature of softening (θ_s) and maximum dilation (θ_d) i.e. $(\theta_s + \theta_d)/2$; the second is a mean temperature weighted according to the contraction and dilation levels $(c\theta_d + d\theta_s)/(c + d)$.

Figure 2 illustrates the dilation characteristics of three coals having different G-values. It should be noted that the G-value refers to the plastic zone properties of a coal and should hence be considered as a caking capacity rather than a coking capacity (6).

The G-value and Prediction of Coke Quality

Simonis (4) showed that, under similar carbonization conditions, coke quality was a maximum for an optimum G-value of a coal or blend. The optimum value was, however, dependent upon blend volatile content (Figure 3). Furthermore, it was claimed that the G-value was additive i.e. the value for a blend was given by the mean of that of the component coals weighed according to their proportions in the blend. As volatile content is also an additive property then, in principle, a blend can be specified which has a G-value at or close to the optimum value for a particular volatile content.

It was also established that the maximum level of the coke strength (at the optimum G-value) varies with blend volatile content. A relationship between coke quality, G-value and volatile content has also been demonstrated for a range of U.K. coals (6).

Extent of Analysis

Technical information relating to coal and coke properties (500 lb test oven data) for western Canadian coals was available from computer memory files. The coals had been carbonized under the following conditions: charge bulk density 52 lb/cu ft; coking rate 1.3 in/hr; charge fineness 80% - 90% -1/8 in. The data referred to single coals only since the plastic zone properties of coal blends had not been measured.

In particular, information was available concerning:

(i) coal volatile content, V, and petrographic composition (including mean reflectance, Ro);

(ii) coal plastic zone properties - dilation and fluidity;

(iii) coke stability, S.

From the data, correlations were sought between the following groups of variables:

(i) G-value and total dilation;

(ii) G-value and fluidity;

(iii) coke stability, coal volatile content and G-value;

(iv) coke stability, coal reflectance and G-value;

(v) coal reflectance and volatile content:

(vi) coke stability and volatile content;

(vii) coke stability and reflectance.

RESULTS AND DISCUSSION

In the assessment of the G-value from dilatometric data, it was found that some 30 - 40% of the western Canadian coals did not dilate sufficiently to give a positive value. In particular, the extent of dilation (as measured from the point of maximum contraction) was either zero or less than the measured maximum contraction c. In keeping with the data used by other workers in developing their predictive relationships (3,5), the current analysis was confined to those western Canadian coals showing a positive dilation. For such coals, a good correlation was shown between the G-value and the total dilation (c + d). The data shown in Figure 4 could be fitted by the expression:

$$G = 0.71 + 0.071 \ln (c + d) \qquad ....(1)$$

(correlation coefficient R = 0.94)

It should be noted that, for highly-dilatant coals, G becomes relatively insensitive to changes in (c + d). A non-dilatant coal (c = - d) would give G = 0 and a coal with a non-positive dilation (d negative, as measured from the baseline) would have a G-value somewhere between about 0.9 and 0.

For the coals analysed, the G-value and maximum fluidity (Geiseler plasticity) correlated by an expression of the form:

$$G = 0.22 \ln (\text{fluidity}) + 0.91 \qquad ....(2)$$

(correlation coefficient R = 0.81)

The G-values obtained are plotted against the volatile matter content of the coals in Figure 5. For each point a coke stability index is known and is approximately displayed in this figure by using different symbols for five different stability index intervals. The data in each stability interval were linearly regressed (using the modified least squares linear regression of Visman and Picard (6)) and after interpolation the relationships shown in Figure 6 were obtained.

The results illustrate that the stability index is predominately dependent on the volatile matter content of the coal. For coals with the same volatile matter content the stability increases as the G-value increases. The influence of the G-value is large for coals of low volatile matter content producing cokes with high stability indices and decreases as the volatile matter increases and the stability indices decrease.

A similar analysis was made using mean vitrinte reflectance (Ro) as an alternative parameter to volatile content. The resultant relationship was as expected (Figure 7) in view of the close correlation between V and Ro (correlation coefficient R = 0.92).

The above results suggested that coke stability S was very strongly dependent on V or Ro. Hence, linear regression analyses were made between (i) S and V (ii) S and Ro, respectively. The corresponding correlation coefficients were 0.74 and 0.78. In both cases, the fitting of more complex relationships to the data (parabolic, logarithmic, semi-logarithmic, and exponential) showed little change in correlation coefficient. When the G-value was included as a variable, the following relationships were obtained:

$$S = 64.3\ (\text{G-value}) - 1.81\ V + 33.45 \qquad ....(3)$$

(correlation coefficient R = 0.79)

$$S = 44.5\ (\text{G-value}) + 40.9\ Ro - 40.04 \qquad ....(4)$$

(correlation coefficient R = 0.809)

Hence, the correlation coefficient was improved with the inclusion of the G-value. It should be noted that equations (3) and (4) will not generate exactly the relationships shown in Figures 6 and 7 respectively. The former equations refer to the results of linear regressions of the whole of the data whereas the relationships (Figure 6 and 7) relate to the analysis of the data after grouping into different stability intervals. Petrographic analysis had been carried out on most of the coals included in this report and a petrographic prediction of the coke strength was available in the computer files (1). In Figure 8 the linear regression lines for plots of oven stability versus three predicted stabilities, petrographic, equation (3) (V, G-value) and equation (4) (Ro, G-value) are shown. The correlation coefficients are 0.674, 0.787 and 0.809 respectively. Thus although the petrographically predicted line follows the equivalence line most closely it has the lowest correlation coefficient.

In the development of equations 1 and 2 no account was taken of the possibility that there may be an optimum G-value for each coal for which the coke stability is a maximum (3). Accordingly, an attempt was made to identify an optimum value of G for western Canadian coals within the respective volatile content ranges 19-19.9%, 20-20.9%, etc. The open circles (Figure 9) refer to the G-values which gave cokes of maximum stability from coals of the stated volatile content intervals. The broken line refers to previously-established data for German coals. The solid circles were obtained by grouping the data into five volatile content intervals and drawing the best-fit parabola on a stability vs G-value plot to obtain the maximum stability for the interval and the magnitude of the

G-value at which it occurred. Both methods indicated that the optimum G-value increased as the volatile content increased to 27%, but it was concluded that there was insufficient data for firm conclusions to be drawn concerning the higher volatile content coals. In Figure 6, it is shown that the stability indices increase as G increases (for a given volatile content). This feature appears inconsistent with the concept of an optimum G-value. Examination of the data shows that the explanation is the preponderance of coals with G-values below the optimum value.

CONCLUSIONS

Examination of data for western Canadian coals has shown a relationship exists between coke stability, the G-value (caking capacity) and the volatile matter content (or reflectance) of the coal. The optimum G-value (i.e. the value that will give the highest coke strength for a particular coal volatile matter content) increases with volatile matter content in the range 18-29%, but does not coincide with that found for European coals.

Future work is planned to assess the additivity of G-values of component coals in binary blends.

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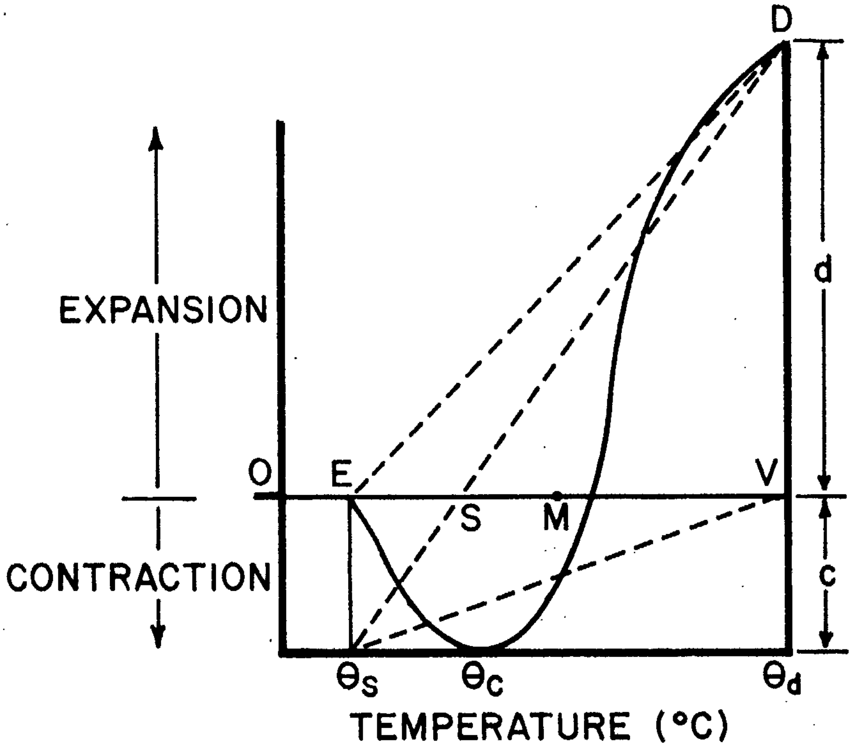

Figure 1. Typical dilatometer for a good caking coal.

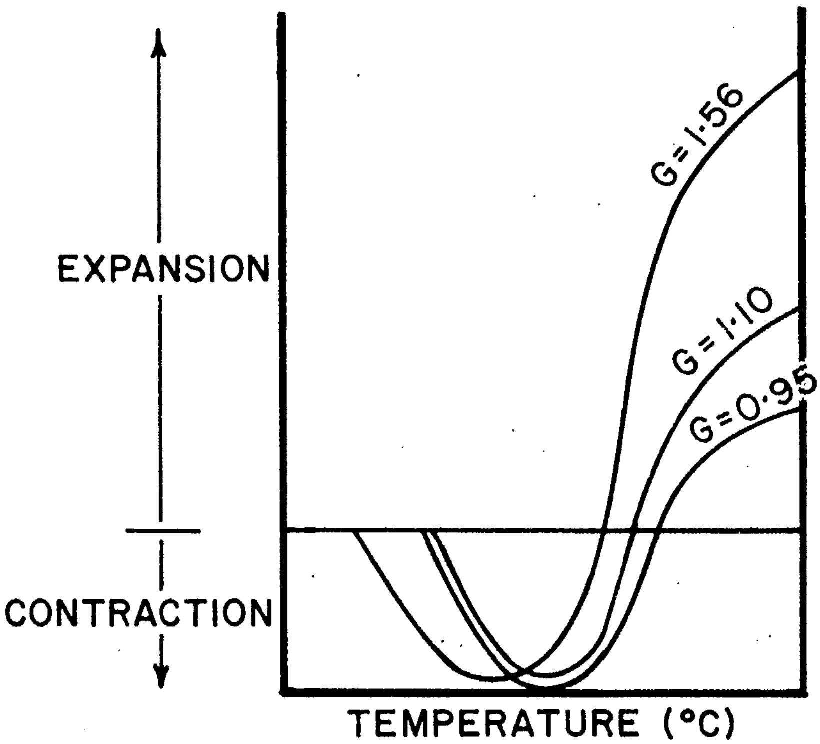

Figure 2. Ruhr dilatometer curves having different G-values (5)

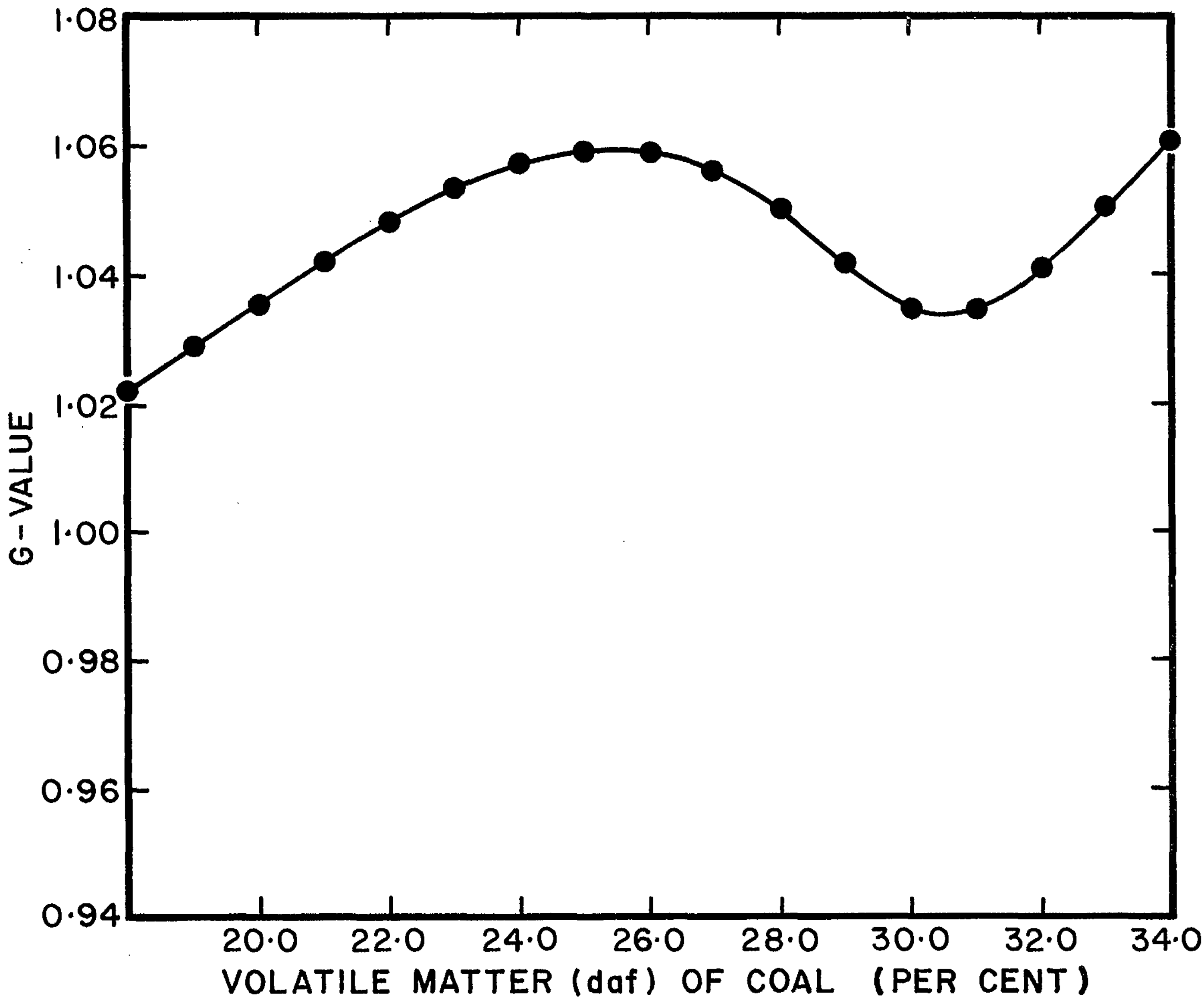

Figure 3. Relationship between volatile matter of coal and optimum G-value.

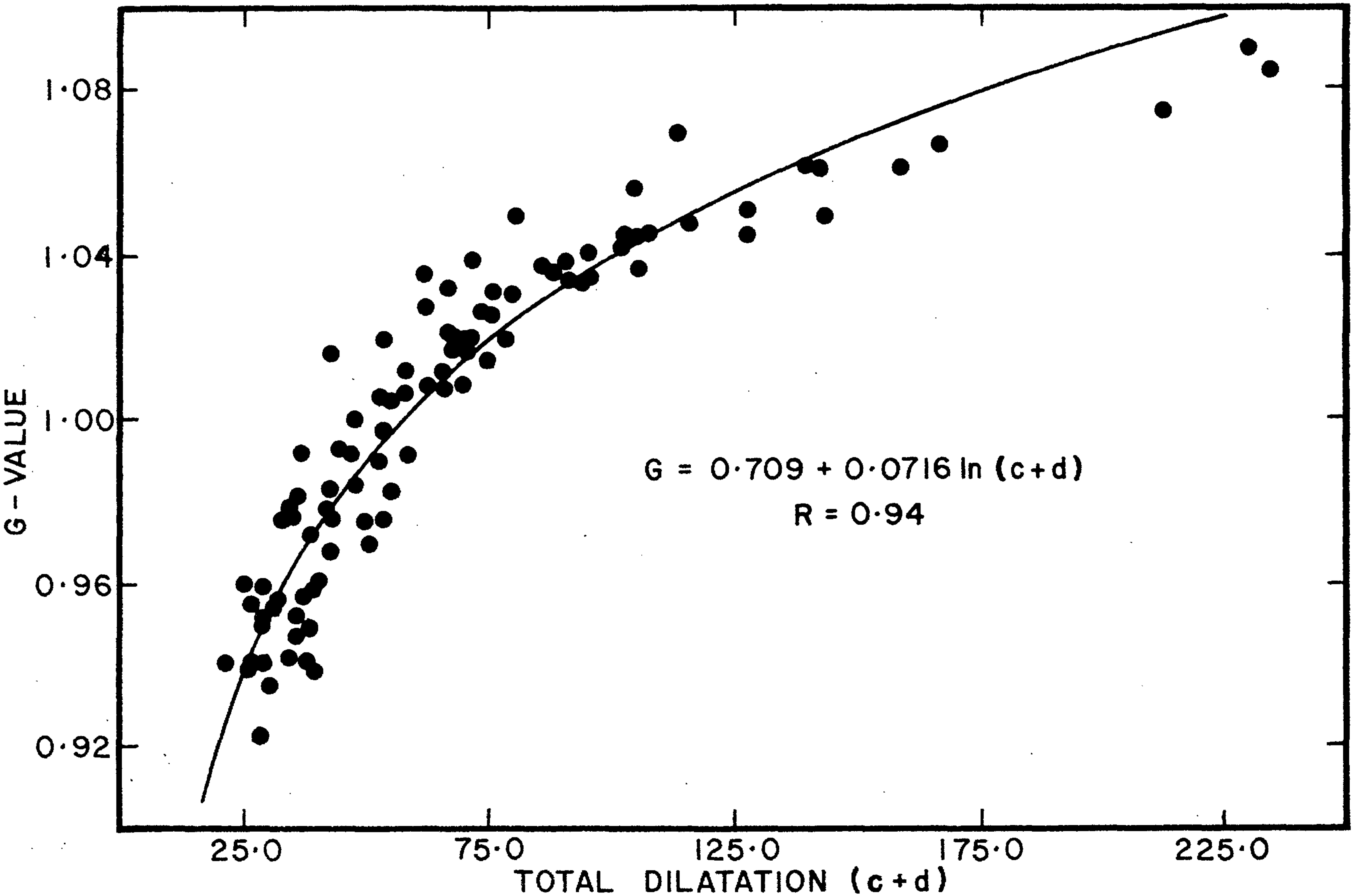

Figure 4. Relationship between the G-value and the total dilatation, (c+d) for Western Canadian coals.

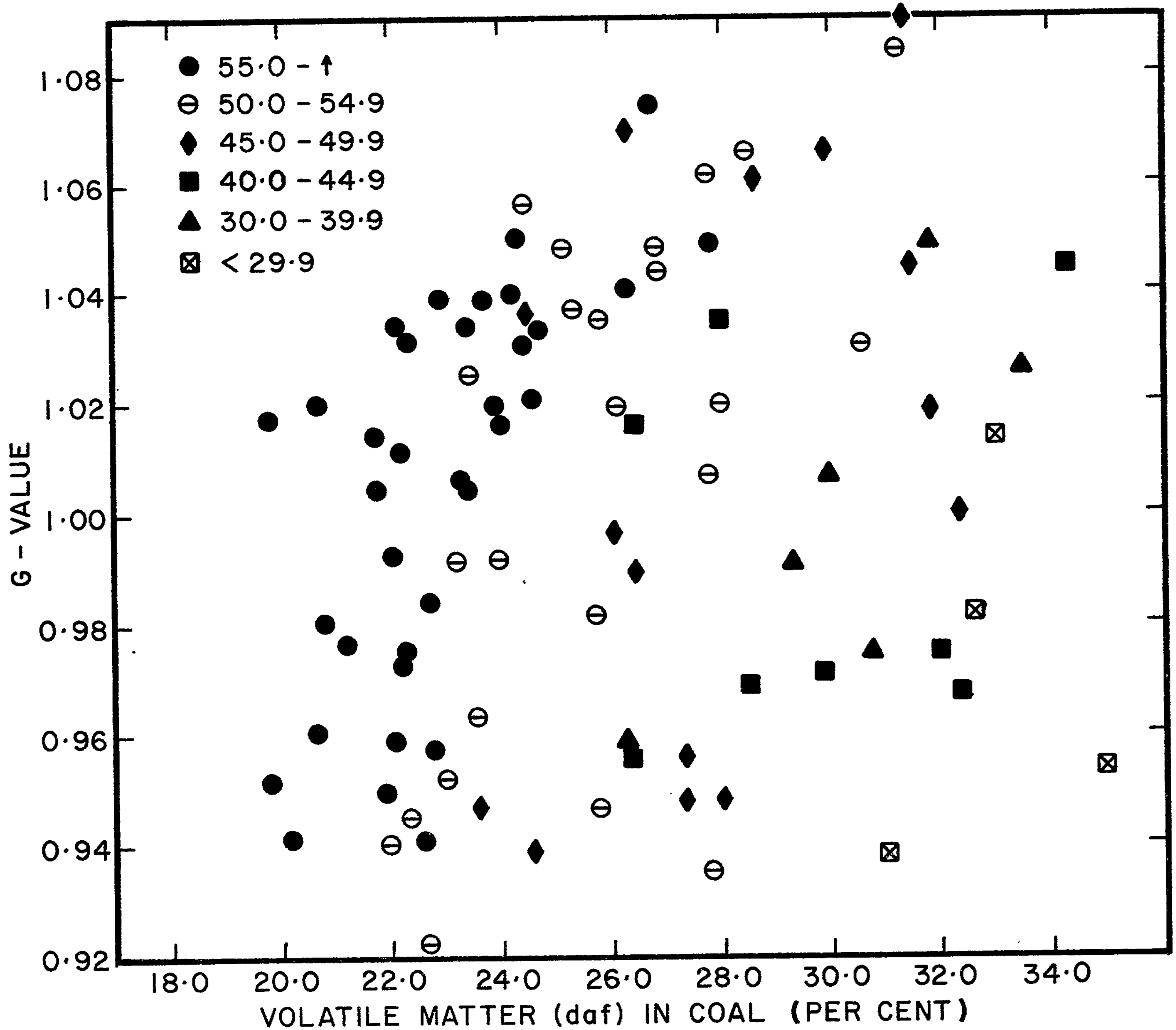

Figure 5. Relationship between G-value and volatile matter content (daf) of coal.

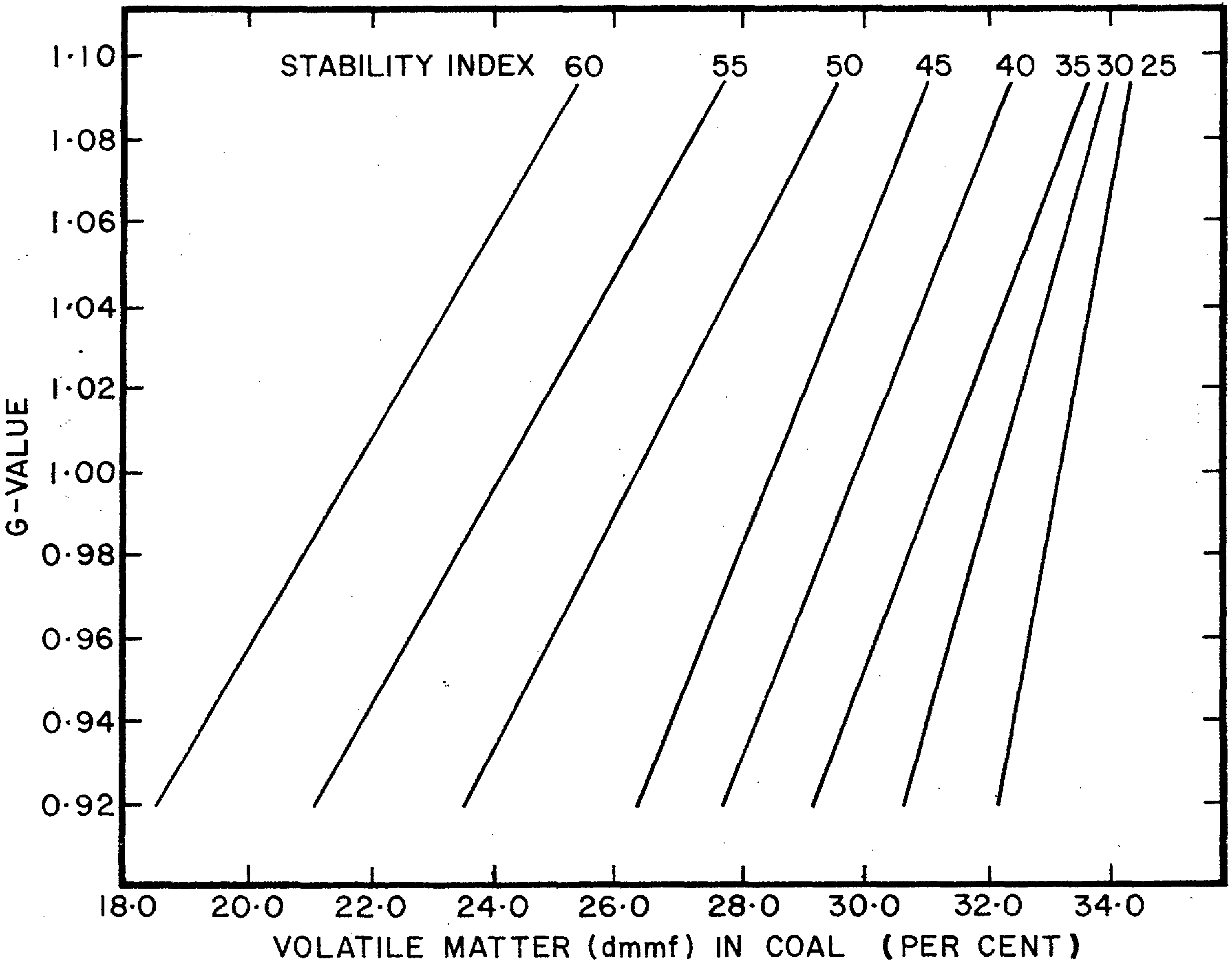

Figure 6. Relationship between G-value and volatile matter of Western Canadian coals for different coke strengths.

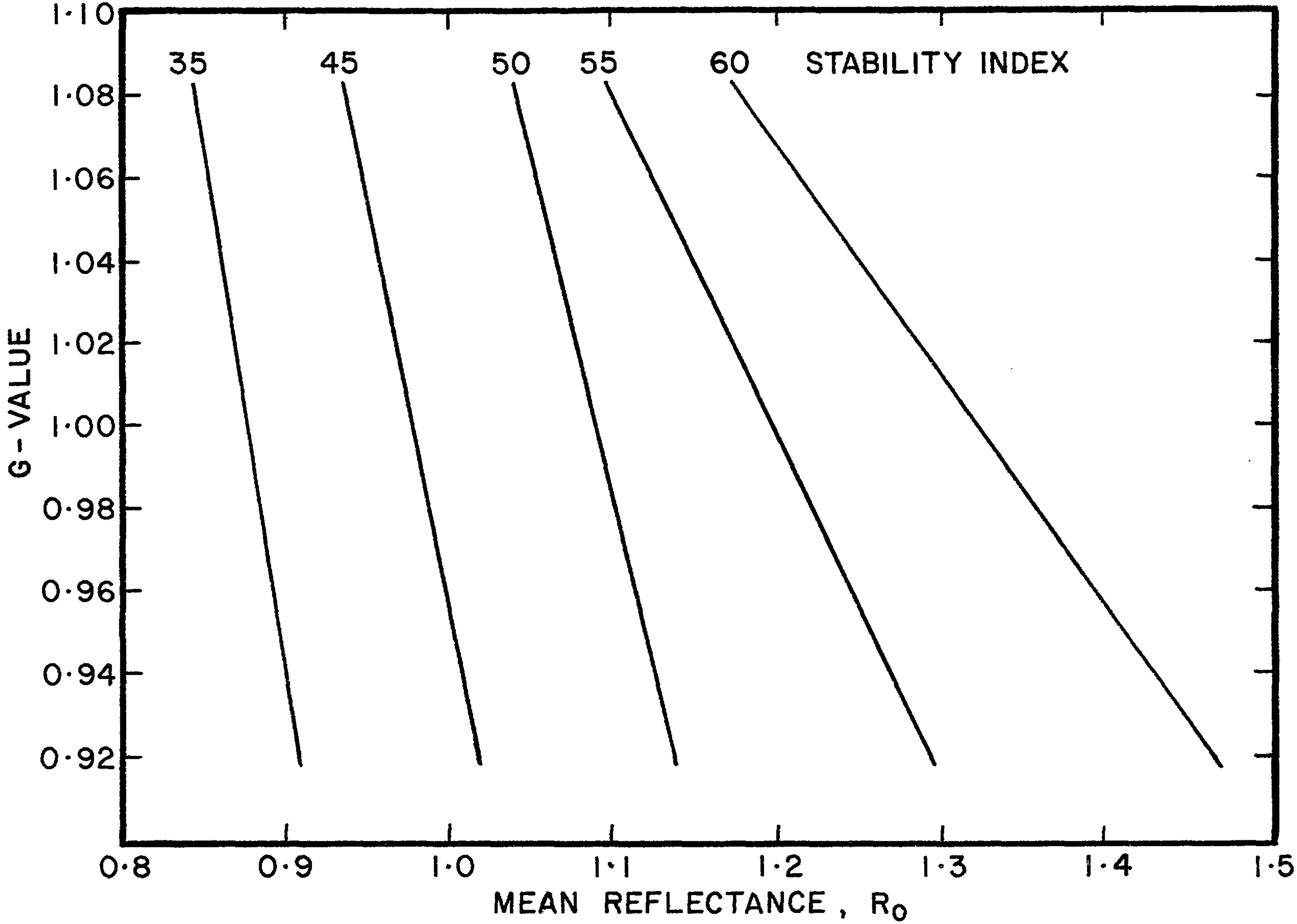

Figure 7. Relationship between the G-value and mean reflectance of Western Canadian coals.

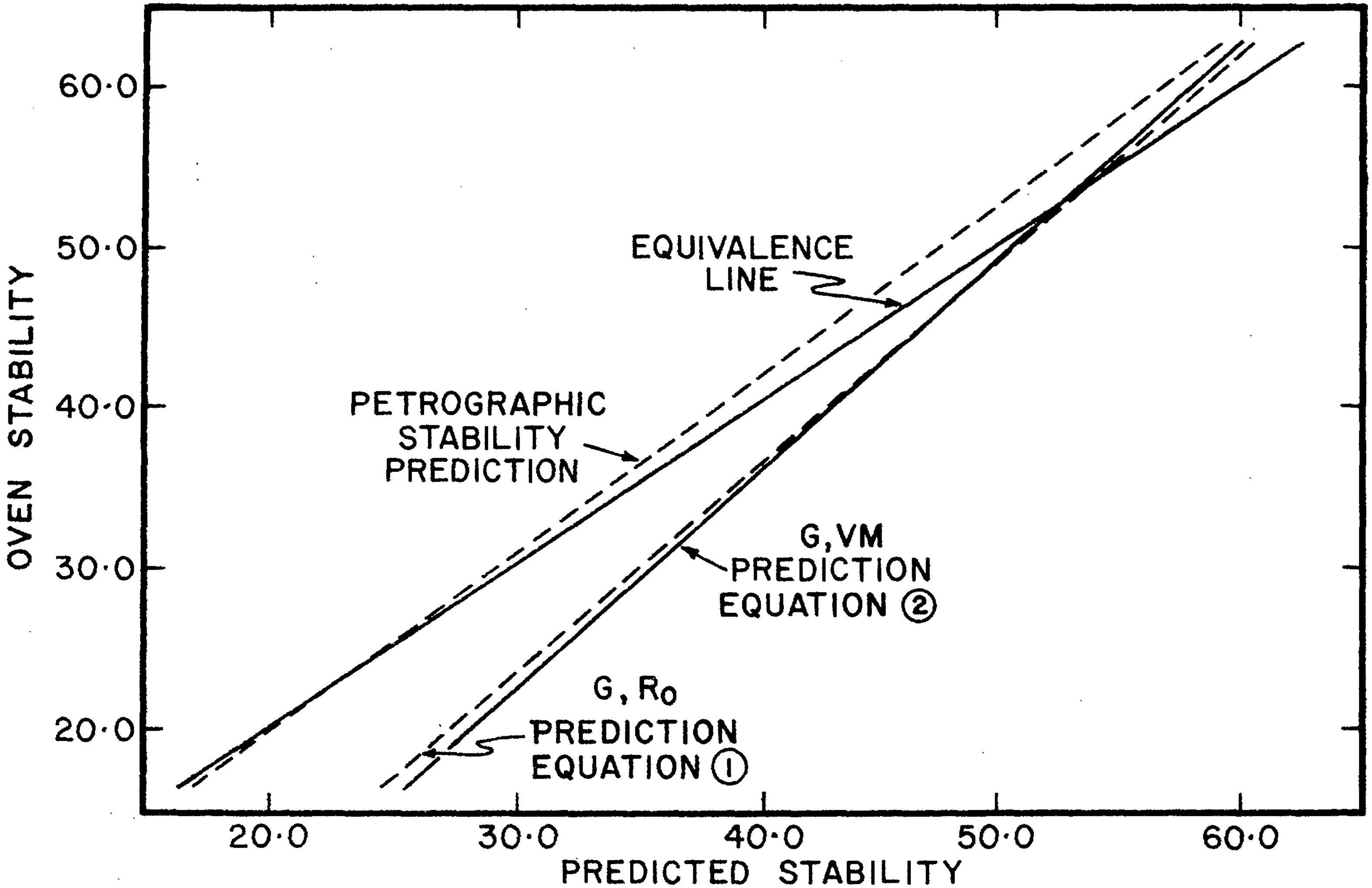

Figure 8. Comparison of oven stability index and predicted stability index.

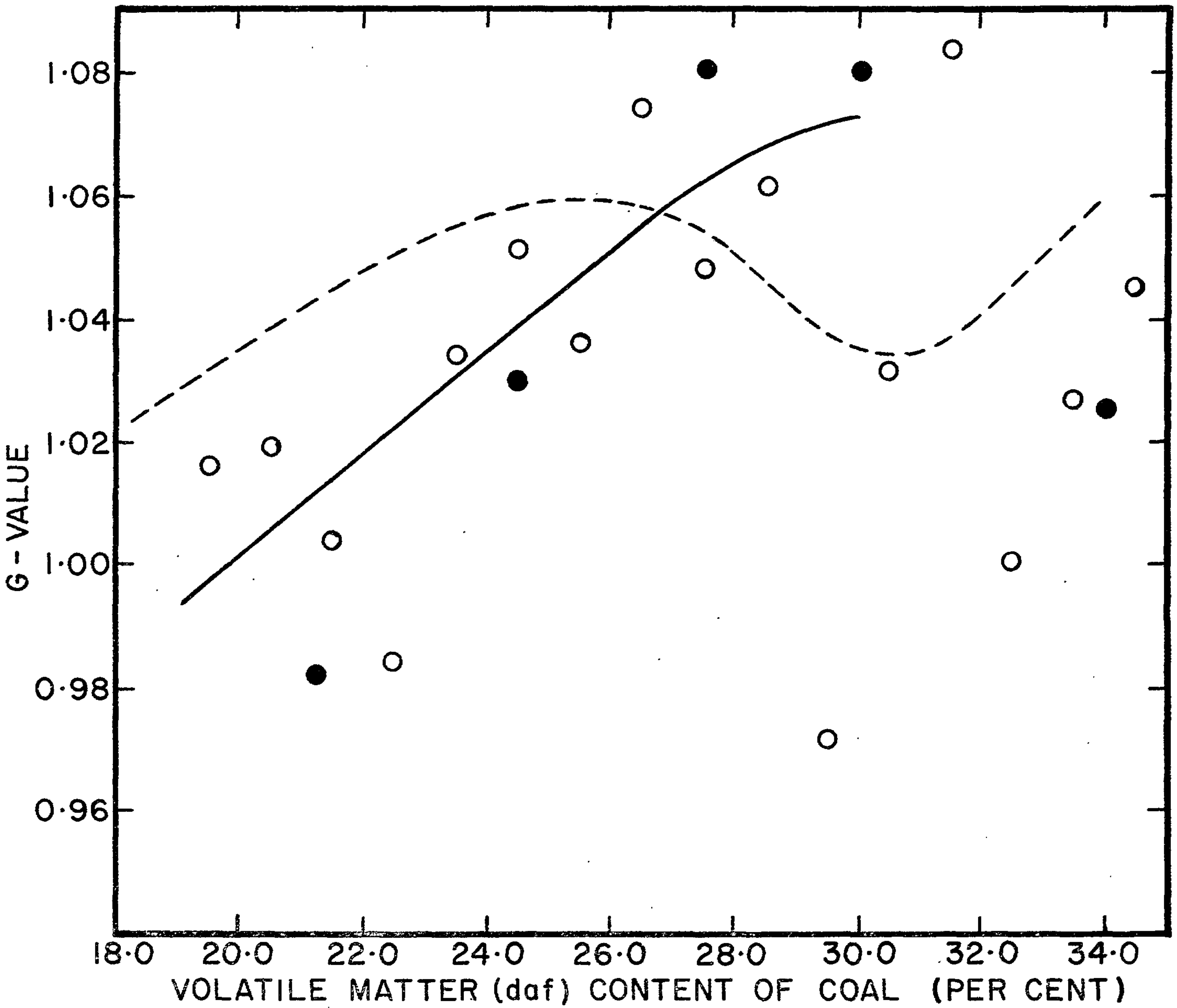

Figure 9. Relationship between the per cent volatile matter content of coal (daf) and the optimum G-value for Western Canadian coals.