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BRANDSTOFNAVORSINGSINSTITUUT
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OF SOUTH AFRICA

ONDERWERP: AN INVESTIGATION INTO THE
 SUBJECT:

IGNITION PROPERTIES OF

SOUTH AFRICAN PULVERIZED COAL.

AFDELING:
 DIVISION:

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AN INVESTIGATION INTO THE
IGNITION PROPERTIES OF
SOUTH AFRICAN PULVERIZED COAL

1.

INTRODUCTION

The process of pulverized fuel combustion has assumed an important position in the field of power generation, and for new installations the problem of selection of a suitable coal arises. Unexpectedly high carbon-in-ash losses recently observed for certain South African pulverized coal emphasize the need to supplement the existing basis of selection with data obtained under conditions more closely related to the practical situation than is the case with currently available comparative data.

The present study is confined to investigation of the ignition phase of the combustion process and deductions must be seen in that light.

2.

IGNITION TEMPERATURE AS COMPARATIVE BASIS

When a dispersion of pulverized coal in air is caused to flow through a heated furnace, it is found that for every fuel/air ratio, within a reasonable range, there exists a furnace temperature which will cause the dispersion to ignite only at the furnace exit. It stands to reason that at lower furnace temperatures ignition cannot yet occur at this point, while at higher furnace temperatures ignition will occur before reaching the exit.

/The ignition

The ignition temperature of pulverized coal, at a specific fuel/air ratio, is, therefore, defined as that furnace temperature which will cause the dispersion to ignite only at the furnace exit.

It may be deduced from the foregoing that the ignition temperature depends on the residence time within the furnace and is, therefore, a relative index of the ignition aptitude of the fuel. To be of significance, the ignition temperature of a specific coal must therefore be compared to that of other coals, determined under identical conditions. Moreover, the ignition temperature depends, inter alia, on the particle size distribution of the coal and comparison should thus be based on some standard particle size distribution.

The particle size distribution is a function of the friability of the coal and to obtain a predetermined, or standard, particle size distribution by means of controlled crushing is impossible in practice. The method adopted was to prepare the sample according to a standardized crushing procedure* and to determine the

/ignition

* A bulk sample of about 40 kg of the coal to be studied was air-dried and then crushed to minus 30 mesh. The minus 30 mesh material was divided into two representative samples. Both samples were separately crushed to minus 60 mesh in a hammer-mill. One of these samples ~~were~~^{was} used as such and for brevity was termed the "coarse" sample. The other sample was crushed again in a laboratory hammer-mill to approximately minus 170 mesh and was termed the "fine" sample.

ignition temperature of the sample. The ignition temperature of a sample of the same coal, having a standard particle size distribution, may then be computed from the ignition data of the experimental sample. (See Section 8).

3. EXPERIMENTAL APPARATUS

In essence, the apparatus consists of a vibrated storage hopper from which the pulverized coal is extracted by means of a variable speed screw extractor. The coal stream is passed through a vibrated screen to render a smooth coal flow, and is passed to a mixer in which the coal is dispersed in the primary air.

Compressed air is admitted to the mixer at a constant rate and in the form of a high speed jet to promote turbulent mixing of the air and the pulverized coal. A side effect of the compressed air jet is the intake of atmospheric air into the mixer along the coal intake passage. The primary air thus consists of compressed air plus entrained atmospheric air. As the coal flow to the mixer is increased so the free area of the coal intake passage, along which the atmospheric air enters, decreases, resulting in a total primary air rate decrease with an increase in the coal feed rate. Within the coal feed rate range employed, the primary air supply rate can be represented by the following equation:

$$G_p = 26,6 - 0,24 M$$

/where G_p

where G_p is the total primary air supply rate (g/min)
M is the coal feed rate (g/min).

From the mixer the coal is pneumatically conveyed to the electrically heated, cylindrical, down-draught furnace and enters the furnace as a co-axial downward jet. The secondary air is supplied at a fixed rate of 78 g/min and in the form of eight equi-spaced jets around the central jet of primary air. Both primary and secondary air ducts are water-cooled upstream from the furnace.

The furnace has a heated length of 450 mm and an internal diameter of 170 mm. The temperature of the furnace is measured by means of a thermocouple embedded in the inner lining of the furnace and positioned midway between the furnace ends. The furnace is directly connected to a water-cooled exhaust section which serves to quench any combustion which may otherwise occur downstream from the furnace exit.

The furnace vents to atmosphere through a stack fitted with an air ejector which ensures a constant pressure reduction of 2 mm W.G. below atmospheric pressure within the furnace.

The occurrence of ignition is monitored by means of an ignition detector positioned axially at the furnace exit. The detector consists of a bare and a sheathed thermocouple connected in opposition. For slowly changing temperatures, such as occurring during the cooling of the furnace, both thermocouples are essentially at the same temperature, maintaining a constant output from

/the detector

the detector. When ignition occurs, causing a rapid temperature increase, the bare thermocouple responds more rapidly than its sheathed counterpart and the detector output is subjected to a rapid deflection signifying the occurrence of ignition.

4. EXPERIMENTAL PROCEDURE

During the flow of cooling water and air, the furnace is brought to its maximum temperature of 1050°C and is maintained at this temperature for a period of three hours. This period is considered sufficient for thermal equilibrium to be achieved. The current to the furnace is subsequently switched off and the furnace is allowed to cool through at least 150°C before any ignition temperature determinations are attempted. This is done to ensure that localized thermal gradients within the furnace wall stabilize.

During the slow cooling of the furnace the coal feed is commenced and the feed rate is gradually increased from zero until an "ignition" is recorded. The furnace temperature is noted and the coal feed rate is determined from a 30-second intercepted sample. The furnace temperature is allowed to cool through approximately 10°C and the process is repeated. In this way a number of ignition temperature determinations, at various coal feed rates, are possible during a single cooling cycle of the furnace.

The individual 30-second intercepted samples are combined and the bulk sample is used for analysis.

/5. IGNITION

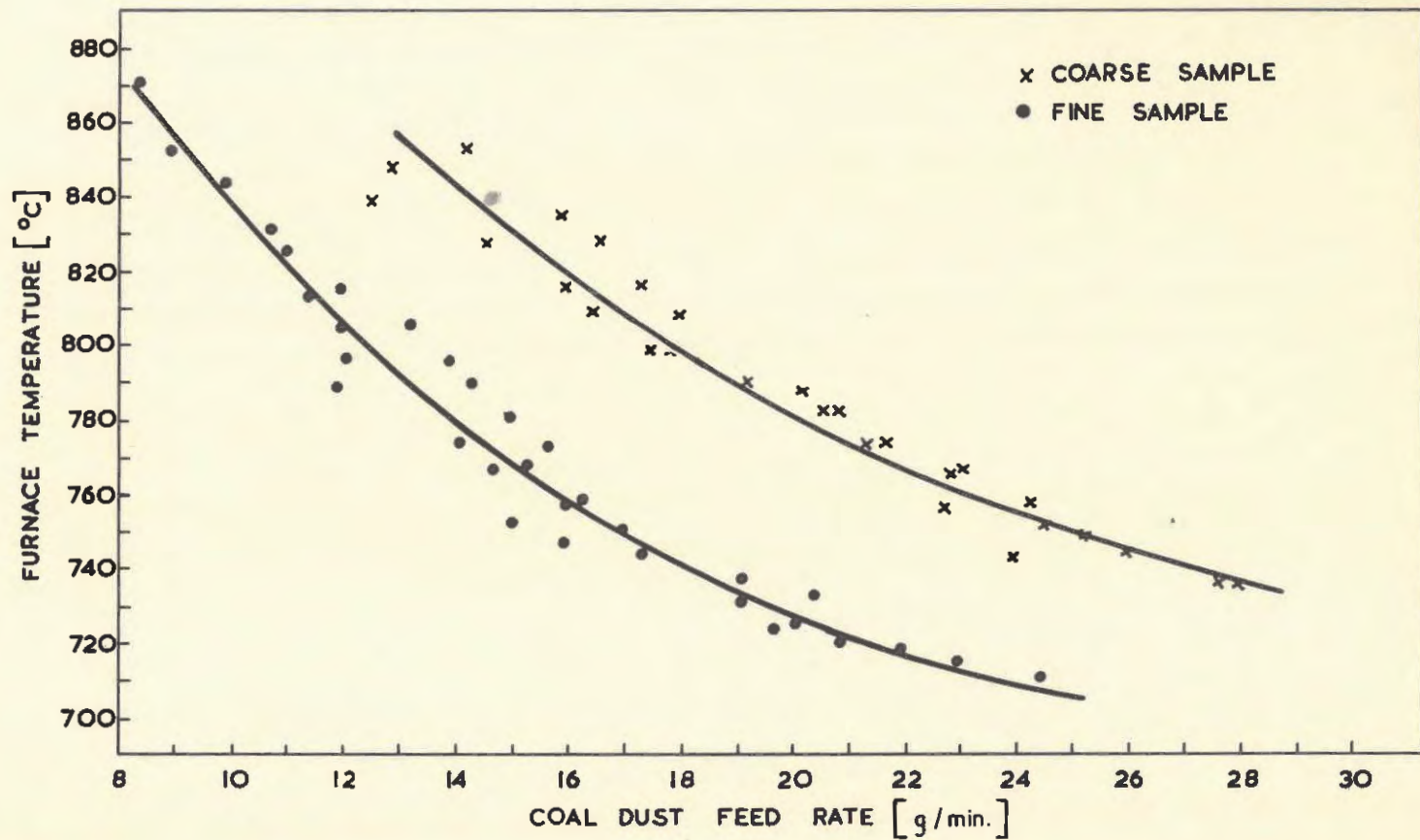
5. IGNITION CURVE

Experience has taught that the ignition temperature of a pulverized coal depends on the fuel/air ratio and generally decreases as this ratio is increased.

Evaluation of the fuel/air ratio is uncertain even though the supply rates of pulverized coal and air to the furnace are known. The central jet of pulverized coal/primary air will progressively entrain secondary air so that the fuel to air ratio will change with progress through the furnace.

It may, however, be inferred that since the total air supply to the furnace remains virtually constant, at various coal feed rates, the effective fuel/air ratio increases as the pulverized coal supply rate to the furnace is increased. It is, therefore, more convenient to present the change in ignition temperature with the change in the fuel/air ratio by a plot of the ignition temperature versus the coal feed rate to the furnace.

Such a plot is termed the ignition curve of the particular pulverized coal at the specified particle size distribution. As an illustration a typical set of ignition curves for a coarse and a fine sample of the same coal is reproduced in figure 1, which also illustrates the dependence of the ignition temperature on the size distribution of the pulverized coal. The difference between the particle size distributions of the coarse and fine samples are shown in figure 11.



IGNITION CURVES FOR THE FINE AND COARSE SAMPLES
OF COAL B.

FIGURE 1

6. COALS STUDIED

The various coal samples studied were selected from collieries in the Transvaal, Natal, and the Orange Free State so as to cover most of the rank range. A summary of the coals studied is given in table 1. (One sample of "foreign coal" was included for the sake of interest).

TABLE NO. 1

A summary of the coals studied.

Rank %C (d.a.f.)	Sample designa- tion	Origin	Analysis (air dry basis)		
			% C	% V.M.	% Ash
88,5	L	Natal	64,8	21,3	12,9
86,3	A	Natal	57,4	30,4	10,8
86,1	F	Natal	54,2	21,5	22,4
85,1	H	Natal	55,3	33,4	9,3
84,2	E	Natal	52,9	27,2	18,1
83,1	C	Transvaal	53,2	24,0	20,4
82,8	M	Transvaal	38,0	25,0	34,6
82,6	B	Transvaal	58,7	29,0	9,5
82,2	D	Transvaal	58,4	26,5	12,5
81,8	I	Natal	56,2	31,8	9,1
81,6	J	Natal	50,6	25,2	20,9
81,5	G	Transvaal	52,1	24,7	21,2
77,0	N	O.F.S.	44,9	21,8	26,8
75,9	K	O.F.S.	42,3	22,6	31,1
85,1	Silkstone	United Kingdom	60,9	34,5	3,4

/7. STANDARD

7. STANDARD DISPERSION

It has been proved that the ignition temperature of a pulverized coal depends, inter alia, on the particle size distribution of the coal and, therefore, comparison of the ignition temperatures of different pulverized coals should be based on some "standard" particle size distribution.

The particle size distribution which is normally ¹⁾ encountered in pulverized fuel used in firing power stations was selected as the standard. For the sake of brevity a dispersion having this standard particle size distribution, will be termed a standard dispersion of the particular coal. The standard particle size distribution is given in table 2.

TABLE NO. 2

Particle size distribution of a
standard dispersion.

Particle size limit	Cumulative mass percentage below size
micron	
76	69
104	81
152	92
295	99,7

/8. CONVERSION

8. CONVERSION OF IGNITION TEMPERATURES

A number of equations have been developed by means of which it is possible to compute the ignition temperature of a standard dispersion from the experimentally determined ignition curve of a sample of the same coal which has a different particle size distribution.

As the development of these equations is involved, only the final equations and the method of application will be given.

The equations are:

$$\frac{PFT^4}{26,6-0,24M} = \text{QUASI-CONSTANT} \quad (i)$$

wherein T is the ignition temperature (absolute, in K)
M is the coal feed rate (g/min.)

The factors P and F are defined by the following equations:

$$P = \frac{M\Delta_1/5 + 10X}{26,6-0,24M+M\Delta_1+50X} \quad (ii)$$

with

$$X = \frac{2,85M[26,6-0,24M]^{1/3}}{\left[M \sum_1^n (\Delta_i/(10i-5)^3)\right]^{1/3}} \sum_2^n (\Delta_i/(10i-5)^2) \quad (iii)$$

$$F = \int_0^1 \left[\int_0^{\pi/2} \text{Cos}A \exp(-QY/\text{Cos}A) dA \right] dY \quad (iv)$$

/with

with

$$Q = [2,6M \sum_1^n (\Delta_i K_i / (10i-5))] / (26,6-0,24M) \quad (v)$$

wherein Δ_1 is the mass fraction of particles within the size range 0-20 ~~N~~ MICRON

Δ_2 is the mass fraction of particles within the size range 20-40 ~~N~~ MICRON.

etc.

$$K_1 = 2,2$$

$$K_2 = 1,1$$

$$K_{3,4,\dots,n} = 1$$

$$(M\Delta_1)_e = (M\Delta_1)_s \quad (vi)$$

The subscripts e and s refer to the experimental and standard dispersions, respectively.

These equations are based on the following simplifying assumptions:

- (a) The coal particles are spherical and non-volatile within the pre-pyrolysis stage, implying that all the radiant energy retained by the particle is utilized in raising the particle temperature;
- (b) The physical properties of the particles and the air remain unchanged within the pre-pyrolysis stage;

/(c) Compared

- (c) Compared to air the particles are perfect conductors of heat;
- (d) The heat transfer within the gas phase takes place by conduction only. The validity of this may be suspect as conduction is obviously augmented by eddy transfer processes. However, it must be borne in mind that the flow relative to such small particles is low enough for eddy transfer to be small. The experimental work on forced convection indicates that eddy transfer becomes appreciable only at Reynolds numbers (Re) exceeding a value of 2. Generally, Re is less than 2 for particles smaller than 100 micron.

The assumptions restrict the validity of the equations to the pre-pyrolysis stage. Nevertheless, it will be shown in Section 9 that the equations may be used to predict the ignition temperature of a dispersion.

The application of these equations is best explained as follows:

Assuming^e the ignition temperature of a standard dispersion, of which the ignition curve at a different particle size distribution is known, is required at a specified feed rate. Since the particle size distribution is known the factors P and F , for the standard dispersion, may be evaluated at the specified feed rate. These may be substituted into equation (i) and the ignition temperature of the standard dispersion, at the specified coal feed rate, may be computed if the magnitude of the quasi-constant is known.

/The value

The value of the quasi-constant is evaluated as follows: Using equation (vi) it is possible to determine the coal feed rate of the experimental dispersion, for which the ignition curve is known, which corresponds to the specified feed rate of the standard dispersion. At this corresponding feed rate the factors P and F for the experimental dispersion may be evaluated and the ignition temperature obtained from the ignition curve. By substitution of these into equation (7) the value of the quasi-constant may be evaluated.

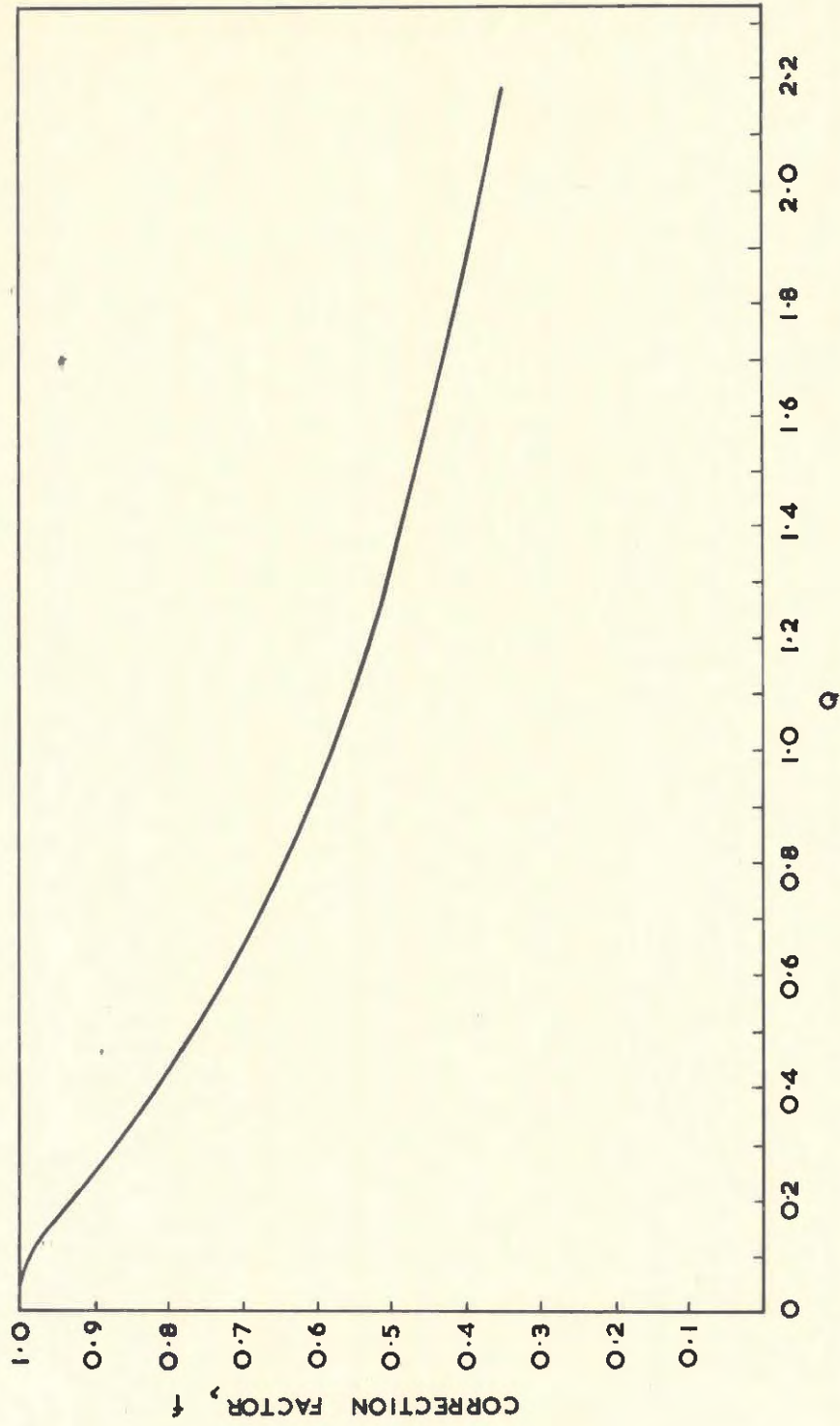
The evaluation of equation (iv) for the factor F is laborious. Different values of F versus Q have been evaluated and are graphically presented in figure 3.

9. ACCURACY OF EQUATIONS

The equations may also be used to compute the ignition temperature of a fine sample (i.e. a high proportion of minus 20 μ material) from the experimentally determined ignition curve of a coarse sample of the same coal. The accuracy of the equations may thus be ascertained by comparing the computed ignition temperature with that determined experimentally. The results of such calculations (for coals of which the ignition curves of both fine and coarse samples, respectively, are known) are summarized in table 3.

/TABLE NO. 3

FIGURE 3



THE SOLUTION OF EQUATION IV AS A FUNCTION OF Q

TABLE NO. 3

A comparison between the computed and observed ignition temperatures of fine samples of a number of coals.

Rank % C (d.a.f.)	Coal designation	Ignition temperature of fine sample	
		°C	
		Computed	Observed
86,3	A	831	835
86,1	F	880	865
84,2	E	793	793
82,8	M	808	794
82,6	B	839	830
82,2	D	779	785
81,8	I	784	785
81,5	G	878	875
75,9	K	699	704

It is obvious that the agreement between the computed and observed ignition temperatures is good and that the maximum difference is of the same order as the experimental error (see figure 1).

10. COMPARISON OF IGNITION DATA

The ignition temperatures of standard dispersions of the various coals studied are compared as follows:

/10.1 Constant

10.1 Constant coal feed rate

It has been shown that the primary air supply rate varies with the coal feed rate. Thus, if the ignition temperatures are compared on the basis of a constant coal feed rate both the primary and secondary air supply rates are the same for the different coals and it may thus be deduced that the mean fuel/air ratio is the same for the different coals studied.

The feed rate selected was 28 g/min. since at most other feed rates the ignition curve of one or more of the fine samples (from which the ignition temperature of the standard dispersion is computed) required extrapolation.

The ignition temperatures of standard dispersions of the various coals studied are plotted against the dry-ash-free (d.a.f.) carbon content and this plot is reproduced in figure 4.

It can be seen that the ignition temperature increases with increasing d.a.f. carbon content.

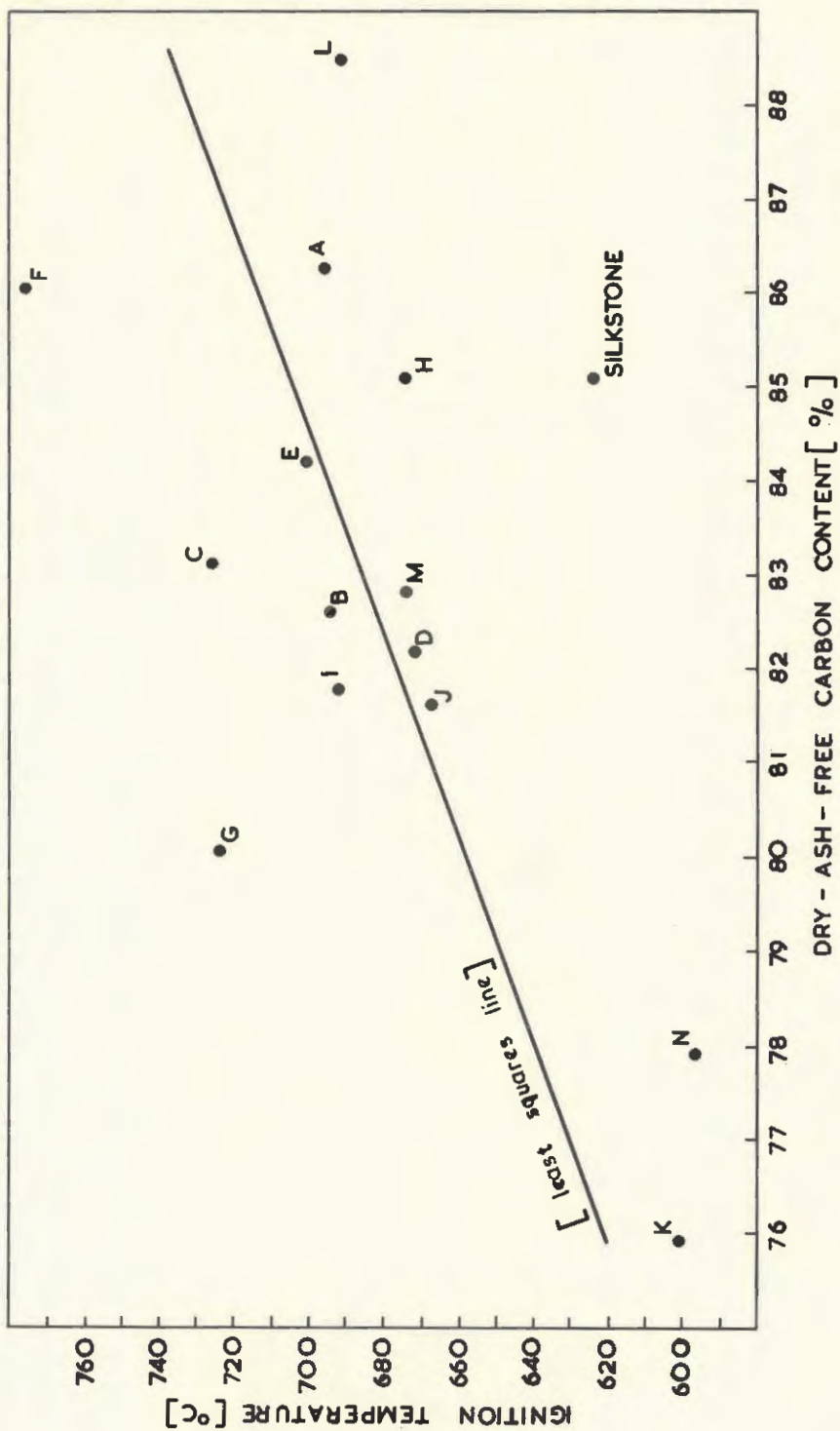
10.2 Constant volatile matter supply rate

The ignition temperatures of standard dispersions of the various coals studied may be compared at different feed rates selected in such a way that the supply rate of volatile matter to the furnace is constant.

The volatile matter supply rate selected was 6 g/min. which corresponds roughly to a coal supply rate of 28 g/min. The reason for this is the same as that given in section 10.1. The results of such computations are reproduced in figure 5.

/10.3 Constant

FIGURE 4

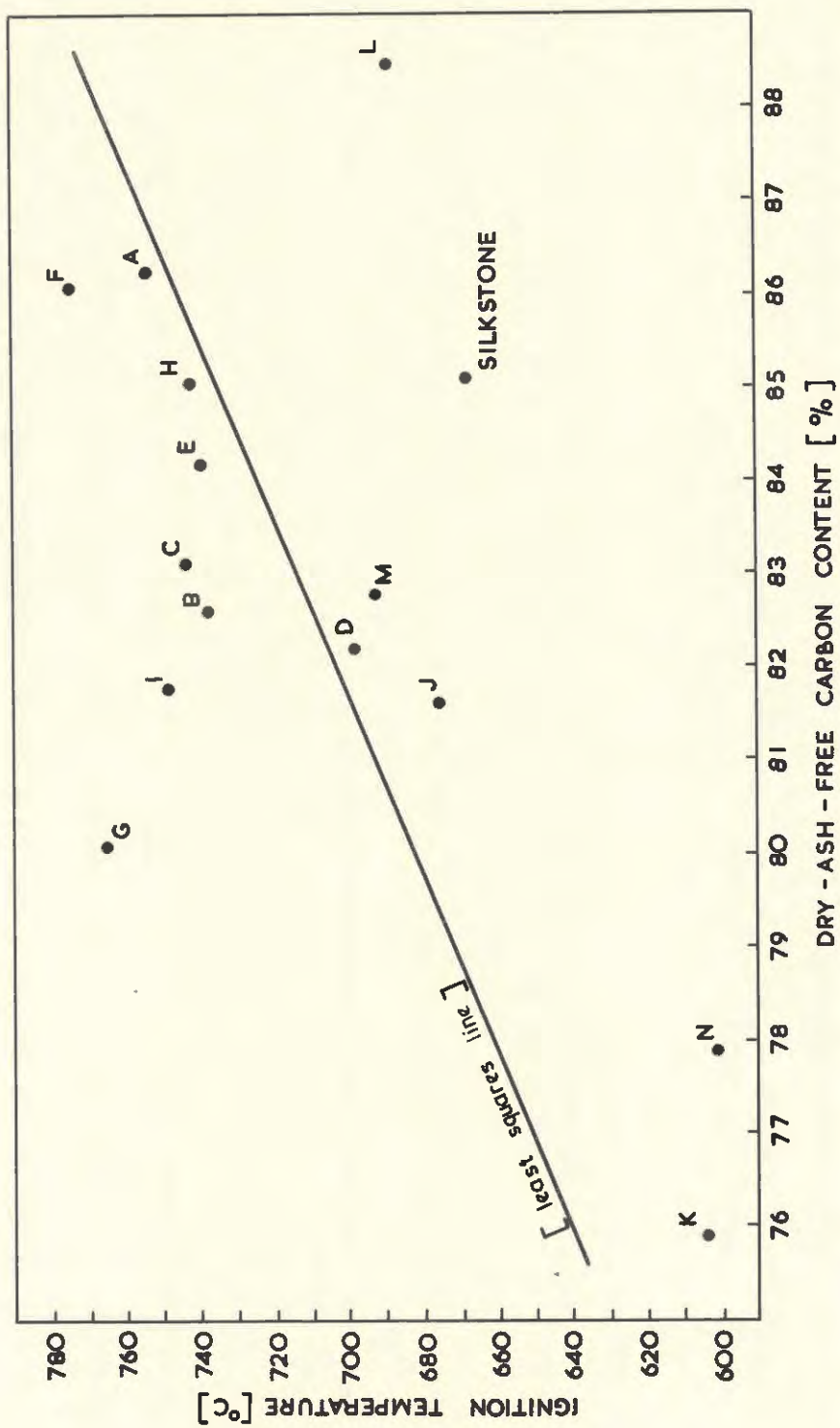


A CORRELATION OF THE IGNITION TEMPERATURES OF

VARIOUS COALS.

BASIS: CONSTANT SOLIDS FEED RATE

FIGURE 5



A CORRELATION OF THE IGNITION TEMPERATURES OF

VARIOUS COALS.

BASIS: CONSTANT VOLATILE MATTER SUPPLY RATE.

10.3 Constant tar supply rate

It has been reported²⁾ that the amount of tar produced on pyrolysis is affected by the heating rate and increases as the latter increases. It stands to reason that the effective tar content of a coal must be evaluated under the conditions pertaining to this study. Due to the complexity thereof this is beyond the scope of the present study. In order to ascertain the importance of the tar content on ignition, one has to resort to other methods by which the effective tar content can be more readily obtained.

In the absence of any proof to the contrary it will be assumed that the tar yield is directly proportional to the rate of carbonization and that the constant of proportionality is the same for all coals. For this comparative study, therefore, the tar contents of the various coals will be taken as those determined by the Gray-King method.

Previous studies* have indicated that the d.a.f. tar content of the majority of South African coals can be correlated against their d.a.f. hydrogen content. Accordingly the following correlations were established:

$$\text{Tar content (d.a.f.)} = K_1 (\text{d.a.f. hydrogen content} - K_2)$$

where $K_1 = 7,72$ and $K_2 = 3,5$ for Transvaal coals
 $K_1 = 10,0$ and $K_2 = 4,0$ for Natal coals.

/With the

* Unpublished work performed at the Fuel Research Institute of South Africa.

With the exception of coals K and N (both from the Orange Free State coalfields) and the foreign coal, for which the tar contents were determined by experiment, the tar contents were evaluated by using the foregoing correlations. The tar contents of the various coals studied, are listed in table 4.

TABLE NO. 4

Tar content of the coals studied.

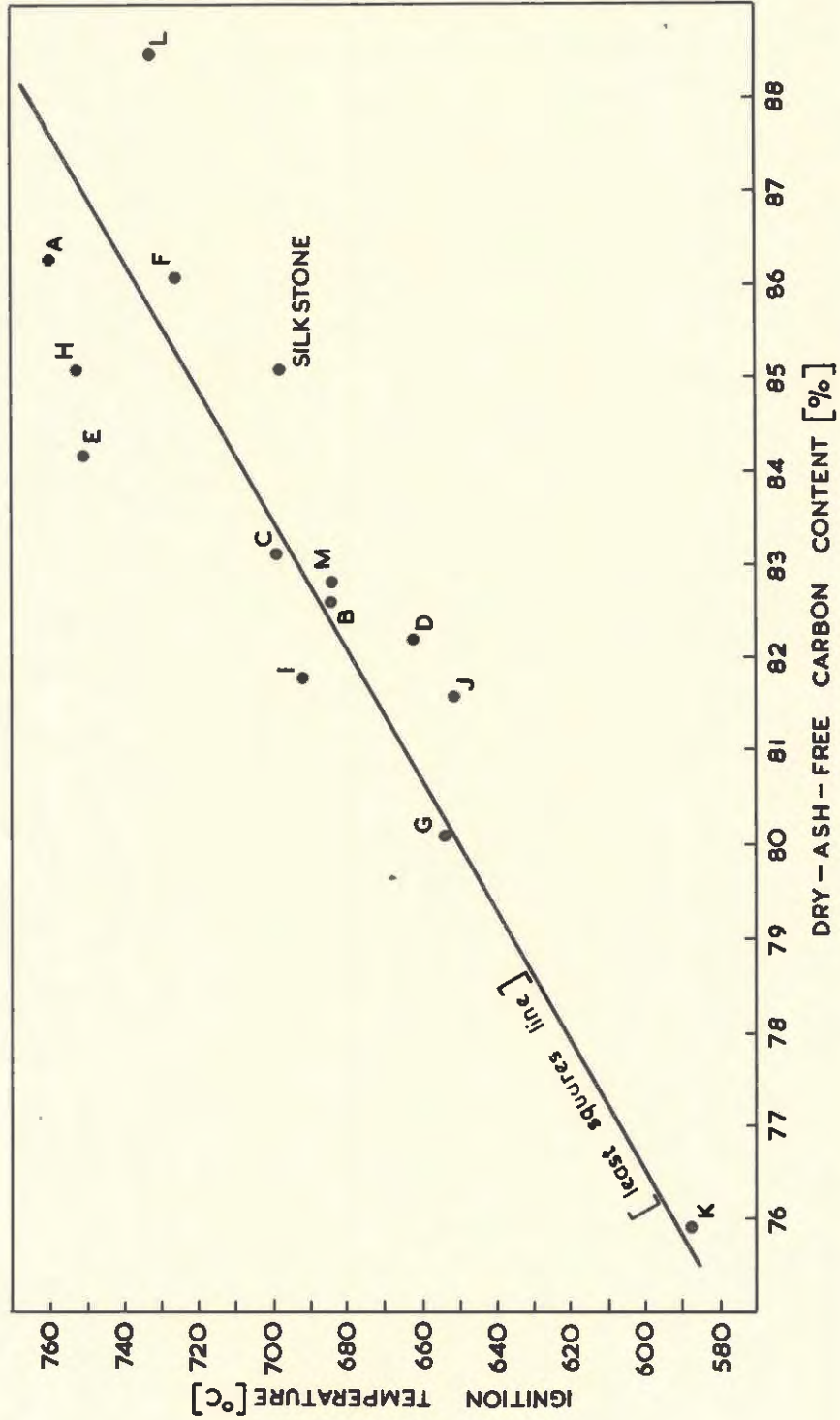
Coal designation	Tar content	Coal designation	Tar content
	%		%
A	10,3	I	7,1
B	6,7	J	5,5
C	6,0	K	2,6
D	6,6	L	8,0
E	9,6	M	7,8
F	4,5	N	2,4
G	3,9	Silkstone	12,7
H	12,0		

The ignition temperatures of standard dispersions of the various coals were compared at feed rates selected in such a way that the tar supply rate to the furnace remained constant. The selected tar supply rate was 2 g/min. and this rate was chosen for the same reason as given under section 10.1.

The plot of ignition temperature versus d.a.f. carbon content is reproduced in figure 6.

/10.4 Constant

FIGURE 6



A CORRELATION OF THE IGNITION TEMPERATURES OF
VARIOUS COALS.

BASIS: CONSTANT TAR SUPPLY RATE

10.4 Constant vitrinite plus exinite

Coal is composed of macerals which are organic components distinguishable by microscopic inspection. Generally speaking, macerals can be divided into two groups, viz., the reactive macerals and the inert macerals. The two most important members belonging to the reactive macerals are vitrinite and exinite.

Vitrinite was produced by the gradual alteration of plant cell substances. It is the maceral component of vitrain which is the material in coal comprising the shiny black bands that display brilliant lustre and a vitreous appearance. Vitrinites of low and medium rank contain a high proportion of volatile matter. As the rank increases a corresponding decrease in the volatile matter is noticeable.

Exinite is the collective name for ~~spore~~^{spore} coats, pollen grains, and cuticles. Exinites of low and medium rank contain high amounts of volatile matter which also decrease with an increase in rank.

Inertinite is the collective name for a number of macerals of which semi-fusinite and fusinite are the most common. The inertinites are characterized by their high carbon and low volatile matter content.

The exinite plus vitrinite content** of the various coals studied is listed in table 5.

/TABLE NO. 5

** This petrographic work was undertaken by the Coal Petrography section of the Fuel Research Institute of South Africa.

TABLE NO. 5

Vitrinite plus exinite content of the
different coals studied

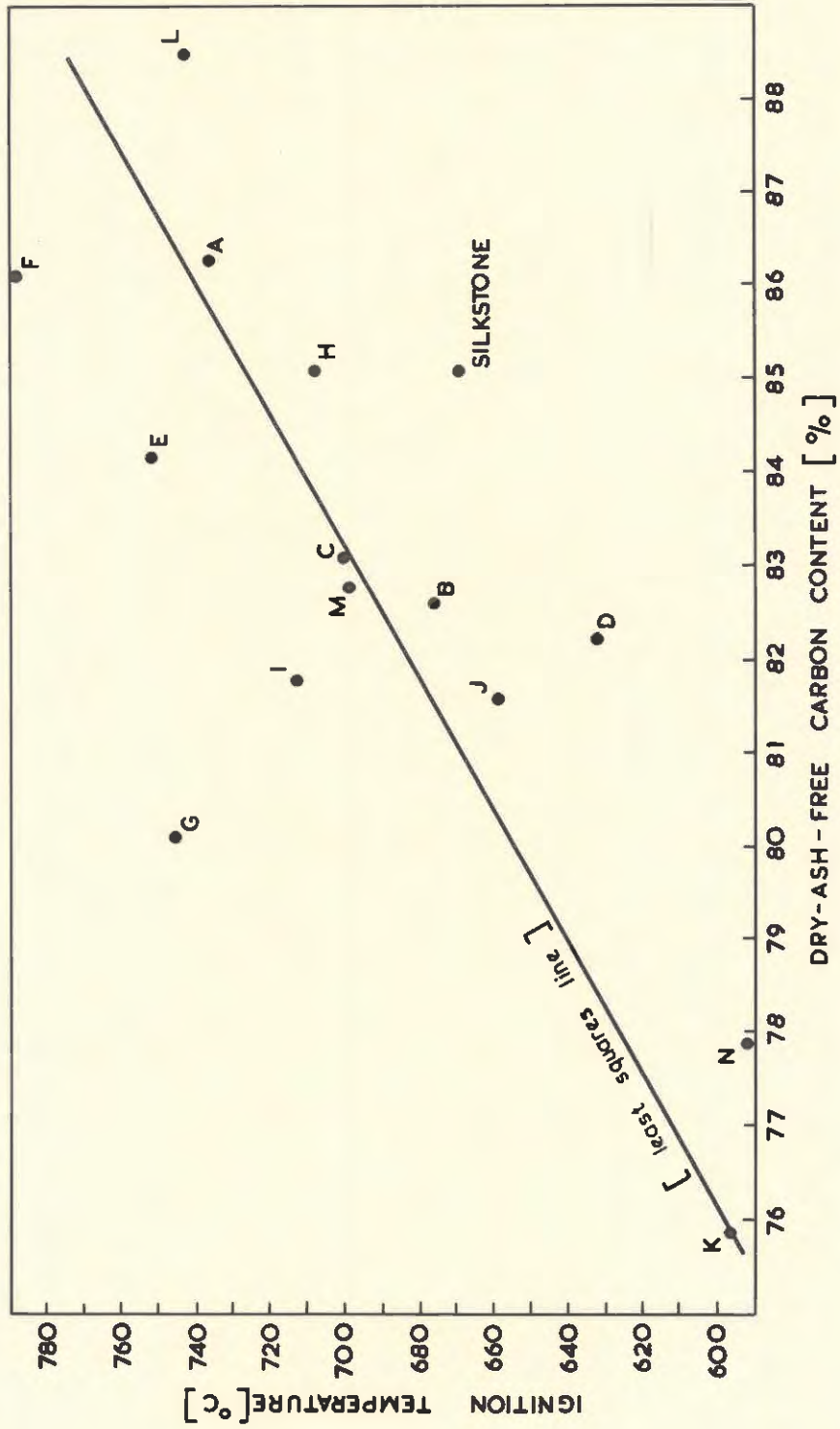
Coal designation	Vitrinite & Exinite content
	%
A	68,5
B	45,7
C	45,7
D	37,6
E	72,7
F	61,0
G	56,1
H	66,4
I	61,4
J	49,6
K	51,8
L	65,9
M	65,2
N	45,8
Silkstone	89,5

The ignition temperatures of standard dispersions of the various coals were compared on the basis of a constant vitrinite plus exinite supply rate to the furnace. The selected vitrinite plus exinite supply rate was 15 g/min.

The resulting ignition temperatures are plotted against d.a.f. carbon content and ~~is~~^{are} illustrated in figure 7.

/11. COMPARISON ...

FIGURE 7



A CORRELATION OF THE IGNITION TEMPERATURES OF
VARIOUS COALS.

BASIS: CONSTANT VITRINITE + EXINITE SUPPLY RATE

11. COMPARISON OF CORRELATIONS

The different correlations presented may be compared most effectively by means of the respective coefficients of linear correlation. In the evaluation of the correlation coefficients, the foreign coal was excluded. The correlation coefficients are listed in table 6.

TABLE NO. 6

Comparison of various correlation coefficients.

Correlation basis	Coefficient of linear correlation
Constant feed rate	0,65
Constant volatile matter supply rate	0,56
Constant tar supply rate	0,89
Constant vitrinite plus exinite supply rate	0,76

Of the various correlations presented, the one based on a constant tar supply rate to the furnace, is the best. It may thus be concluded that the tar, liberated during pyrolysis, is an important factor as regards the ignition temperature of coal.

/The liberated

The liberated tar (or more likely its products of decomposition) has a lower ignition temperature ²⁾ (of the order of 300°C) than that of other permanent gases (H₂ :- 580°C, CO :- 644°C, CH₄ :- 650°C)³⁾ evolved during pyrolysis. Accordingly, the tar will ignite before the permanent gases and these may, therefore, be regarded as diluents of the more important tar as far as ignition is concerned.

The volatile matter content of the coal includes tar and permanent gases. Thus, when comparing the ignition temperatures on a basis of a constant volatile matter supply rate, the dilution (which varies from one sample of coal to another) of the more important tar by the other gases will tend to make the correlation appear less effective when compared to the one based on tar only.

If the ignition temperatures are compared on the basis of a constant vitrinite plus exinite supply rate, it is to be expected that this correlation should be better than that based on a constant volatile matter supply rate. In this case the effect of the inertinite has been eliminated which contributes towards the supply of volatile matter, while its contribution towards the quantity of tar liberated is insignificant. It may thus be visualized that the detrimental dilution effect would not be as severe as in the case of a constant volatile matter supply rate.

/12. THE

12. THE EFFECT OF THE ASH CONTENT OF A COAL ON ITS
IGNITION TEMPERATURE

The mineral matter present in a coal can influence its ignition temperature in one, or more, of the following ways:

- (i) By acting as an inert diluent;
- (ii) By acting as a thermal load; and
- (iii) By acting as a component that alters the permeable structure of the coal and, therefore, obstructs the process of ~~de~~volatilization.

If the mineral matter acts merely as an inert diluent it follows that for the correlation, where the tar supply rate is constant, the effect of the ash content will be eliminated. This correlation should, therefore, be unaffected by the ash content of the coal.

That this is indeed the case may be seen from figure 6. Compare, for example, coals B and M. Coal B has an ash content of 9,5% as opposed to 34,6% of coal M. Similarly, coals I (9,1% ash) and C (20,4% ash), as well as coals A (10,8% ash) and F (22,4% ash), testify to this.

It may thus be concluded that although a large proportion of the mineral matter is intimately associated with the coal (a general property of South African coal), it merely acts as an inert diluent in so far as the ignition is concerned.

/That the

That the mineral matter may act as a heat sink is possible although this probably exerts a negligible effect on the ignition temperature. The mineral matter is subjected to the same heat transfer processes applying to the coal and it is doubtful whether its thermal properties differ ^{sufficiently} ~~significantly~~ from those of the organic substance to ~~affect~~ ignition significantly.

It may also be concluded that the ash content does not obstruct the ^{de} volatilization process significantly prior to ignition. If the opposite were true then the ash content would seriously affect the correlation of the ignition temperatures, as based on a constant tar supply rate, especially in the case of coal M having an ash content of 34,6%.

The mineral matter may, however, be of considerable importance in the combustion proper. It is conceivable that as the particle size is reduced by combustion, the mineral matter will alter the permeable structure which will be detrimental to the diffusional processes. At extremely high combustion temperatures fusion of the ash may even occur to form an isolating layer around the carbonaceous residue and so prevent its complete combustion. These aspects were not studied as the present research programme was confined to a study of the ignition phase only.

13. THE EFFECT OF THE CONCENTRATION OF LIBERATED VOLATILE MATTER

When a dispersion of coal is exposed to a furnace temperature, equal to its ignition temperature, the liberated volatile matter concentration and the dispersion temperature at the furnace exit are sufficient for ignition to occur.

Suppose this dispersion is diluted with a non-volatile diluent, having the same size distribution as that of the pure fuel, but maintaining the total particle concentration. If this diluted dispersion is exposed to the same furnace temperature as that of the pure fuel the dispersion temperature at the furnace exit will be identical to that of the pure fuel.

However, the liberated volatile matter concentration at the furnace exit will have been reduced to a value below that of the pure fuel. If the concentration of the liberated volatile matter is of importance, ignition of the diluted dispersion cannot occur.

If the furnace temperature, to which the diluted dispersion is exposed, is increased above that of the ignition temperature of the pure fuel the heating rate, and consequently the pyrolysis rate is increased. The liberated volatile matter concentration again reaches a "critical" value (at the new exit temperature) and ignition once again occurs. It follows that the ignition temperature of the diluted dispersion will be greater than the corresponding ignition temperature of the pure fuel if the volatile matter concentration is of importance.

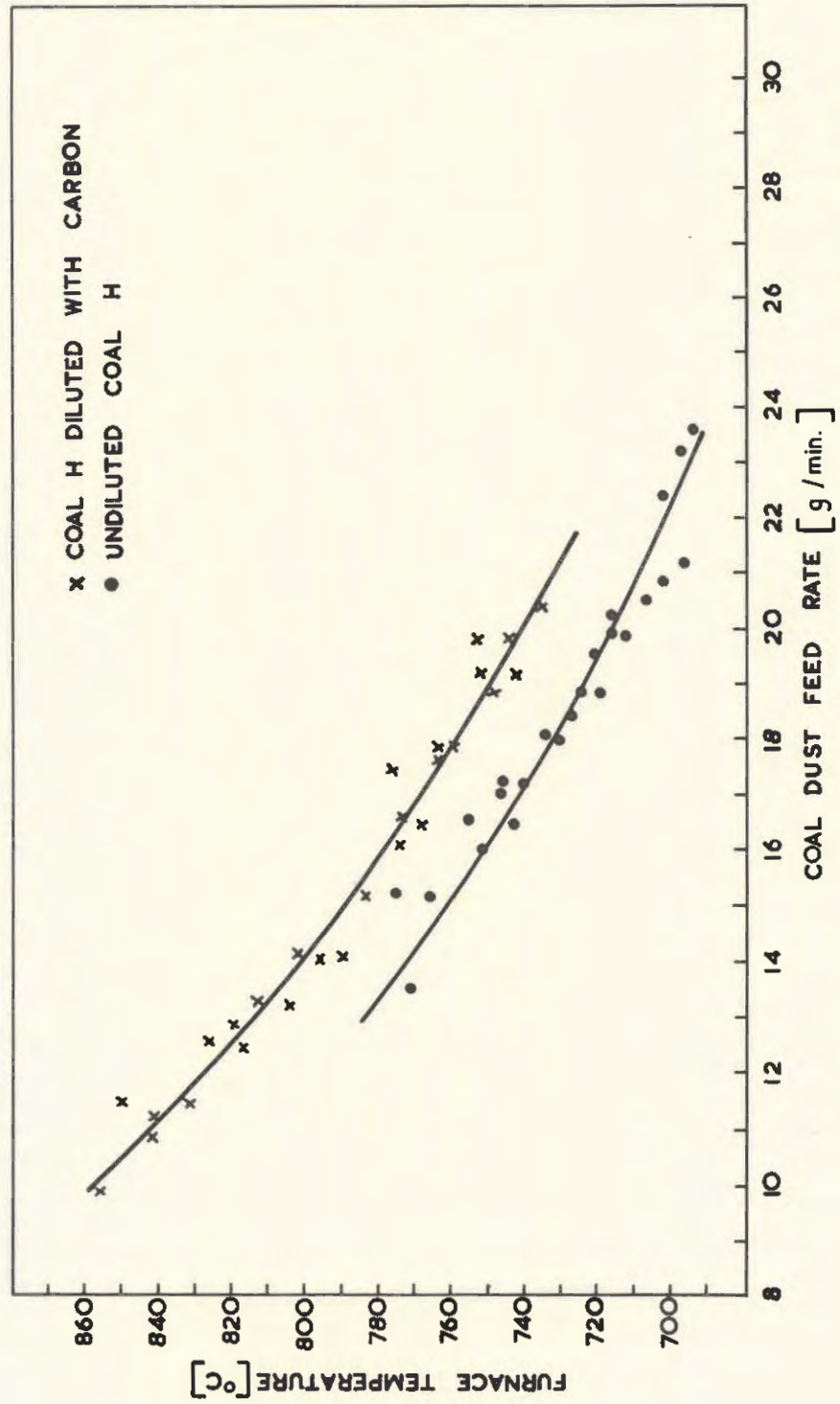
/A similar

A similar argument applies to low volatile content diluents (e.g. anthracites) as these also effectively reduce the volatile matter content of the dispersion.

The validity of the foregoing was demonstrated experimentally by comparing the ignition curves of pure coal with that diluted with electrode carbon; and by comparing the ignition curves of different mixtures of the same coal with a sample diluted with an anthracite. These are illustrated in figures 8 to 11. The graphs of the respective particle size distributions are included to demonstrate that the difference in ignition temperature is not due to differences in the particle size distribution. (Compare figures 1 and 2).

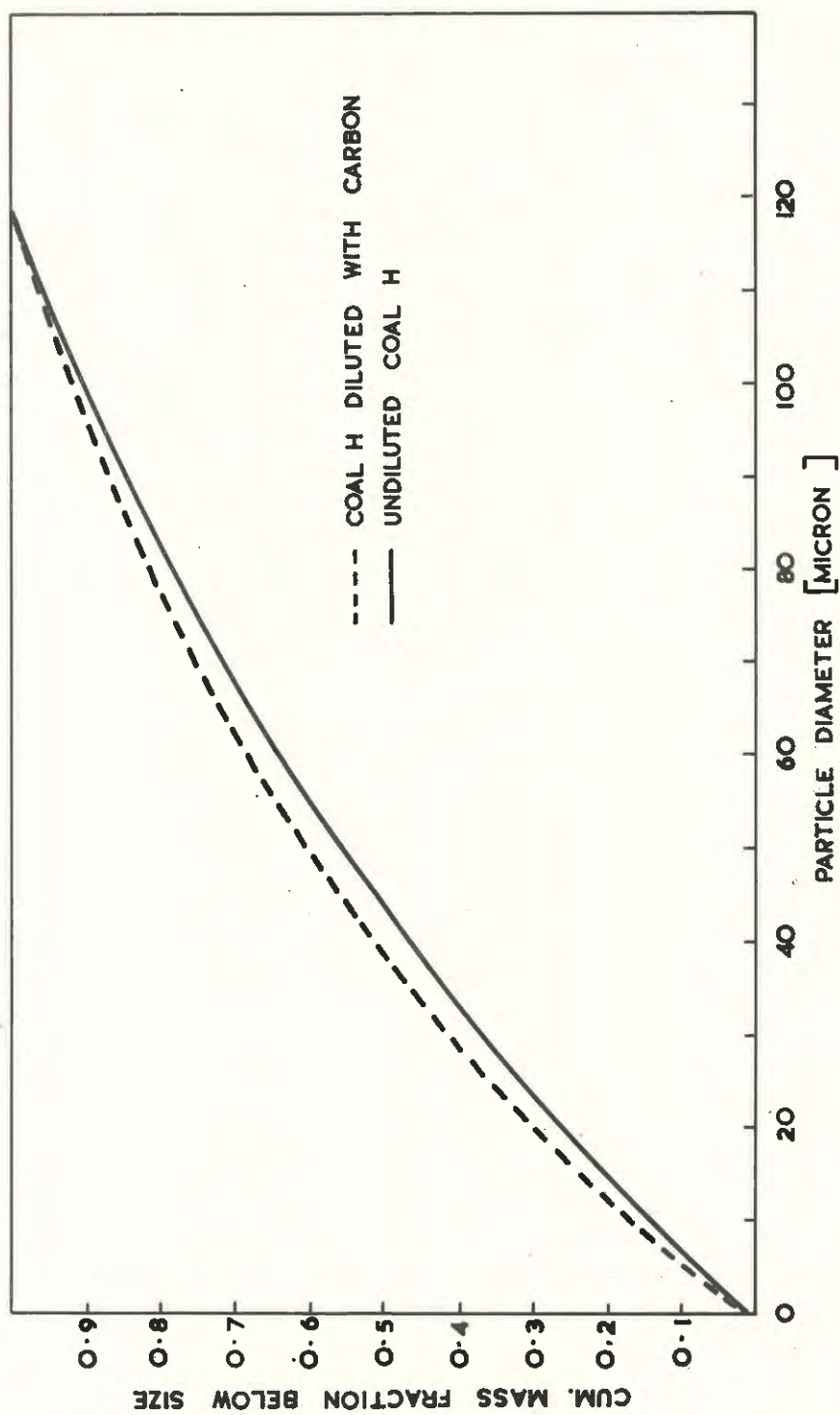
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FIGURE 8



IGNITION CURVES FOR DILUTED AND UNDILUTED SAMPLES
OF COAL H.

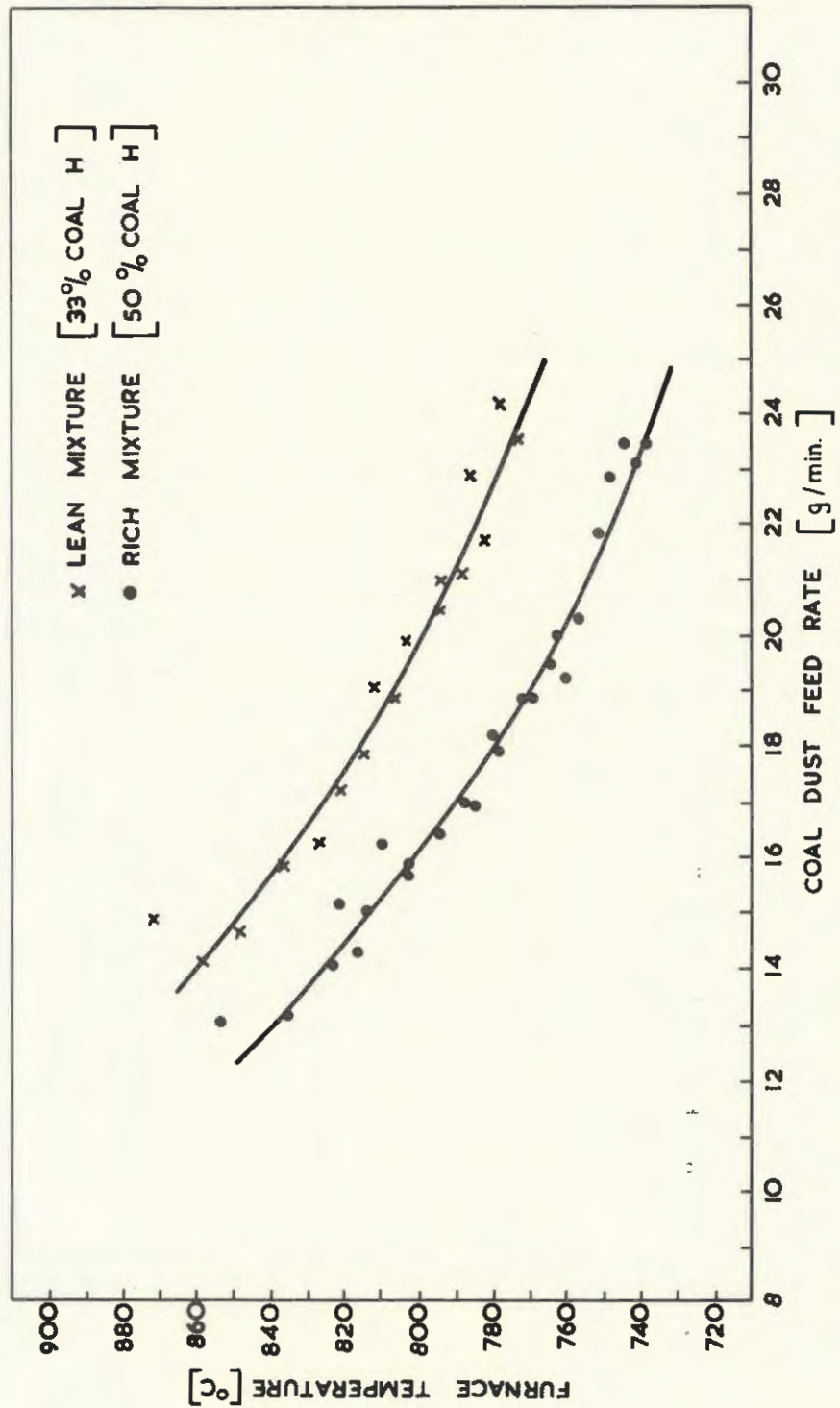
FIGURE 9



CUMULATIVE SIZE DISTRIBUTION OF DILUTED AND

UNDILUTED COAL H.

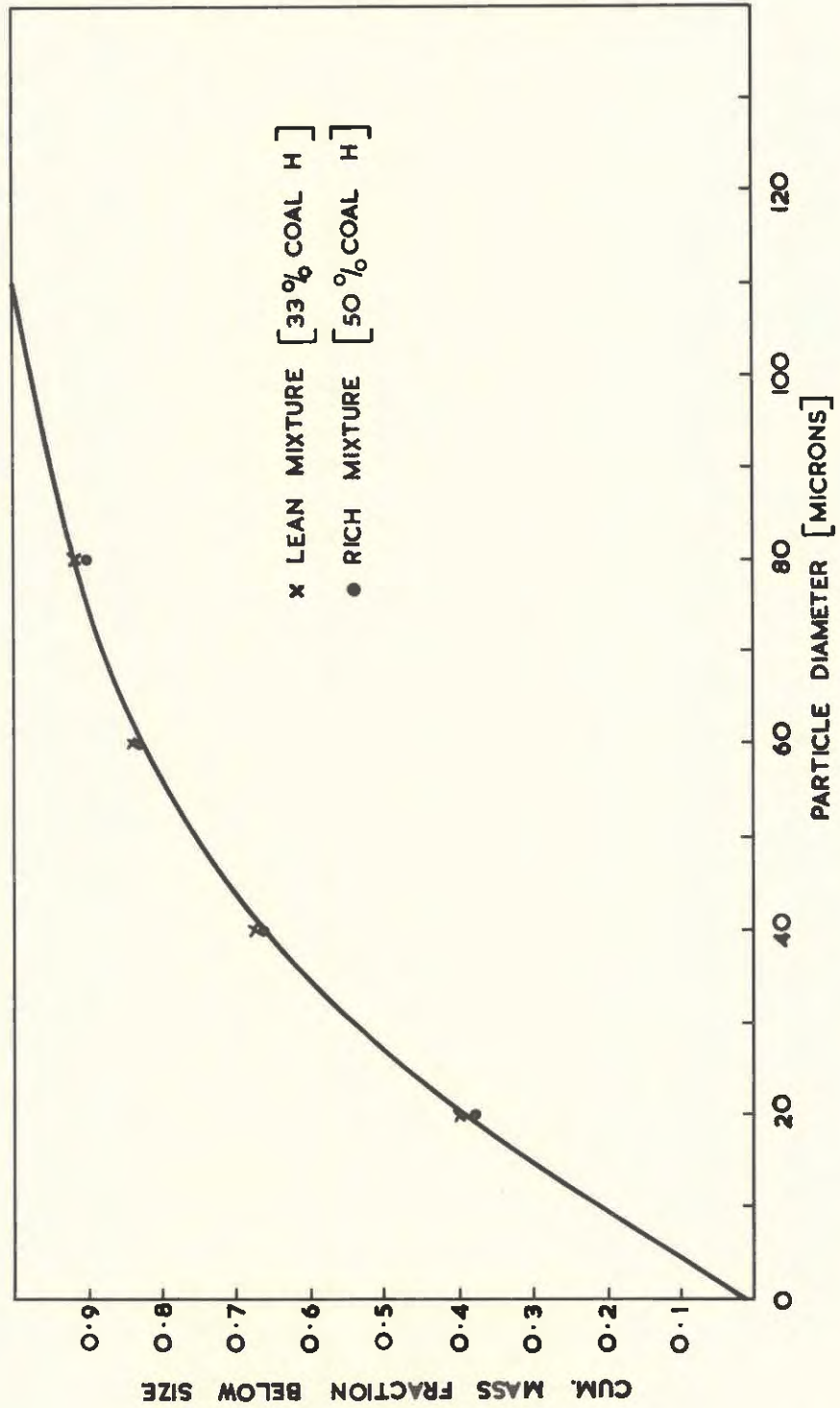
FIGURE 10



IGNITION CURVES FOR MIXTURES OF COAL H WITH AN

ANTHRACITE.

FIGURE 11



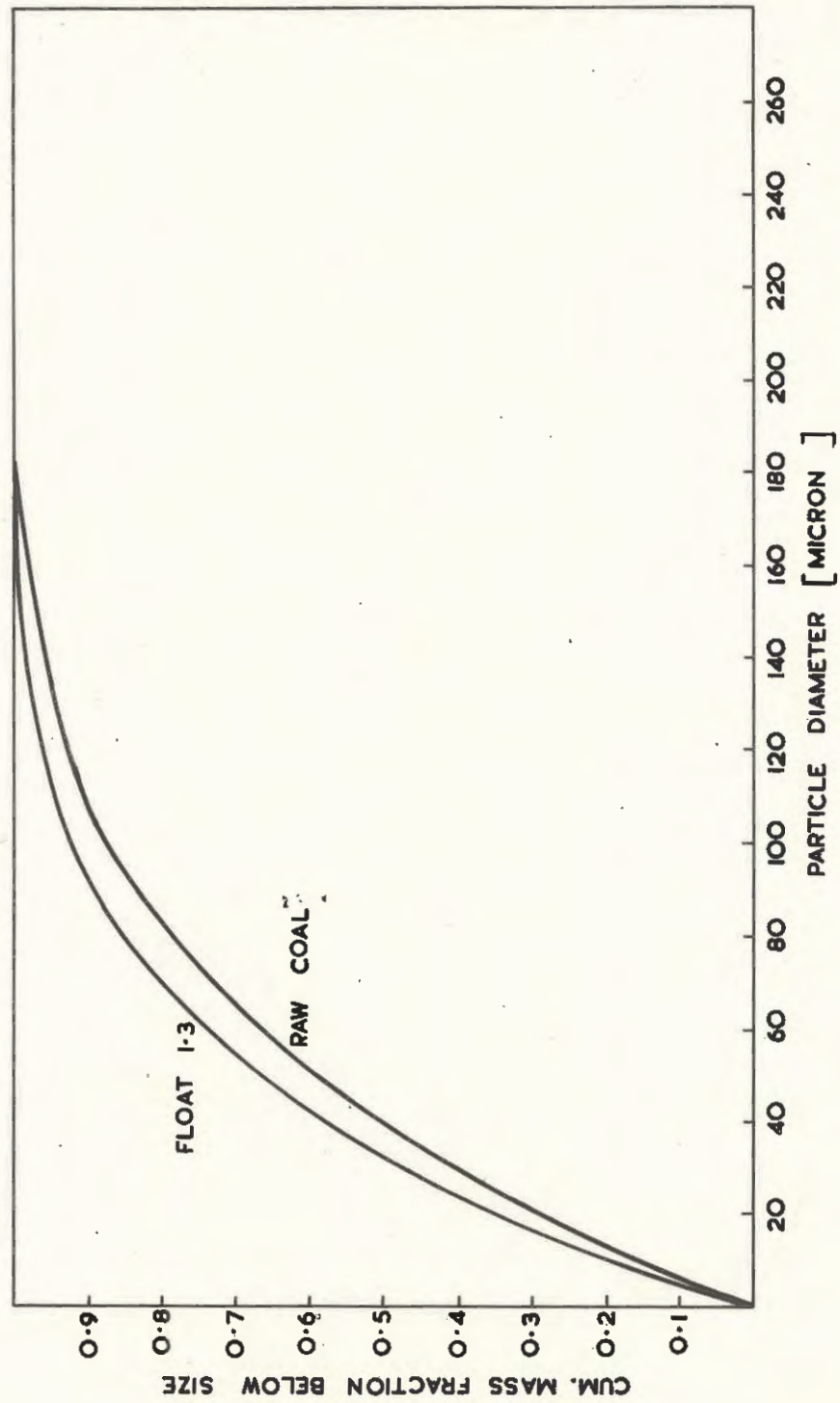
CUMULATIVE SIZE DISTRIBUTIONS OF LEAN AND RICH

MIXTURES OF COAL H.

A similar difference will exist between the ignition temperature of a raw coal and the corresponding ignition temperature of its washed product. The removal of the higher specific gravity fractions results in an effective increase in the vitrinite content which, having a relatively high volatile matter content, effectively increases the volatile matter content of the washed product.

The raw coal may thus be visualized as being the "diluted" form of ^{the} product obtained by washing. Consequently, the raw coal should have a higher ignition temperature than that of its lower specific gravity product. This is illustrated in figures 12 and 13, figure 13 serving to indicate the insignificance of the difference in the particle size distribution.

FIGURE 13



CUMULATIVE SIZE DISTRIBUTIONS OF RAW COAL SAMPLE, AND OF
FLOAT SAMPLE [S.G. < 1.3] OF COAL

14. CONCLUSIONS

With reference to the ignition curve (see figure 1) the following conclusions can be drawn:-

- (i) The ignition temperature of a dispersion generally decreases as the fuel/air ratio (coal feed rate to the furnace) is increased.
- (ii) The ignition curve is concave, i.e., the slope of the ignition curve becomes less negative as the fuel/air ratio is increased.
- (iii) The ignition temperature of a dispersion is affected by the particle size distribution of the coal. At any specific fuel/air ratio the ignition temperature of a dispersion, composed of relatively coarse particles, is higher than that of a dispersion composed of comparatively finer particles of the same coal.

Mathematical equations have been presented by means of which it is possible to convert the ignition temperature of a coal, having a particular particle size distribution, to that applying to any other particle size distribution. The accuracy of the equations has been demonstrated by comparing the observed ignition temperature of a fine sample with that computed from the ignition data of a coarse sample of the same coal.

/It has

It has been demonstrated that the ignition temperature is a function of the particle size distribution of the coal. The effect of this variable may be eliminated by using the equations presented to convert the ignition data of the various coals studied to those pertaining to a standard particle size distribution. On this basis the ignition temperatures of the various coals were correlated against the dry-ash-free carbon content in the following ways:-

- (i) On a basis of a constant coal feed rate to the furnace;
- (ii) On a basis of a constant volatile matter supply rate to the furnace;
- (iii) On a basis of a constant vitrinite plus exinite supply rate to the furnace;
- (iv) On a basis of a constant tar supply rate to the furnace.

Each of the different modes of correlation indicates that the ignition temperature increases as the rank, or dry-ash-free carbon content, increases. By comparison it was found that the fourth mode of correlation is the best. It may, therefore, be concluded that the tar liberated during pyrolysis is an important factor *insofar as* ignition is concerned.

/From the

From the correlation of the ignition temperatures, based on a constant tar supply rate, it may be deduced that for coals of equal rank the ignition temperature, at a constant fuel/air ratio, decreases as the tar content increases.

From the correlation of ignition temperatures, on the basis of a constant tar supply rate, it was also possible to deduce that the mineral matter contained within a coal has no effect on its ignition temperature other than behaving as an inert diluent. Any detrimental effects of the ash, that may arise during the progress of combustion, are thus not reflected by the ignition temperature of the coal.

With reference to figures 10 and 12 it may be concluded that the ignition temperature of a coal, at a specific fuel/air ratio, may be altered by any of the following processes:-

(a) blending, and (b) washing.

The ignition temperature of a high volatile matter content coal will be increased by blending it with a low volatile matter content coal to obtain a "balanced" volatile matter content fuel. The disadvantage (i.e. increase in ignition temperature) may, however, be offset by the advantage of the creation of an outlet for the low volatile matter content coal.

/As opposed

As opposed to this the ignition temperature of a coal may be reduced by the removal of the higher specific gravity fractions as achieved during washing.

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