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Influence of the mineral matter content on the combustion characteristics of Turkish lignites

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Abstract

In this study, DTA ignition temperatures and DTG maximum peak temperatures were correlated with the CaO, MgO, Na_2O and K_2O contents of twenty-one Turkish lignites. All correlations were developed by means of least-squares regression analyses.

The combustion curves of the lignite samples before and after mineral matter removal were compared and discussed.

INTRODUCTION

Coals contain mineral components, which contribute to their combustion behaviour. The amount and composition of the mineral matter can influence the combustion characteristics of coal, which is important in the design of coal-fired boilers. The reactive constituents of the mineral matter in coal can undergo a variety of changes during coal combustion.

Thermal analysis plays an important role in determining the combustion characteristics of coal. A DTA curve of a coal obtained in the presence of air is called a "combustion curve" and gives information about combustion characteristics, such as the ignition temperature and heat release rate.

The purpose of this study is to investigate the influence of the mineral matter content on the combustion characteristics of twenty-one Turkish lignites.

EXPERIMENTAL

Differential thermal analysis was carried out using a Shimadzu DTC 40 analyser. The thermogravimetric analysis was performed using a Shimadzu TG 41 analyser.

20 mg lignite samples which have been ground to pass a 0.25 mm sieve were heated at a constant 10°C min^{-1} while being swept by air at a rate of

40 cm^3 min^{-1} up to 800°C and held for 10 min at constant temperature. The chart speed was selected at 2.5 mm min^{-1}. The working conditions of the DTA and TGA measurements were the same. The reference material of the DTA experiments was α-alumina.

The proximate analyses were carried out according to the ASTM standards [1].

Chemical analyses of the ashes produced from lignite samples according to the ASTM standards have been determined [2].

Determination of the total mineral matter content of 21 lignite samples was carried out according to the ISO-602 standard [3].

The demineralisation of the lignite samples was performed by treatment with hydrochloric and hydrofluoric acids under the conditions described in the ISO-602 standard.

RESULTS AND DISCUSSION

The proximate analyses of the lignite samples are shown in Table 1. The moisture content of the lignites varies between 2.0 and 40.4%, the ash

TABLE 1

Proximate analysis of the lignite samples

Sample No.	Moisture (wt.%)	Volatile matter (wt.%)	Ash (wt.%)	Fixed carbon (wt.%)
L01	4.4	22.2	40.6	32.8
L02	15.7	36.1	31.8	16.4
L03	9.6	39.2	11.0	40.2
L04	10.5	36.8	12.1	40.6
L05	19.9	30.3	14.0	35.8
L06	27.6	39.8	9.8	22.8
L07	24.2	38.4	6.2	31.2
L08	2.0	32.0	14.4	51.6
L09	14.0	36.1	26.6	23.3
L10	7.2	46.4	7.3	39.1
L11	15.9	41.0	6.7	36.4
L12	35.4	32.2	9.0	23.4
L13	12.5	32.3	22.9	32.3
L14	17.9	37.3	18.7	26.1
L15	27.0	34.4	20.6	18.0
L16	14.1	33.4	12.7	39.8
L17	13.9	24.6	39.2	22.3
L18	40.4	32.1	15.2	12.3
L19	6.4	28.6	27.6	37.4
L20	5.9	31.8	8.9	53.4
L21	27.5	34.4	14.1	24.0

TABLE 2

The mineral matter content of the lignite samples (dry basis) and the composition of the ashes

Sample No.	SiO_2 (wt.%)	Al_2O_3 (wt.%)	Fe_2O_3 (wt.%)	CaO (wt.%)	MgO (wt.%)	Na_2O (wt.%)	K_2O (wt.%)	Mineral matter (wt.%)
L01	54.40	21.20	12.49	4.12	2.15	1.67	1.99	44.37
L02	37.40	33.36	12.02	11.75	0.74	0.40	1.96	46.22
L03	12.02	30.41	45.05	5.42	1.89	4.05	0.44	11.92
L04	30.17	35.23	24.63	7.76	0.30	0.97	0.12	16.51
L05	28.30	30.79	16.08	15.88	4.04	2.93	0.44	16.42
L06	33.28	29.74	12.36	15.77	2.12	1.31	0.44	12.30
L07	29.40	34.40	10.62	15.86	1.64	0.55	0.39	7.68
L08	33.05	33.46	23.11	7.24	0.51	0.30	1.42	17.04
L09	33.59	28.62	21.19	8.79	2.85	0.52	3.21	34.72
L10	16.08	38.69	34.48	6.51	1.22	0.77	1.15	12.46
L11	13.25	24.52	18.79	23.62	12.37	0.25	0.18	13.67
L12	27.84	20.46	26.02	11.89	7.84	0.96	0.46	15.27
L13	48.61	35.60	9.64	2.92	0.70	0.51	1.24	27.66
L14	23.67	20.44	22.14	15.63	3.26	0.92	0.70	28.88
L15	35.22	24.79	13.42	13.68	2.06	0.81	1.30	26.80
L16	32.57	27.72	18.16	9.03	4.74	2.32	0.89	15.14
L17	60.14	17.38	14.01	0.86	4.56	0.35	1.19	47.97
L18	30.00	19.44	20.30	15.26	3.38	0.40	1.14	35.60
L19	54.48	28.58	8.03	1.08	0.98	0.71	2.32	33.94
L20	29.20	28.00	30.41	9.01	0.31	0.29	0.91	8.84
L21	28.46	22.59	25.54	13.08	2.04	1.47	0.60	27.62

content between 6.2 and 40.6%, the volatile matter content between 22.2 and 46.4% and the fixed carbon content between 12.3 and 53.4%.

The chemical composition of the lignite ashes are shown in Table 2. The SiO_2 content of the ash samples varies between 12.02 and 60.14%, Al_2O_3 content between 17.38 and 38.69%, Fe_2O_3 content between 8.03 and 45.05%, CaO content between 0.86 and 23.62%, MgO content between 0.30 and 12.37%, Na_2O content between 0.25 and 4.05% and K_2O content between 0.12 and 3.21%.

The mineral matter content of 21 lignite samples used in this study varies between 7.68 and 47.97% (dry basis), as shown in Table 2.

The ignition temperatures determined by DTA were correlated with the CaO, MgO, Na_2O and K_2O contents of the lignite samples. The concentrations of these mineral components in the lignite samples were calculated using the ash analysis results.

The relationship of the DTA ignition temperature with the CaO content, and with the sum of the CaO, MgO, Na_2O and K_2O contents, of the lignite samples is shown in Figs. 1 and 2, respectively. The correlations were

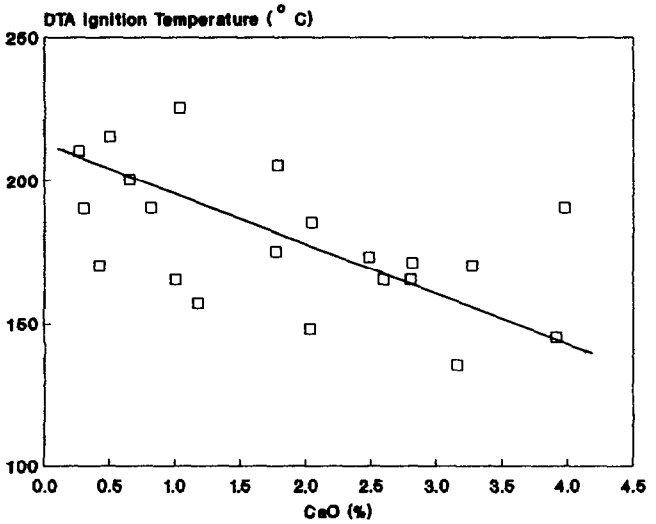

Fig. 1. The relationship of DTA ignition temperature with CaO content.

examined using least squares regression analysis. The regression coefficient of the relation shown in Fig. 1 is 0.5426 and eqn. (1) represents the relation obtained by means of regression analysis.

$$\text{DTA ignition temp} = 198.4544 - 10.8069 \times (\text{wt.\% CaO}) \quad (1)$$

Equation (2) represents the relationship between the DTA ignition

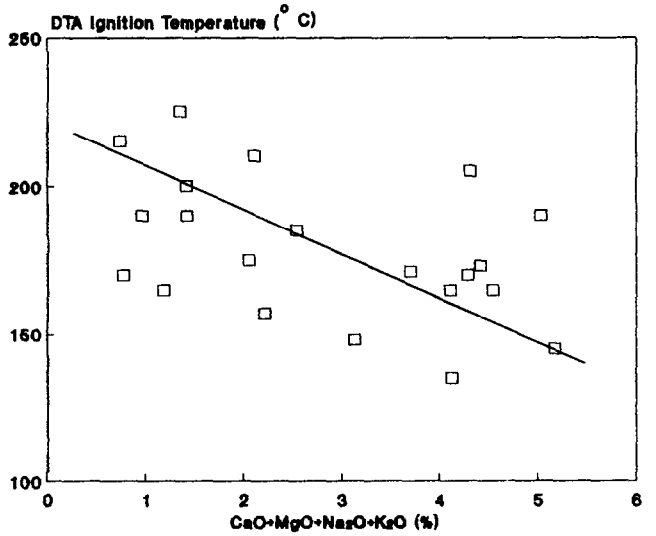

Fig. 2. The relationship of DTA ignition temperature with the sum of the CaO, MgO, Na_2O and K_2O contents.

temperature and the sum of the CaO, MgO, Na_2O and K_2O contents of the lignite samples obtained by means of regression analysis. The regression coefficient is 0.4538.

$$\text{DTA ignition temp} = 198.4880 - 7.0519 \times (\text{wt.\% CaO} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) \quad (2)$$

There is a better correlation for the lignite samples between the DTA ignition temperature and the CaO content than between the DTA ignition temperature and the sum of the CaO, MgO, Na_2O and K_2O contents.

The DTG curves of the samples were derived from TG applications. The DTG curves obtained generally take the form of a curve with two maxima, corresponding to water release followed by progressive combustion. The temperature at which the maximum combustion rate occurs is taken as a measure of the combustibility or reactivity of a coal: the lower the temperature of the combustion peak, the more reactive a coal may be considered [4, 5]. The rate of coal combustion can influence the design of boilers.

The peak temperatures at which the rate of weight loss due to combustion of the lignite samples is a maximum is called the "DTG maximum peak temperature" (DTG-MPT). This maximum lies for the 21 Turkish lignites in the range 330–550°C. The relationship of the CaO content of the lignite samples with the maximum peak temperature of the DTG curves can be seen in Fig. 3. It has been observed that an increase in

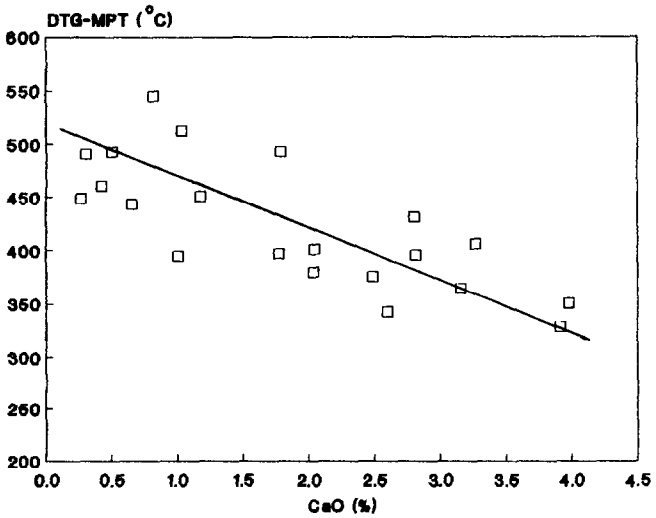

Fig. 3. The relationship of maximum peak temperature of the DTG curves with the CaO content.

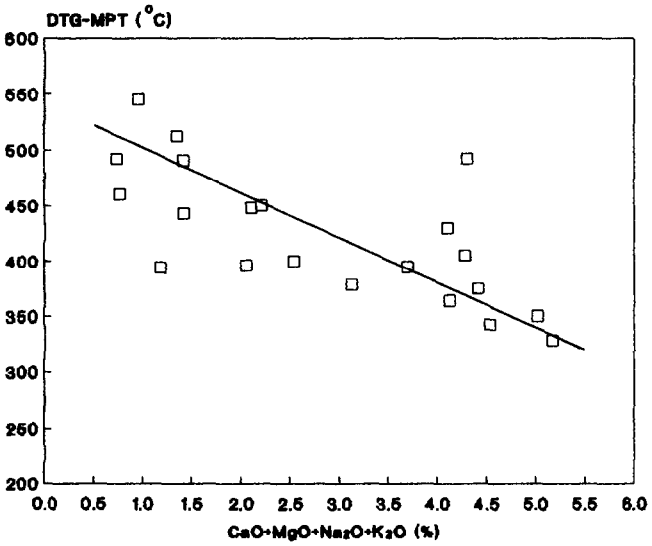

Fig. 4. The relationship of maximum peak temperature of the DTG curves with the sum of the CaO, MgO, Na_2O and K_2O contents.

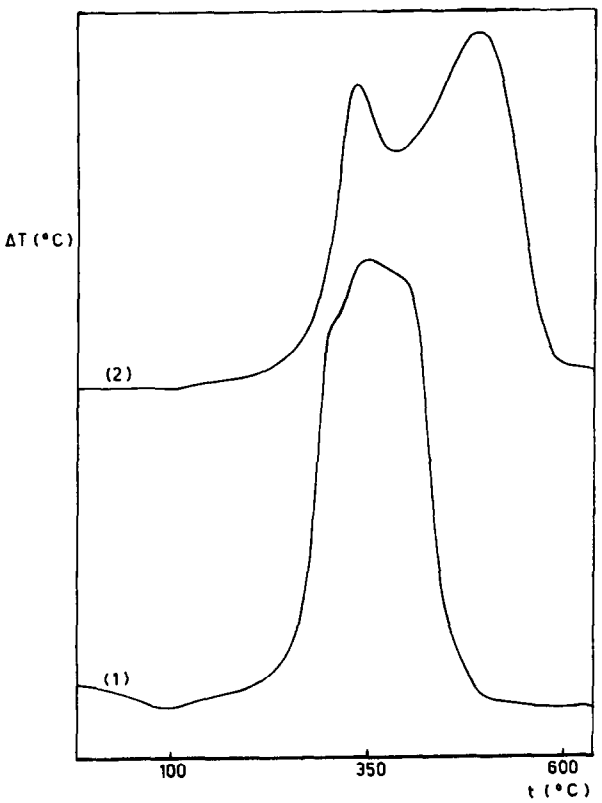

Fig. 5. The combustion curves of the lignite sample L07 before (1) and after (2) mineral matter removal.

the CaO content of the lignite sample causes a decrease in the maximum peak temperature of the DTG curve. Equation (3) represents the correlation obtained by means of regression analysis. The regression coefficient is 0.7588.

$$\text{DTG-MPT} = 493.6424 - 38.1236 \times (\text{wt.\% CaO}) \quad (3)$$

The relationship of the sum of the CaO, MgO, Na_2O and K_2O contents of the lignite samples with the maximum peak temperature of the DTG curves can be seen in Fig. 4. Equation (4) represents the correlation obtained by means of regression analysis. The regression coefficient is 0.7038.

$$\text{DTG-MPT} = 501.4396 - 27.5892 \times (\text{wt.\% Cao} + \text{MgO} + \text{Na}_2\text{O} + \text{K}_2\text{O}) \quad (4)$$

The results suggest that the CaO content of the lignite samples is more effective in determining the DTG maximum peak temperature than the sum of the CaO, MgO, Na_2O and K_2O contents.

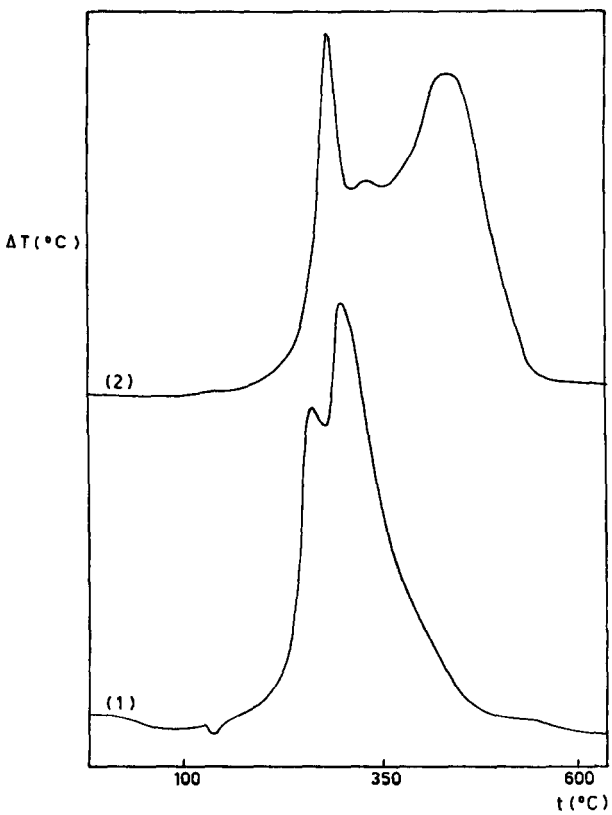

Fig. 6. The combustion curves of the lignite sample L09 before (1) and after (2) mineral matter removal.

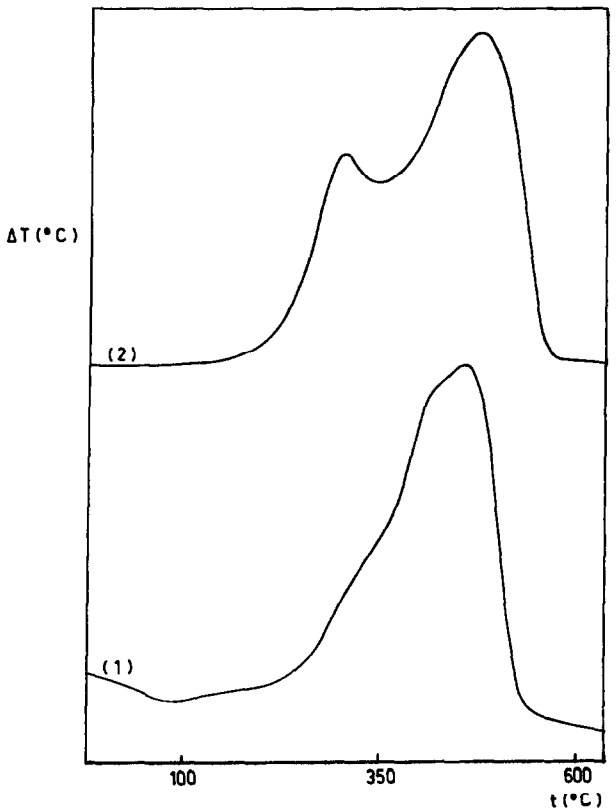

Fig. 7. The combustion curves of the lignite sample L13 before (1) and after (2) mineral matter removal.

The combustion curves of the lignite samples before and after mineral matter removal show significant differences. The curves obtained for five of the samples are shown in Figs. 5–9. The combustion curves of the original lignite samples show initially an endothermic peak related to the release of moisture, one or two combined exothermic maxima due to the combustion of the volatile matter released on heating, followed by burning of the residual solid. The combustion curves of all lignite samples after mineral matter removal contain two exothermic peaks due to combustion of the volatile matter and the residual solid.

The combustion curves of the demineralised lignite samples are broader than those of the original lignites because of the longer combustion time.

It is observed that the combustion of the demineralised fixed carbon occurs at higher temperatures.

The heat release rate of coal is as important for coal-fired boiler furnaces

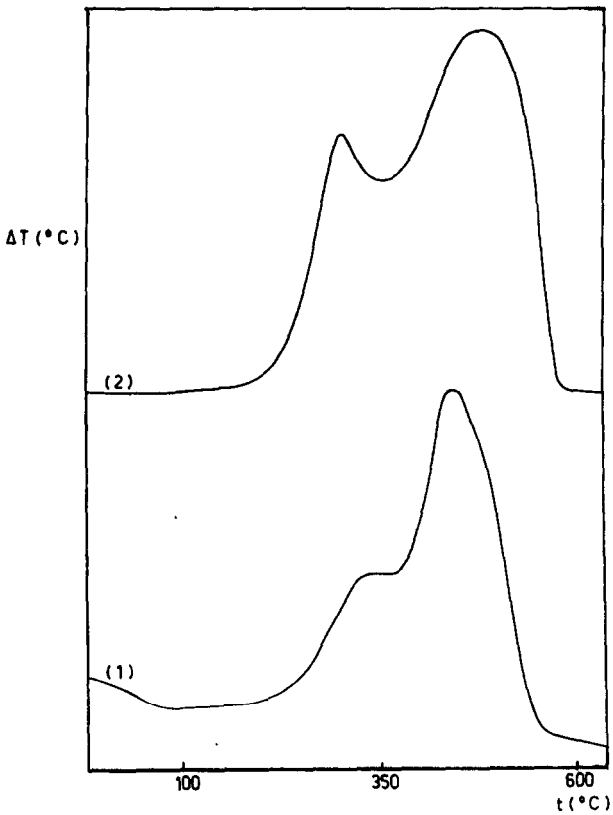

Fig. 8. The combustion curves of the lignite sample L17 before (1) and after (2) mineral matter removal.

as its heat content. The area under the exothermic peak of the combustion curve can be used to determine the heat release rate of coal. The heat release rates of the demineralised lignite samples and their dependence on temperature are considerably different from those of the original lignite samples. In Figs. 10 and 11 the heat release rate curves prepared for two lignite samples (L09 and L21) before and after mineral matter removal can be seen. The original lignite sample L09 loses 70% of its calorific value up to 370°C, but after demineralisation this occurs up to about 470°C (Fig. 10). The lignite sample L21 loses 70% of its calorific value up to 400°C before demineralisation and up to about 500°C after demineralisation. Mineral matter contained in the coal influences the rate of combustion by catalytically increasing the rate.

The mineral matter content of the lignite samples therefore plays an important role in determining the combustion characteristics of the lignite samples.

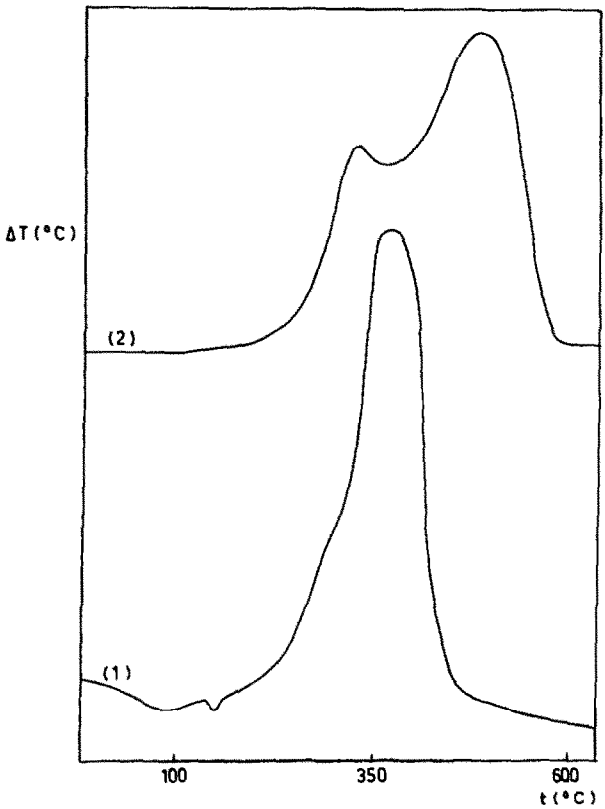

Fig. 9. The combustion curves of the lignite sample L21 before (1) and after (2) mineral matter removal.

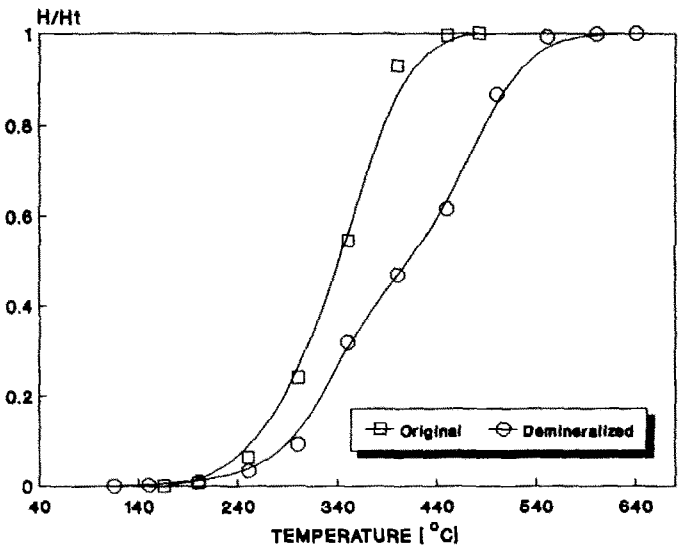

Fig. 10. Effect of temperature on the heat release rate of the original and demineralised lignite sample L09 (Ht = net calorific value; H = heat released up to temperature T).

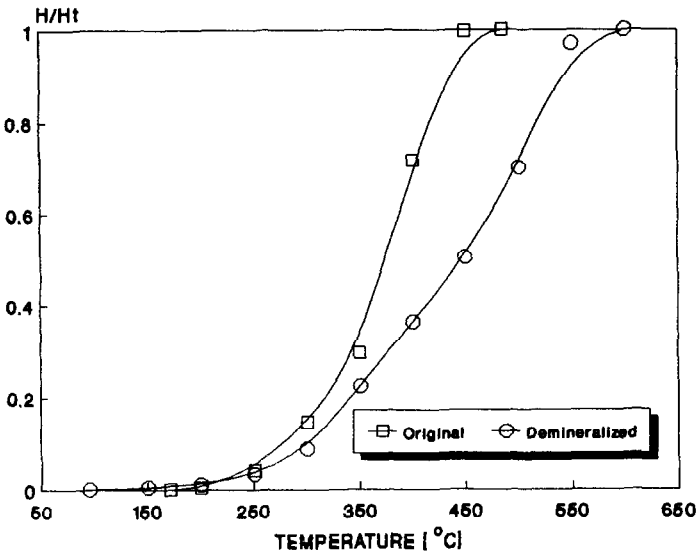

Fig. 11. Effect of temperature on the heat release rate of the original and demineralised lignite sample L21 (*Ht* = net calorific value; *H* = heat released up to temperature *T*).

REFERENCES

1 Annual Book of ASTM Standards, American Society for Testing and Materials, Easton, Part 26, D 3173-73, D 3175-77, D 3174-73, 1977.
2 Annual Book of ASTM Standards, American Society for Testing and Materials, Easton, Part 26, D 2795-69, 1977.
3 Determination of mineral matter, International Organization for Standardization, ISO 602-1983 (E), Switzerland, 1983.
4 J.W. Cumming and J. McLaughlin, Thermochim. Acta, 57 (1982) 253–272.
5 W.A. Kneller, Thermochim. Acta, 108 (1986) 357–388.