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COMBUSTION EVALUATION OF McLEOD RIVER COAL IN A PILOT-SCALE UTILITY BOILER

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ABSTRACT

The combustion performance of McLeod River coal was evaluated in pilot-scale, pulverized-fired research boiler. The coal, containing about 9% total moisture, handled and flowed readily and burned with good ignition, flame stability and carbon burn-out. The coal ash slagged on high temperature refractory-lined boiler surfaces, but deposits on superheater surfaces were light and powdery and did not constitute a fouling problem. The coal's potential for low-temperature corrosion was minimal. Emissions of nitric oxide and sulphur dioxide were comparable or less than current allowable North American guidelines.

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INTRODUCTION

Under a cost-shared agreement with Techman Engineering Limited, the Canadian Combustion Research Laboratory (CCRL) carried out a research project to evaluate the combustion performance of a thermal coal from the McLeod River deposit located in north-western Alberta.

The McLeod River coal used for the combustion trials, comprised a 77%:23% mix by weight of the Val d'Or and McPherson seams respectively. The coal ranked as a high volatile bituminous by ASTM classification procedures, had not been previously burned in industrial-size equipment. The joint project formed part of the CANMET Energy Research Program and included an analytical investigation of the parent coal seams, the bulk coal mix and the coal ash properties as well as combustion studies of the mixed coal in the CCRL pilot-scale boiler under conditions representative of those in large boilers.

This report describes the objectives of the project, the analyses of the coals, the facilities used and the operational procedures selected.

RESEARCH OBJECTIVES

The objectives of the combustion trials and related analytical studies were:

1. to determine the comminution and handling characteristics of the coal;
2. to analyze the parent coal seams and the bulk coal sample;
3. to evaluate the combustion performance at specified feed fineness and excess combustion air levels;
4. to characterize the particulate and the gaseous pollutants generated during combustion;
5. to assess the slagging and fouling potential of ash constituents within the furnace and on radiant heat transfer surfaces and superheater tubes respectively;
6. to determine the fly ash resistivity characteristics and ease of fly ash collection by electrostatic precipitation; and
7. to derive coal combustion charts based on heat losses calcualted from the ultimate coal analyses.

COAL CHARACTERISTICS

Handling and Preparation

The 6 tonne sample of McLeod River coal, which comprised 4-1/2 tonnes of the Val d'Or seam and 1-1/2 tonnes of the McPherson seam, were delivered to CCRL in sealed plastic-lined drums. The coals with their "as received" moisture contents of 7 and 11.5% were free flowing and no problems were experienced in mixing them or feeding the mix through the pilot-scale coal handling system. Samples of the individual seams were taken for analytical purposes only.

Combustion Reactivity

The screen, proximate, ultimate, ash and trace analyses of the two coal seams comprising the coal mixture are shown in Tables 1 to 4.

Previous research at CCRL has shown that the efficiency of carbon burn-out in turbulent diffusion flames is strongly dependent on the reactivity or combustion characteristics of the coal macerals present. The influence of the main maceral types on combustion, in order of their relative reactivity, is listed in Figure 1. The petrographic data for the component coal seams are shown in Table 5.

With 25% and 34% inert macerals in the minor and major component seams, respectively, the coal mix should burn and ignite readily with excellent stability and carbon burn-out. This is endorsed by the high volatile matter content (33%), the Volatile Matter/Fixed Carbon ratio (>0.6) and the calorific value of about 26 MJ/kg for the major component.

The bulk coal and ash analyses are given in Tables 6 and 7. These figures were computed by prorating the component seam analyses, except for the ash fusion characteristics which were determined on the sample mix.

A mineralogical examination of the coal mix, performed by the CORE laboratories of Calgary, Alta., is given in Appendix A.

Combustion Charts

Combustion charts, based on the ultimate analyses of the coal, are given in Appendix B. These charts provide a rapid, graphical means of determining boiler efficiency by the Indirect ASME Heat Loss Method.

HIGH-TEMPERATURE ASH DEPOSITS

Two general types of high-temperature ash deposition can occur on gas-side surfaces of coal-fired boilers:

1. Slagging-fused deposits that form on surfaces exposed predominantly to radiant heat transfer, such as on refractory furnace bottoms.
2. Fouling-high temperature bonded deposits that form on surfaces exposed predominantly to convective heat transfer, such as on superheater or reheated surfaces.

Slagging Indicators

The slagging potential of coal can often be assessed by using indices or composite parameters to describe the nature and severity of the slag deposits (1).

Two common indices for determining the slagging potential of the coal ash and furnace deposits are described below:

(1) The Base:Acid Ratio (B/A) is defined:

$$\text{as} \quad \frac{Fe_2O_3 + CaO + MgO + Na_2O}{SiO_2 + Al_2O_3 + TiO_2} ,$$

where each oxide is expressed as a percentage of the total ash. A maximum of 0.5 for the base:acid ratio has been suggested for dry-bottom pulverized-fired units, although this is not a necessary restriction. Values below 0.27 indicate that slagging is unlikely to be a problem at normal furance operating temperatures.

(2) Potential Slagging Temperature (Tps) is defined:

$$\text{as} \quad \frac{HT + 4IT}{5} \; {}^{\circ}C,$$

where IT is the minimum temperature at which initial ash deformation occurs (normally in a reducing atmosphere) and HT is the maximum temperature at which hemispherical deformation occurs (normally in an oxidizing atmosphere).

Temperature values greater than 1340°C indicate a low slagging potential, whereas values less than 1150°C indicate a severe slagging potential.

Both the base:acid ratio of 0.24 and the potential slagging temperature of 1181°C (see Table 12) derived from the ash analyses and the ash fusion data, respectively, suggest that the McLeod River coal will have a medium to high slagging tendency.

Fouling Indicators

Most indices are applied by categorizing the coals as having an "eastern type" or a "western type" ash. The term "western type" ash is defined as an ash having more CaO + MgO than Fe_2O_3, when the three components are measured as a weight per cent of the coal ash. This criterion is dependent solely on ash analyses and does not have any rank or geographic connotation. On the above basis the ash from the McLeod River coal has a CaO + MgO/Fe_2O_3 ratio of 1.30 and can be classified as a "western" coal ash.

There has been general agreement between research and operating practice that one of the dominate factors influencing superheater fouling is the sodium content of the coal ash. The following classification has been proposed:

Fouling category	% Na_2O in Ash "eastern" coals	"western" coals
Low	<0.5	<2.0
Medium	0.5 - 1.0	2.0 - 6.0
High	1.0 - 2.5	6.0 - 8.0
Severe	>2.5	>8.0

The ash from the McLeod River coal has an Na_2O content of 0.60% which would indicate that it is in the low fouling category of the "western type" coal ash.

PILOT-SCALE RESEARCH BOILER

The CCRL research boiler, illustrated schematically in Figure 2, is a pulverized-coal-fired boiler incorporating two tangentially opposed in-shot burners. The furnace is of membrane-wall construction and operates at pressures of up to 2.5 kPa (10 in WC). At the full-load firing rate of 2500 MJ/h (0.7 MW), the boiler generates 730 kg/h of steam at 690 kPa (6.8 atm). The heat is dissipated in an air cooled condenser.

Crushed coal is supplied from a 4500 kg hopper, mounted on an electronic weigh scale, through a variable-speed worm feeder to a ring-and-roller type of pulverizer, which is normally swept and pressurized by air at any temperature up to 230°C. If necessary, the pulverizer can be swept and pressurized with a mixture of air and flue gas at any temperature up to 490°C. The pulverizer contains a motor-driven classifier for controlling coal fineness and a riffle at the pulverizer outlet proportions the coal to each burner. Secondary air can be supplied to the burner at any temperature up to 260°C.

Combustion gases leave the furnace between 900-1100°C and then pass through a transition section, a test-air heater and conventional three-pass air heater before entering a long horizontal sampling duct. A by-pass from the air heater to the stack breeching and additional heat exchanger surface in the sampling duct, permit the gas temperature in the sampling duct to be varied between 150°C and 300°C.

A forced-draft fan supplies air to the air heater at 7 kPa (28 in WC). The air, on leaving the heater, is divided into three systems; primary air to the pulverizer, secondary air to the burners and cooling air to the test-air heater. The last stream, after leaving the test-air heater, can either be exhausted to the atmosphere of blended with the primary-air supply to the pulverizer.

The research boiler is manually controlled, except for electrical interlocks to ensure that safe start-up and shutdown procedures are followed. When burning high-grade coals, it has been possible to operate with as little at 1.0% O_2 and less than 0.1% CO in the flue gases, with a smoke density of less than No. 1 Ringlemann.

EXPERIMENTAL PROCEDURES

Operating Procedure

The operating procedure given below was used for all trials with some minor variations in timing, as necessary.

1. Before starting each test, all boiler and air heater fireside surfaces were thoroughly cleaned by air lancing and the furnace bottom was relined with a refractory blanket. Sufficient coal was bunkered to provide eight hours of continuous operation.
2. At 0800 h, the cold boiler was preheated on No. 2 fuel oil at 16 gph. Excess air was adjusted to provide 5% O_2 in the flue gas and the boiler was allowed to stabilize at full steaming rate and pressure. All continuous monitoring instruments were calibrated and put into service.
3. At 0900 h, pulverized coal was fed to the boiler at a specified classifier speed, mill temperature and excess air level. One oil torch was left in operation.
4. At 0945 h, the oil torch was removed, leaving the boiler operating on pulverized coal only.
5. At 1100 h, scheduled testing was begun. Boiler panel readings were continuously monitored and recorded half-hourly. A specified coal feed rate, coal fineness and excess air level was maintained as closely as possible for the test duration.
6. By 1700 h all measurements were completed and the boiler was shut down.
7. The furnace was allowed to cool overnight. Then the furnace bottom was removed and the ash remaining in the furnace bottom and duct work was collected, weighed and sampled.

Parameters of Combustion Performance

The following parameters of combustion performance were measured at the sampling stations illustrated in Fig. 2.

1. Coal quality of a composite sample taken from the crushed coal feed at the pulverizer inlet. Station 1.
2. Moisture and sieve analyses of pulverized coal samples taken at the pulverizer outlet. Station 2.
3. CO_2 and CO content of the flue gas measured continuously by infrared monitors. Station 10.

4. O_2 content of the flue gas measured continuously by paramagnetic monitor. Station 10.
5. NO content of the flue gas measured continuously by a chemiluminescent monitor. Station 10.
6. SO_2 content of the flue gas measured continuously by an infrared monitor. Station 10.
7. SO_3 content of the flue gas measured by the modified Shell-Thornton method. Station 15.
8. Fly-ash loading measured by an isokinetic sampling system, two to four samples per test. These samples were analyzed for carbon content, chemical composition and aerodynamic size distribution. Station 16.
9. Fouling of heat-transfer surfaces evaluated by visual examination of ash build-up on a simulated superheater, installed immediately downstream of the screen tubes. Station 20.
10. Slagging propensity by examining the thickness, physical structure, chemical composition and melting characteristics of ash deposits selected from various parts of the furnace. Station 7-9 and 19.
11. Fly-ash resistivities measured by an in-situ, point-plane resistivity apparatus at flue gas temperature of about 180°C at Station 17 and about 350°C at Station 15.

COMBUSTION PERFORMANCE

Coal Comminution

The coal was crushed, metered and pulverized to the selected degrees of fineness without difficulty. The CCRL coal drying and grinding system is illustrated in Fig. 3. The pulverized coal was then transported directly to the burners without moisture separation from the carrying air. The grinding performance of the pulverizer, which produced products of 87% and 65% minus 200 mesh, was consistent with the coal's low Hardgrove grindability index of 41. The size distribution of the pulverized coal is shown in Table 8, together with the boiler operating data.

Flame Characteristics

The combustion conditions remained essentially constant throughout each combustion trial and confirmed that the handling characteristics of the mixed coal were good. The flame was bright, clean and stable under steady-state conditions; an oil support flame was only required for a few minutes at the start of each trial to establish combustion.

Gaseous Emissions

Carbon monoxide levels at less that 50 ppm did not constitute either an emission problem or a thermal penalty.

The sulphur dioxide emissions from this low-sulphur coal were less than 250 ppm or 0.23 g/MJ, which is well below the U.S. Environmental Protection Agency 1977 guideline of 0.58 g SO_2/MJ for new combustion systems. These emissions were less than total theoretical because of neutralization reactions occurring between the fuel sulphur and the alkaline ash cations. Only trace quantities of sulphur trioxide were detected. Low-temperature corrosion probes inserted in the utility boiler indicated that sulphuric acid buildup was below the minimum detectable limit.

The nitric oxide emission rate of 0.36 g/MJ was slightly higher than the 1977 EPA guideline of 0.34 g/MJ for new sources.

Fly Ash Characteristics and Coal Burn-out

The mass loadings and aerodynamic particle size analyses of the fly ash entering the electrostatic precipitator are shown in Table 9. These data show that about 60 to 70% by weight of the fly ash particles were less than 10 µm and that the combustion efficiency corresponding to about 2% combustible in the fly ash was greater than 99.7%. The combustion efficiency in full-scale furnaces should be just as good or better since flame quenching is slower and combustion residence times are much longer relative to the pilot-scale system, where burn-out tends to be inhibited by the high surface to volume ratio and the small flame zone of the furnace.

The in-situ resistivities for the McLeod River coal are given in Table 9. In general, high electrical resistivity ($>10^{12}$ ohm-cm) indicates that precipitated fly ash will retain a strong electrical charge and repel any similarly charged particle or generate a back corona within the deposit; precipitation is therefore difficult. A low resistivity ($<10^{7}$ ohm-cm) fly ash will readily precipitate but will not adhere strongly to the collecting plates and will easily be re-entrained in the flue gas. Low resistivities are usually associated with high carbon losses. Intermediate values of approximately 10^8 to 10^{11} ohm-cm are considered to yield the best precipitator efficiencies. The in-situ resistivities of the McLeod River fly ash (see Table 9) were very close to the maximum of this desirable range.

Ash Slagging and Fouling

The fusion data for the furnace bottom ashes are similar to those for the parent coal ash. The ash analyses and fusion temperatures, given in Tables 6, 7 and 11 are normally associated with medium to high slagging ashes and are consistent with the fluid structure of the bottom ash deposits shown in Figures 4 and 5.

Figure 6, which shows photographs of the powdery, loosely adherent superheater deposits, confirms the low-fouling tendency predicted by the analytical and empirical data for the coal ash and the superheater deposits given in Tables 7 and 11. Table 12 indicates that the Base:Acid ratio was relatively unaffected by combustion. Measurements of the potential slagging temperature of the coal and related deposits were essentially unchanged by combustion as shown in Table 12. This table indicates that the McLeod River coal ash will have a medium to high propensity for slagging.

CONCLUSIONS

The McLeod River coal handled and flowed readily with excellent ignition, flame stability and combustion characteristics.

The sulphur content of this fuel is low and a small amount of the sulphur was neutralized by alkali metal ions in the coal ash. The measured emission rate of 250 ppm corresponded to 0.23 g SO_2 per MJ of fuel input, well below the maximum EPA 1977 guideline of 0.58 g SO_2/MJ for new combustion sources.

The nitric oxide emission rates of 860 to 900 ppm corresponded to 0.34 to .36 g NO per MJ of fuel input, which is marginally higher than the maximum EPA 1977 guideline of 0.34 g NO/MJ.

The tendency of the coal ash to produce boiler wall slag deposits is fairly high but superheater fouling problems should be low and controllable by routine soot-blowing. A porous but liquid slag about 10 cms thick was formed in the furnace bottom after 8 h operation.

It is estimated that the electrical resistivity of the fly ash, with combustible contents typical of levels found in full-scale units (5%), would be in the preferred range of 10^8-10^{11} ohm-cm, which gives the best precipitator efficiencies.

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REFERENCE

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Table 1 - Screen analyses of McLeod coal samples

Screen size (mm)	weight % (cumulative)	
	Val d'Or	McPherson
+25.4	0.2	0.1
+19.1	4.0	4.0
+12.7	18.8	20.9
+6.4	46.0	48.4
+3.2	74.5	76.5
-3.2	25.5	23.5
Bulk density	793 kg/m^3 at 7% moisture	785 kg/m^3 at 11.5% moisture

Table 2 - Chemical and physical analyses of McLeod coal samples

Analysis	Val d'Or seam		McPherson seam	
Moisture, wt %				
As received	7.0%		11.5%	
Proximate, wt % (dry)				
Ash	12.21		16.33	
Volatile matter	36.09		32.51	
Fixed carbon	51.70		51.16	
Ultimate, wt % (dry)				
Carbon	68.05		65.62	
Hydrogen	3.79		3.72	
Sulphur	0.28		0.26	
Nitrogen	0.78		0.72	
Ash	12.21		16.33	
Oxygen (by diff.)	14.89		13.35	
Calorific value, MJ/kg	27.15		15.99	
Grindability index, Hardgrove	39		44	
Chlorine in coal, %	<0.1		<0.1	
Free swelling index	non-agglomerating		non-agglomerating	
Ash fusibility, °C	Reducing	Oxidizing	Reducing	Oxidizing
Initial	1149	1260	1138	1279
Softening	1260	1291	1238	1316
Hemispherical	1332	1343	1343	1371
Fluid	1396	1385	1371	1400

Table 3 - Analyses of ashes from McLeod coal samples

Major elemental oxides	weight % of ash	
	Val d'Or seam	McPherson seam
SiO_2	56.44	55.86
Al_2O_3	18.66	19.15
Fe_2O_3	7.07	9.66
TiO_2	0.54	0.57
P_2O_5	0.07	0.07
CaO	9.21	7.33
MgO	1.18	1.15
SO_3	3.70	2.58
Na_2O	0.51	0.90
K_2O	0.79	0.57
SrO	0.06	0.10
BaO	0.62	0.49
L.O.F.	1.61	1.13

Table 4 - Trace elements determined in McLeod coal samples

	X-ray fluorescence analyses, ppm (dry fuel basis)				
	Val d'Or	McPherson		Val d'Or	McPherson
Beryllium (Be)	0.6	0.8	Manganese (Mn)	65.5	39.5
Cadmium (Cd)	0.3	0.4	Mercury (Hg)	<0.1	<0.1
Cobalt (Co)	4.6	4.5	Molybdenum (Mo)	3.7	4.5
Copper (Cu)	7.3	9.9	Nickel (Ni)	7.6	7.4
Chromium (Cr)	7.3	7.0	Selenium (Se)	0.4	0.5
Lead (Pb)	10.4	15.7	Vanadium (V)	14.0	27.6
			Zinc (Zn)	14.0	27.6
	Neutron activation analyses, ppm (dry fuel basis)				
	Val d'Or	McPherson		Val d'Or	McPherson
Antimony (Sb)	0.6	0.6	Iodine (I)	<10	<10
Arsenic (As)	<1	7.0	Lanthanum (La)	10.0	10.0
Bromine (Br)	8.0	43.0	Lutecium (Lu)	0.1	0.1
Caesium (Cs)	<2	2.0	Neodynium (Nd)	<50	<50
Cerium (Ce)	<30	<30	Rubidium (Rb)	<100	<100
Chlorine (Cl)	<100	1800	Samarium (Sm)	2.0	2.0
Dysprosium (Dy)	1.7	1.4	Scandium (Sc)	4.0	3.0
Europium (Eu)	0.5	0.4	Tantalum (Ta)	<5	<5
Hafnium (Hf)	<0.5	<0.5	Thorium (Th)	3.0	2.0
Holnium (Ho)	<1	<1	Uranium (U)	1.0	2.0

Table 5 - Petrographic examination of coal macerals

Maceral form	Volume %	
	Val d'Or	McPherson
<u>Reactives</u>		
Exinite	2	2
Vitrinite	72	64
Reactive semi-fusinite	-	-
Sub-total	74	66
<u>Inerts</u>		
Fusinite	8	9
Semi-fusinite	10	14
Micrinite	1	2
Mineral matter	7	9
Sub-total	26	34
Mean reflectance	0.53	0.53

Table 6 - Coal analysis, McLeod coal mix

Analysis*	Coal		Pacific Rim Specifications	
			KECO	EPDC
Moisture, wt %				
As received	9		<15	<10
Proximate, wt % (dry)				
Ash	13.14		<17	<20 C.H.B.**
Volatile matter	35.29		22-36	$\frac{VM}{FC}$ >0.40
Fixed carbon	51.57		50-60	
Ultimate, wt % (dry)				
Carbon	67.50		-	-
Hydrogen	3.77		-	-
Sulphur	0.27		<1.0	<1.0
Nitrogen	0.77		<2.0	<1.8
Ash	13.14		-	-
Oxygen (by diff.)	14.55		-	-
Calorific value, MJ/kg	26.89		>25.12	>25.12
Grindability index, Hardgrove	41		>45	>45
Chlorine in coal, %	<0.1		-	-
Free swelling index	non-agglomerating			
Ash fusibility, °C	Reducing	Oxidizing	Reducing	Oxidizing
Initial	1138	1251	>1250	-
Softening	1260	1285	-	-
Hemispherical	1293	1352	-	>1200
Fluid	1329	1382	-	>1300

* All analyses, except ash fusibility, were prorated from component seams.

**C.H.B. - Constant Humidity Basis.

Table 7 - Analysis* of coal ash from McLeod coal mix

Major elemental oxides	wt % in ash
SiO_2	56.31
Al_2O_3	18.77
Fe_2O_3	7.65
TiO_2	0.55
P_2O_5	0.07
CaO	8.79
MgO	1.17
SO_3	3.45
Na_2O	0.60
K_2O	0.74
SrO	0.07
BaO	0.59
L.O.F.	1.50

*Prorated from component seams.

Table 8 - Boiler operating conditions

	Trial 1	Trial 2
Fuel rate, kg/h	73.1	72.8
Fuel moisture, wt %	5.5	5.3
<u>Coal fineness</u>		
+100 mesh	0.1	0.2
100 x 140 mesh	0.5	4.0
140 x 200 mesh	12.0	31.0
200 x 325 mesh	59.0	36.0
325 x 400 mesh	12.0	15.0
-400 mesh	16.4	13.8
-200 mesh	87.4	64.8
Heat input, MJ/h	1857	1854
Boiler exit temp., °C	910	880
<u>Air temperatures, °C</u>		
Pulverizer in	178	192
Pulverizer out	108	111
Secondary	194	200
Steam rate, kg/MJ	0.193	0.187
Flue gas rate, Nm^3/MJ	0.280	0.315
<u>Flue gas analyses, Volume</u>		
CO_2 , %	16.0	14.6
O_2 , %	3.0	4.9
CO , ppm	30	35
NO , ppm	900	860
SO_2 , ppm	240	250
SO_3 , ppm	<1	<1
<u>Emission rates, g/MJ</u>		
NO	0.338	0.363
SO_2	0.192	0.225

Table 9 - Fly ash characteristics

	Trial 1	Trial 2
Precipitator inlet loading,		
g/Nm^3	2.957	2.710
g/MJ	0.828	0.854
Combustible content, wt %	2	<1
Aerodynamic particle size, wt %		
+30 µm	20	32
+10 µm	30	40
+1 µm	82	90
Electric resistivity, log ohm-cm		
at 185°C	11.3	11.2
at 285°C	11.2	10.6
Combustion efficiency, %	99.7	99.8

$$\text{Combustion, \%} = 100 - \frac{14{,}500\ CA}{(100 - C)\ C_V}$$

where C = % carbon in ash

A = % ash in coal

C_V = Calorific value of coal (Btu/lb)

Table 10 - Fly ash analyses

Major elemental oxides	Weight %	
	Trial 1	Trial 2
SiO_2	52.00	53.59
Al_2O_3	20.36	20.37
Fe_2O_3	7.06	7.18
TiO_2	0.99	0.88
P_2O_5	0.22	0.19
CaO	11.79	12.29
MgO	1.46	1.65
SO_3	0.25	0.32
Na_2O	0.68	0.66
K_2O	0.71	0.67
BaO	0.64	0.80
SrO	0.11	0.11
L.O.F.	3.60	0.50

Table 11 - Analyses of furnace bottom and superheater deposits

	Furnace bottom deposits		Superheater deposits	
	Trial 1	Trial 2	Trial 1	Trial 2
Major elemental oxides, wt %				
SiO_2	59.45	61.46	55.32	55.37
Al_2O_3	20.74	19.87	20.00	19.84
Fe_2O_3	8.97	8.17	8.92	8.81
TiO_2	0.59	0.49	0.69	0.70
P_2O_5	0.13	0.07	0.14	0.11
CaO	8.17	6.39	10.78	10.50
MgO	1.31	1.14	1.31	1.67
SO_3	0.24	0.21	0.49	0.61
Na_2O	0.55	0.49	0.58	0.57
K_2O	0.72	0.72	0.68	0.67
BaO	0.45	0.43	0.70	0.65
SrO	0.07	0.06	0.09	0.10
L.O.F.	<0.01	<0.01	1.10	0.90
Ash fusibility, °C				
Reducing atmosphere				
Initial	1184	1204	1177	1182
Softening	1207	1252	1257	1218
Hemispherical	1240	1438	1338	1362
Fluid	1407	1465	1388	1368
Oxidizing atmosphere				
Initial	1235	1263	1274	1296
Softening	1249	1315	1293	1324
Hemispherical	1307	1368	1343	1346
Fluid	1449	1443	1371	1357

Table 12 - Indices of slagging potential

Slagging propensity	Reference limits	Ash source				
		McLeod River Coal	Furnace bottom deposits		Superheater deposits	
			Trial 1	Trial 2	Trial 1	Trial 2
Base/Acid (B/A) ratio						
Low	<0.15	-	-	-	-	-
Medium	0.15-0.30	0.24	0.23	0.19	0.28	0.28
High	0.27-0.50	-	-	-	-	-
Severe	>0.50	-	-	-	-	-
Potential slagging temp., (Tps, °C)						
Low	<1340	-	-	-	-	-
Medium	1340-1230	-	-	1251	-	-
High	1230-1150	1181	1209	-	1210	1218
Severe	>1150	-	-	-	-	-

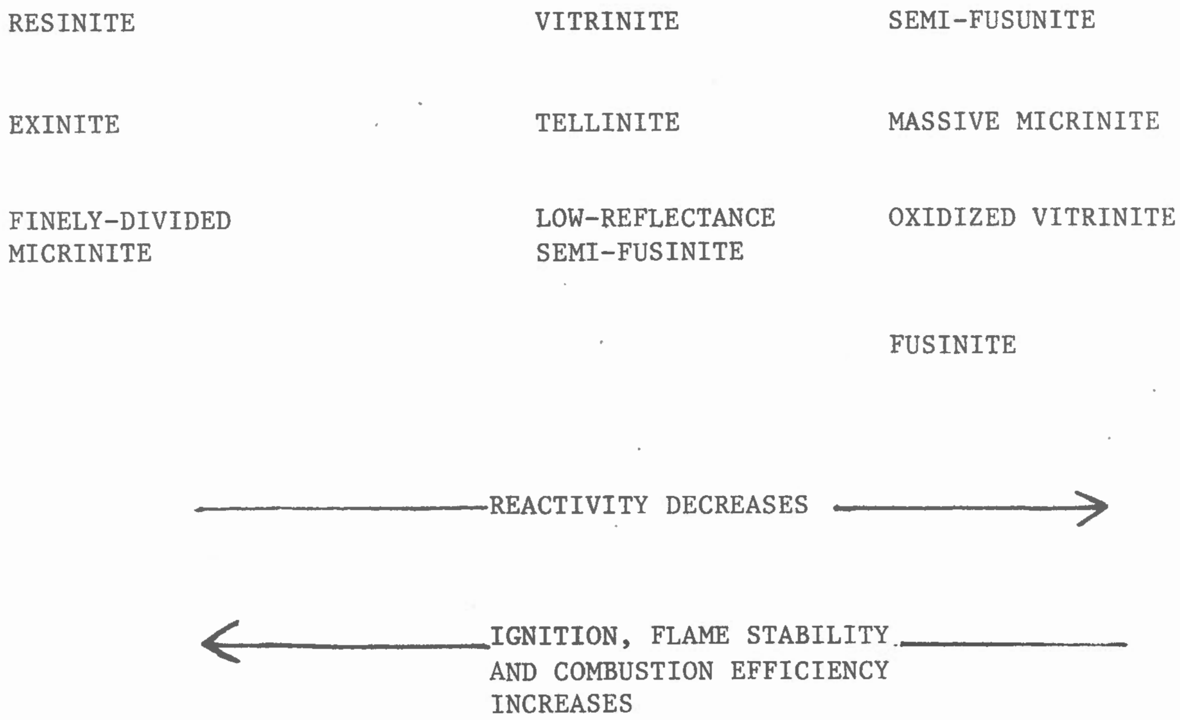


Fig.1 - Influence of coal maceral type on combustion.

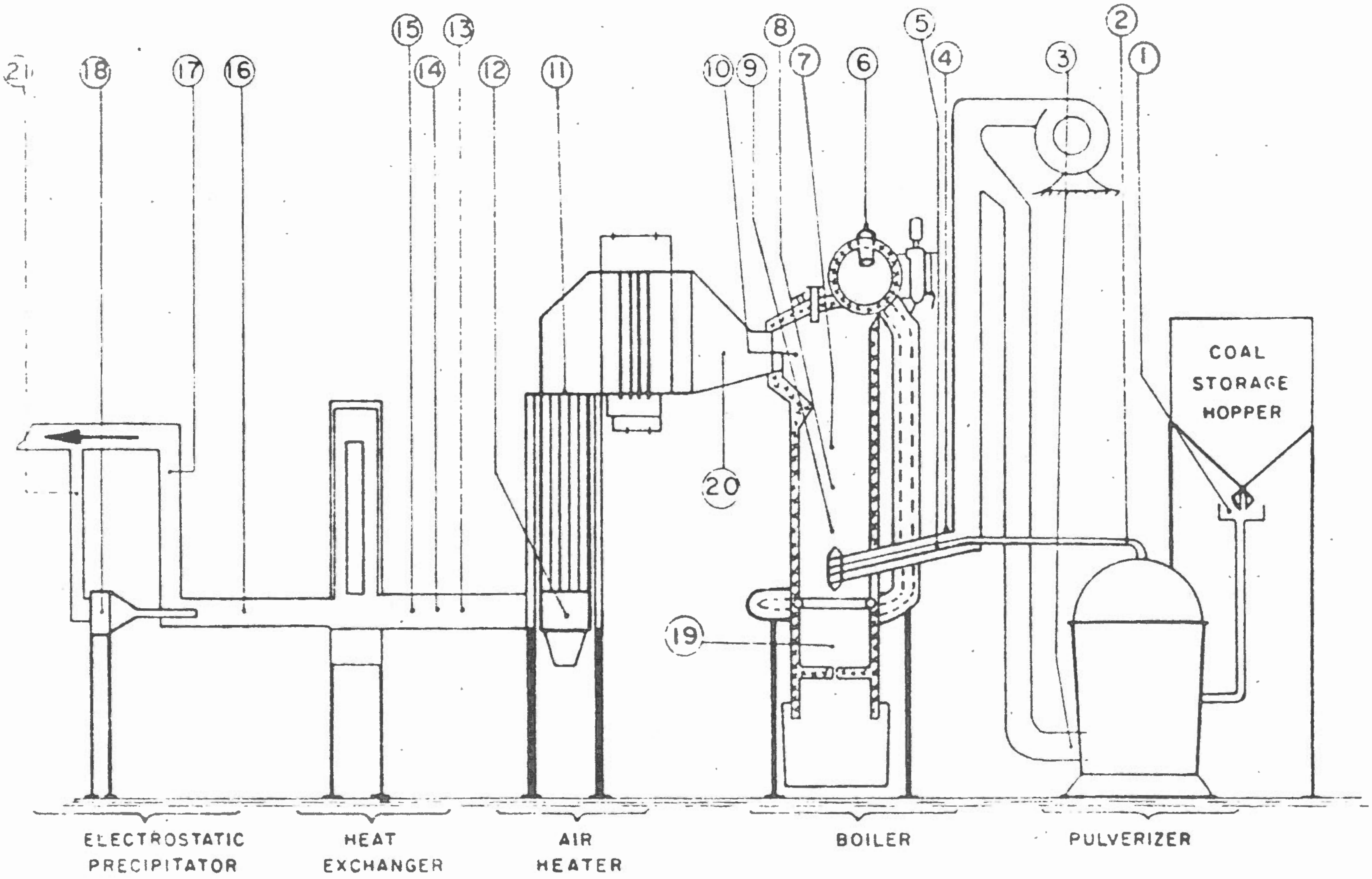


Fig. 2 - Schematic illustration of the pilot-scale boiler showing the sampling stations

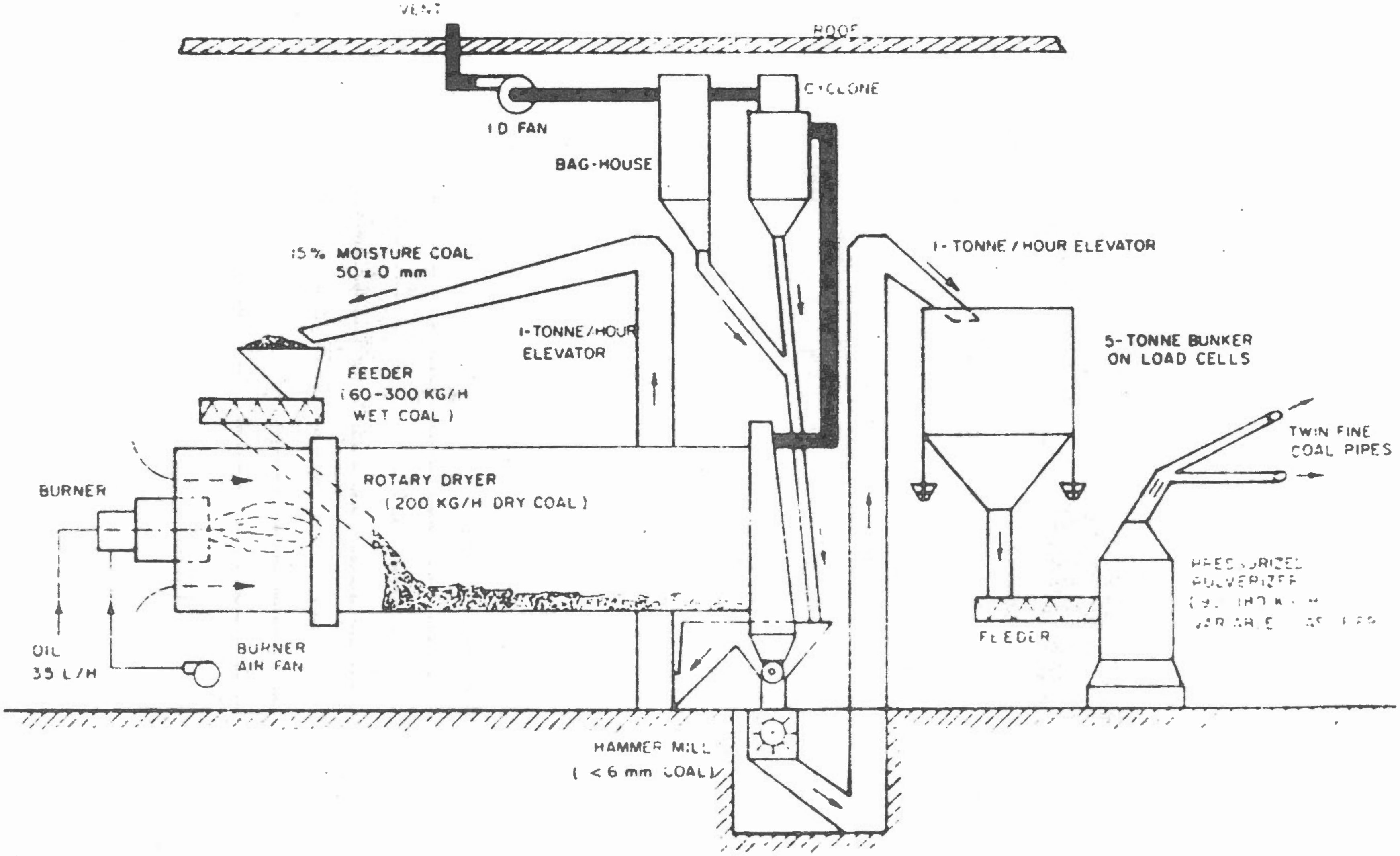
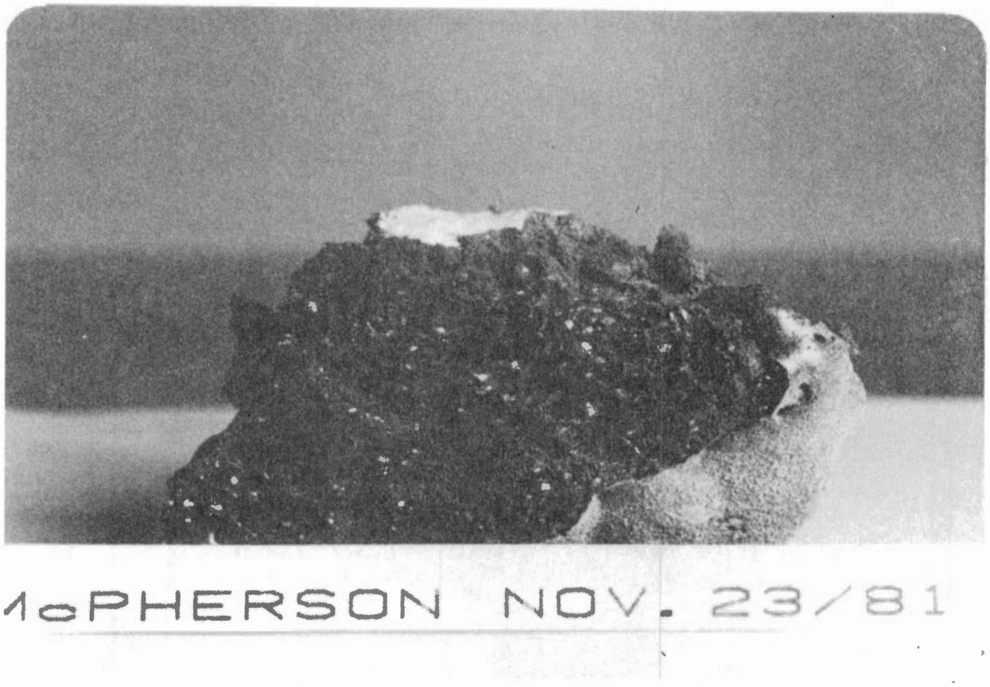


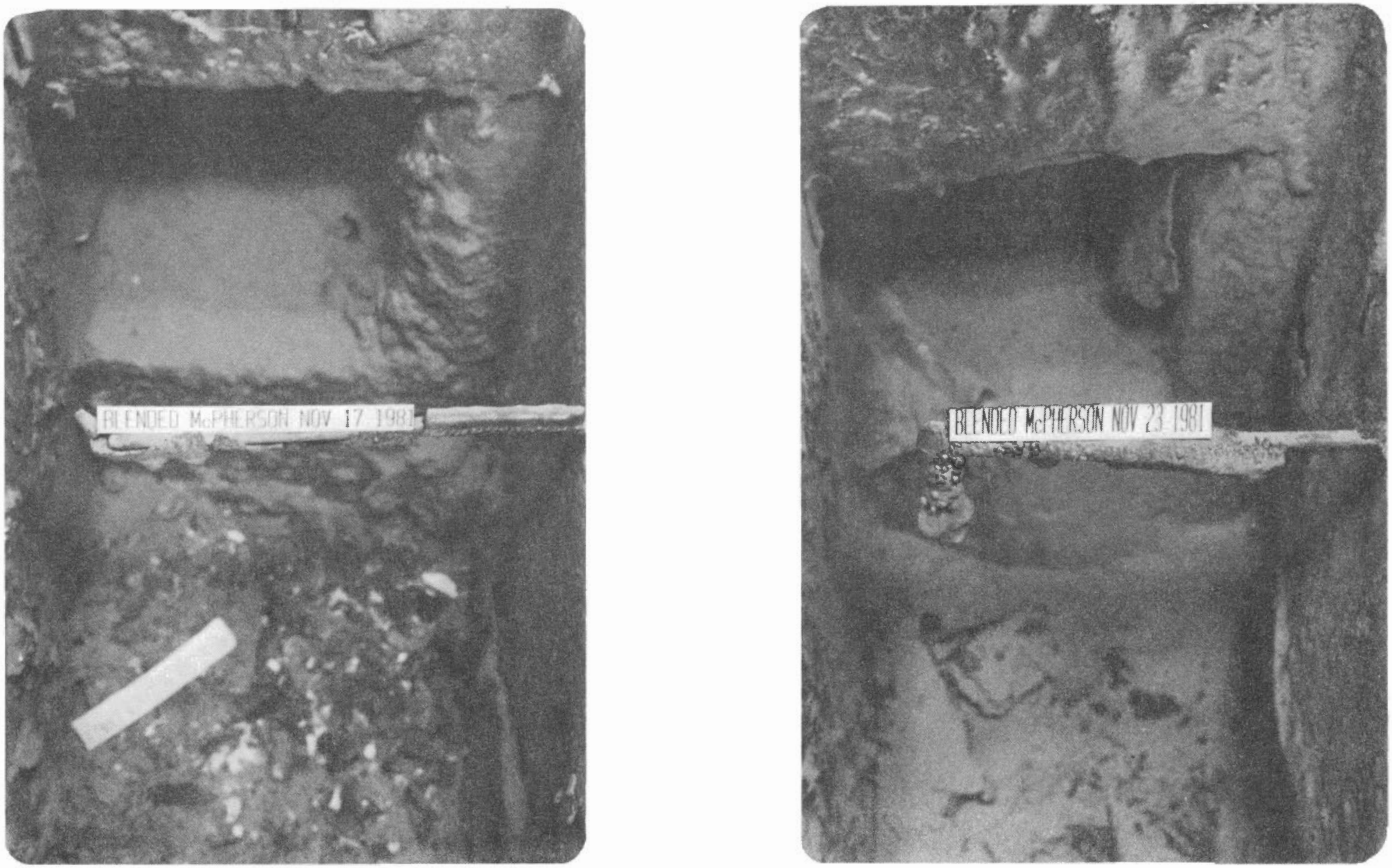
Fig. 3 - Schematic illustration of solid fuel drying and grinding system

Trial 1



Trial 2

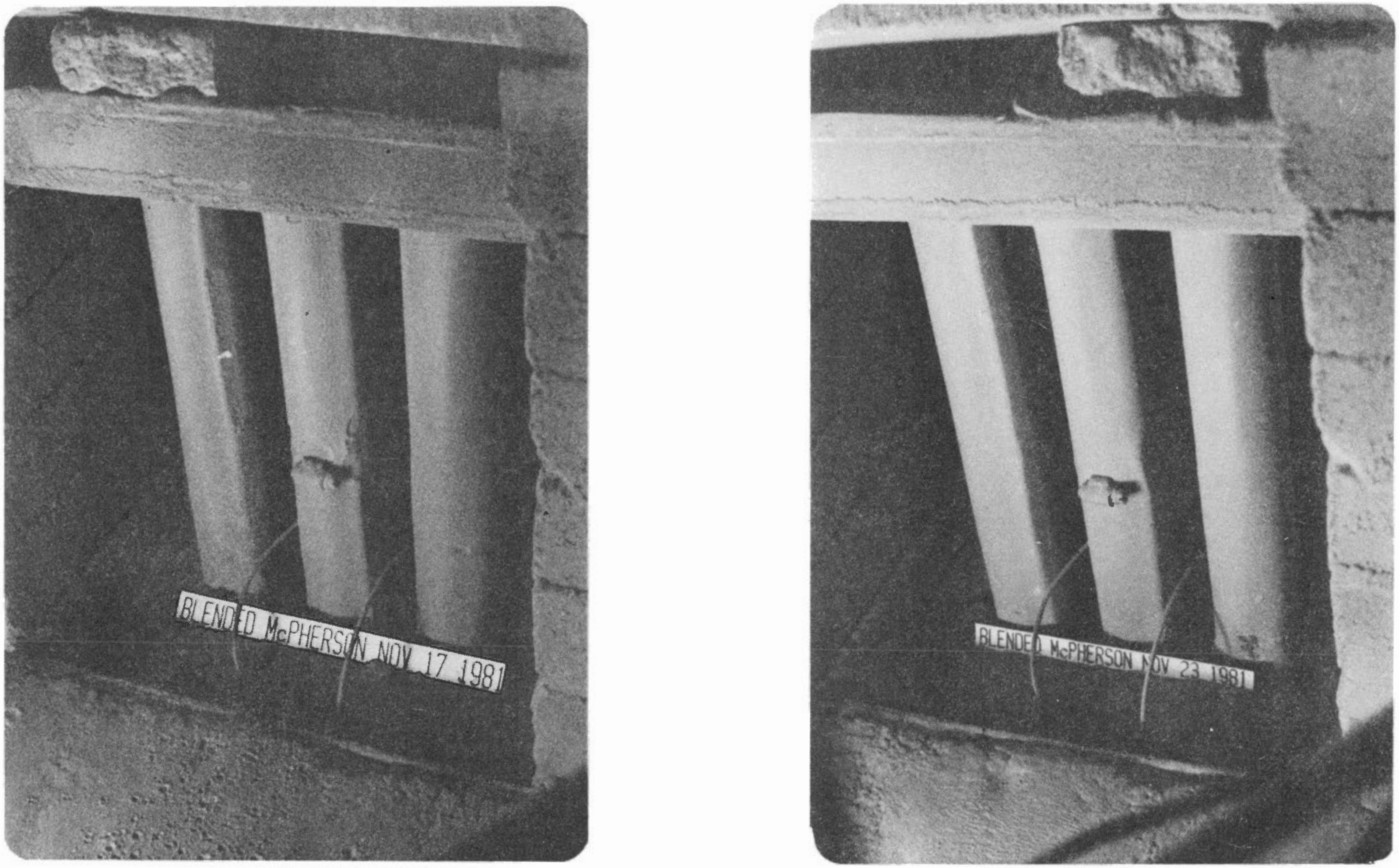
Fig. 4 - Photographs of furnace bottom deposits



Trial 1

Trial 2

Fig. 5 - Deposits in furnace bottoms



Trial 1

Trial 2

Fig. 6 - Deposits on superheater tubes

APPENDIX A

MINERAL ANALYSIS
OF
McLEOD RIVER COAL

COMPANY *Energy, Mines & Resources Canada* *FILE 70CL-82-9*

Introduction

Eight (8) samples of coal were submitted by CANMET, Energy Research Labs., for mineral content determination by X-Ray Diffraction.

Sample Treatment

X-Ray Diffraction Analysis: *A sample representing the interval indicated is disaggregated and subjected to a five step analysis: bulk (greater than 5 microns), clay size fraction (less than 5 microns), at room humidity, clay size fraction glycolated, clay size fraction heat treated and, where necessary, clay size fraction acidized. The clay fraction is prepared by dispersion in sodium hexametaphosphate solution and flocculation in magnesium chloride solution. This also stabilizes the ionic state of some clays. The glycolation treatment is used to identify swelling clays such as smectites and vermiculites. These clays expand on glycolation to different degrees when the available cation sites are magnesium saturated. The heat treatment aids in identification of chlorite type and also differentiates between some chlorites and kaolinite. Where further identification of clay type in a chlorite-kaolinite mix is necessary, the sample is treated with warm dilute hydrochloric acid, which decomposes the chlorite.*

COMPANY	Energy, Mines & Resources Canada	PAGE	2 of 8
WELL		FILE	7062-82-[illegible]
LOCATION		DATE	82 03 02
FIELD			

Sample Number: A 709 McPherson Blend

CLAY SEPARATION BY FLOTATION

Material Less than 5 Microns	22.3 %
Material Greater than 5 Microns	77.7 %

X-RAY DIFFRACTION ANALYSIS

	Material Less than 5 Microns	Material Greater than 5 Microns	Calculated Bulk Composition
Quartz	27	63	56
Feldspar	trace	17	13
Calcite	nil	nil	nil
Dolomite	nil	nil	nil
Siderite	nil	trace	trace
Pyrite	nil	nil	nil
Kaolinite	23	20	20
Illite	20	nil	5
Chlorite	trace	nil	trace
Smectite	30	nil	7
Mixed Layer Clays (Swelling)	present	nil	present
Clay Minerals	NA	NA	NA

APPENDIX B

McLEOD RIVER COAL COMBUSTION CHARTS

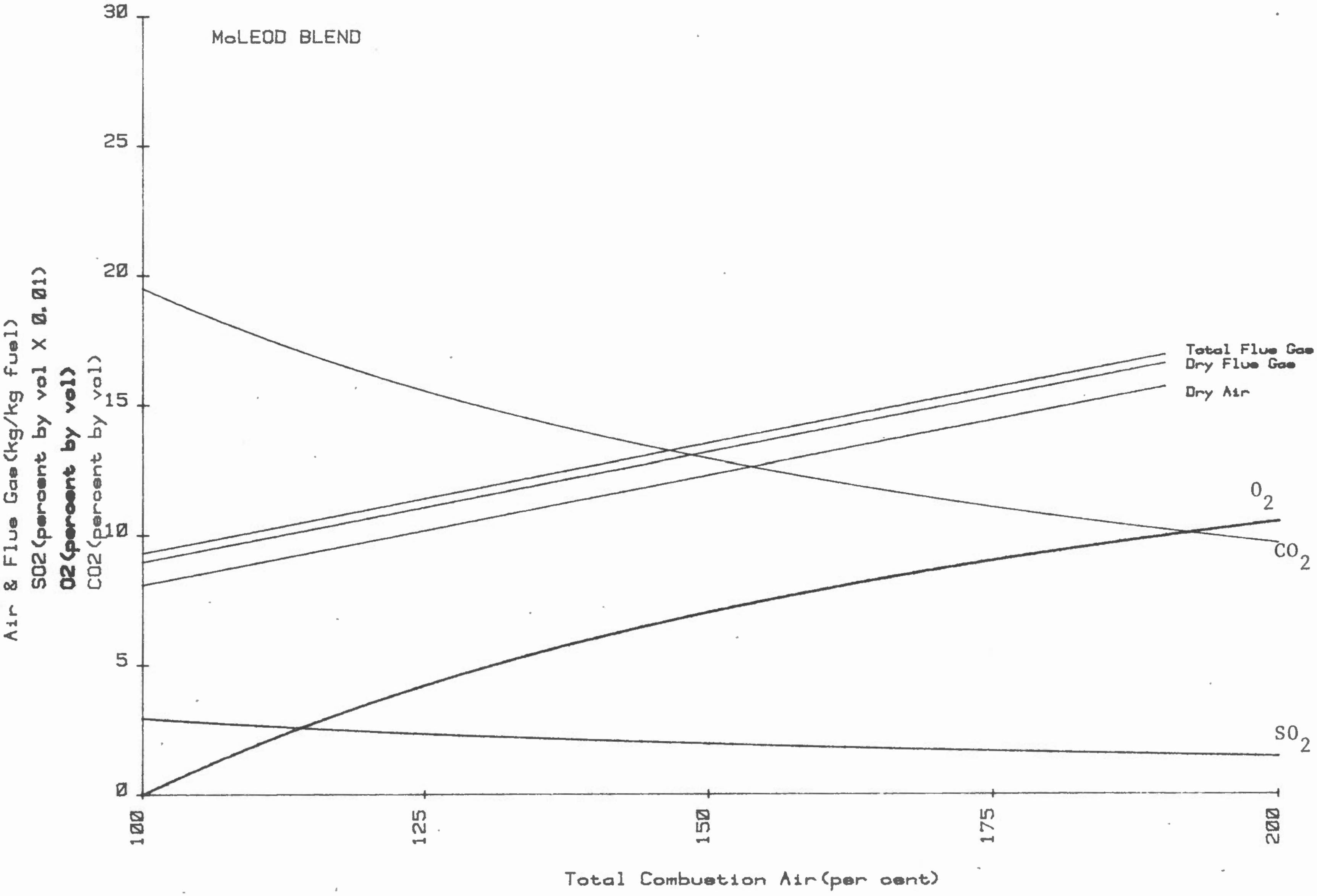


Fig. 1A - Combustion data, eight basis

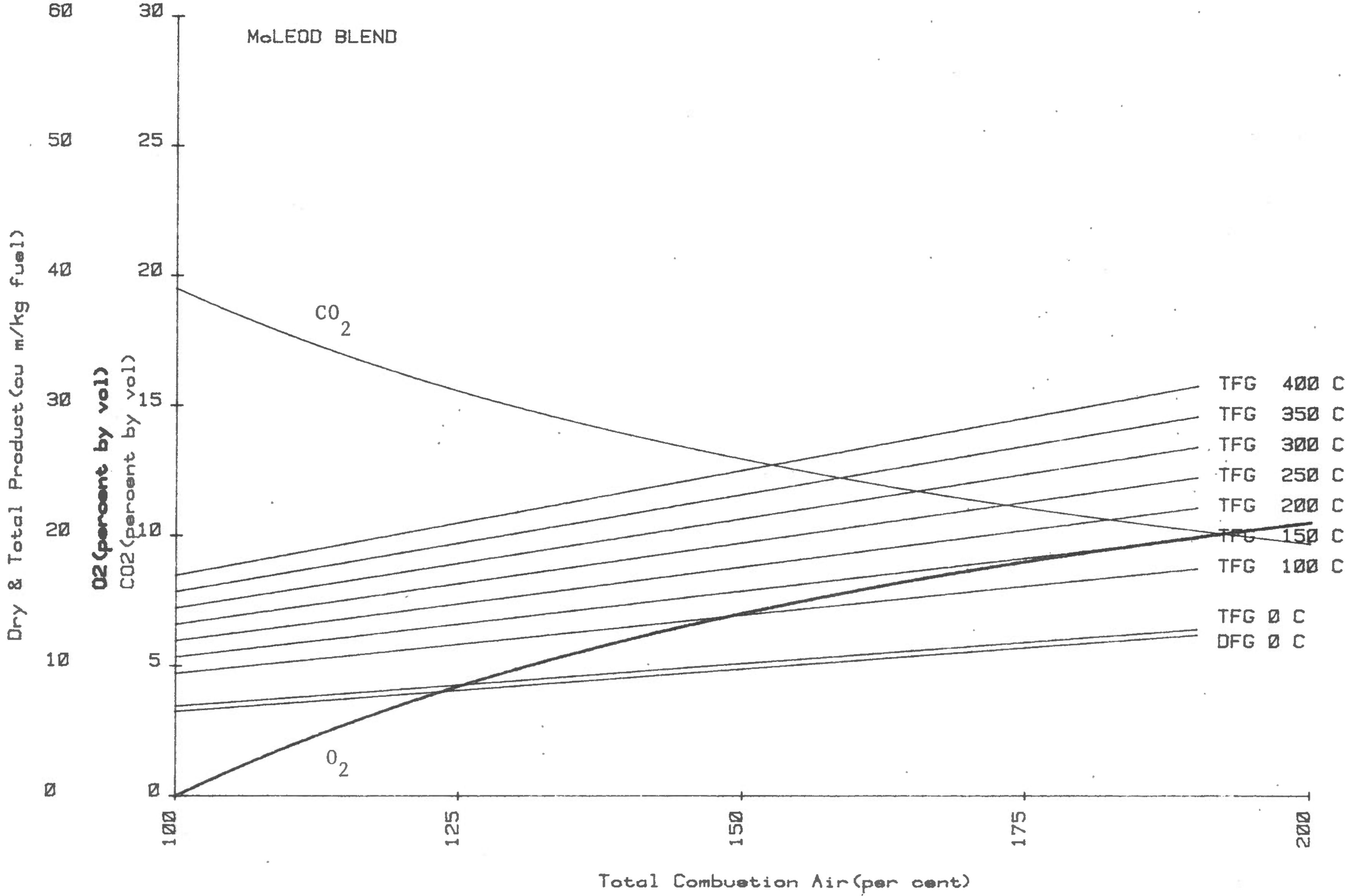


Fig. 2A - Combustion data, volume basis

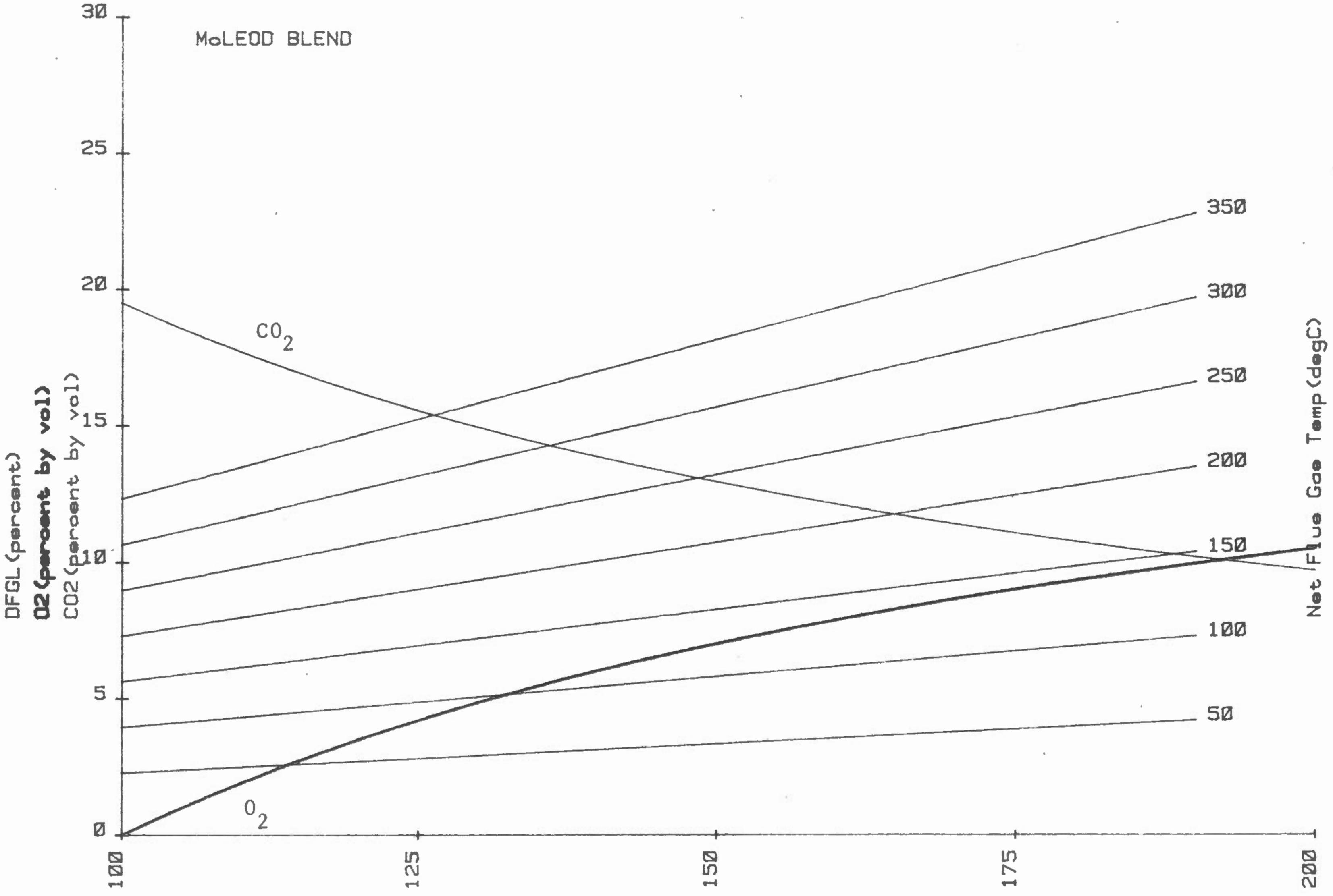


Fig. 3A - Dry flue gas loss for a range of temperature differentials

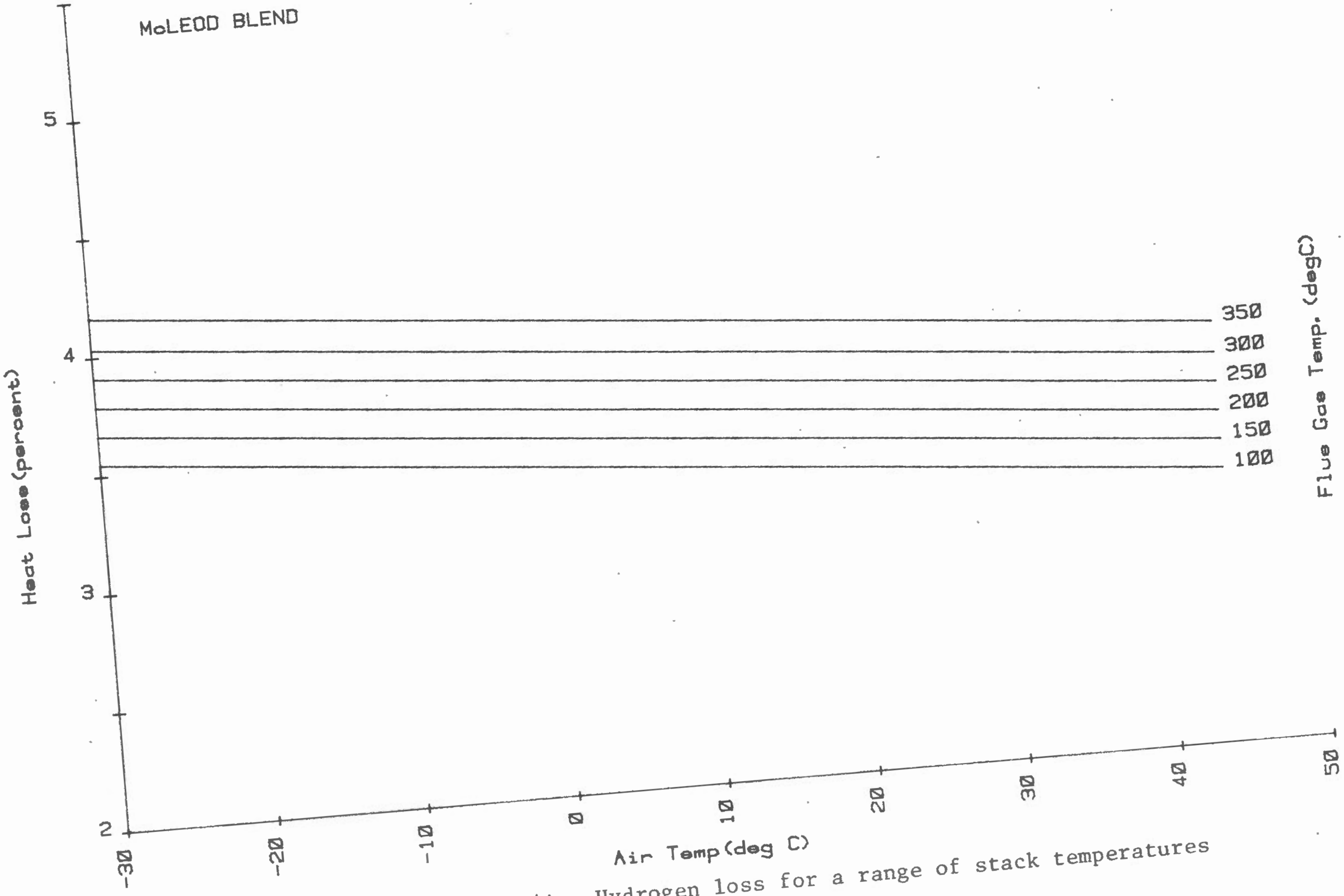


Fig. 4A - Hydrogen loss for a range of stack temperatures

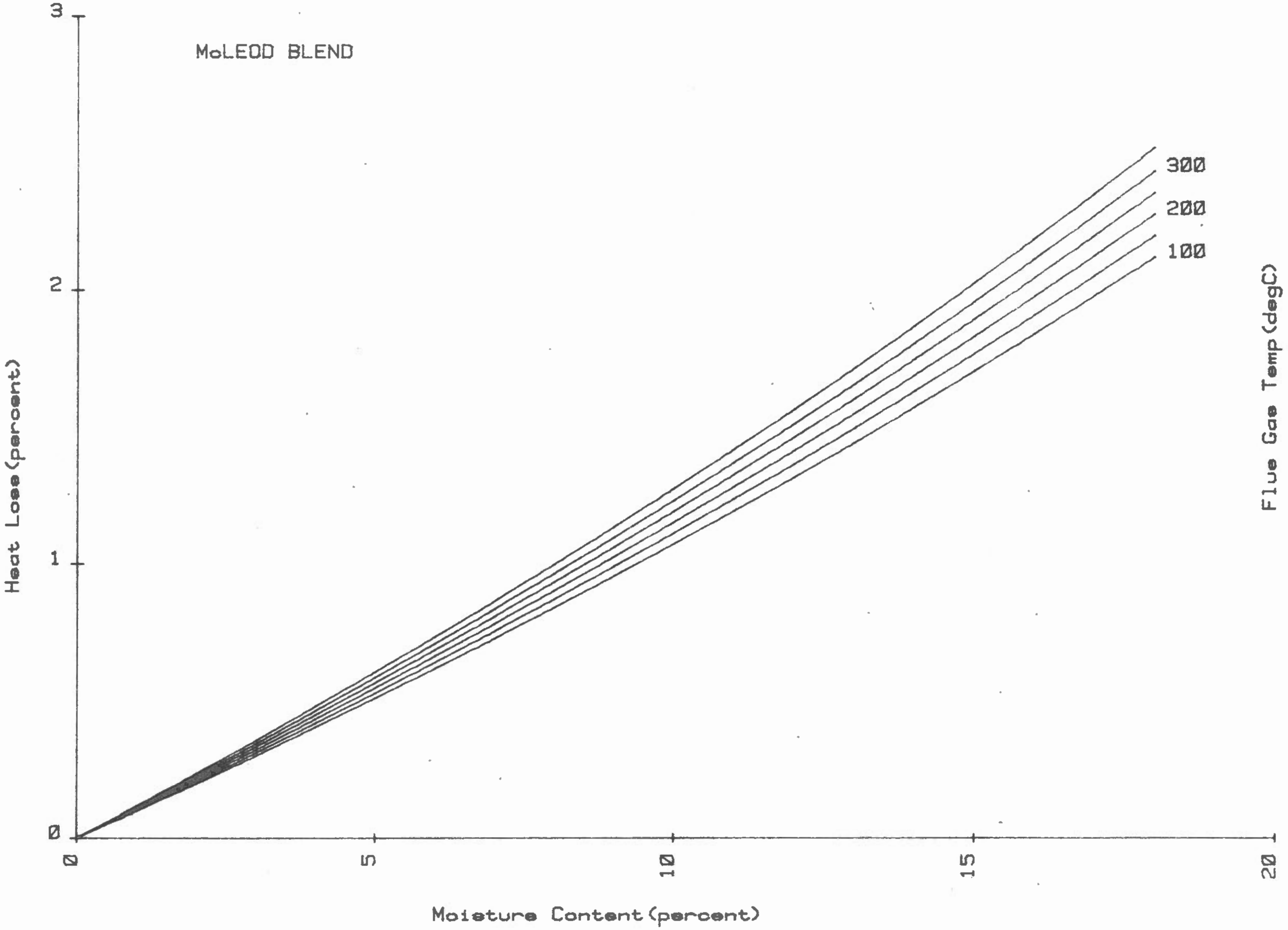


Fig. 5A - Heat loss due to moisture in coal at 20^{o}C.

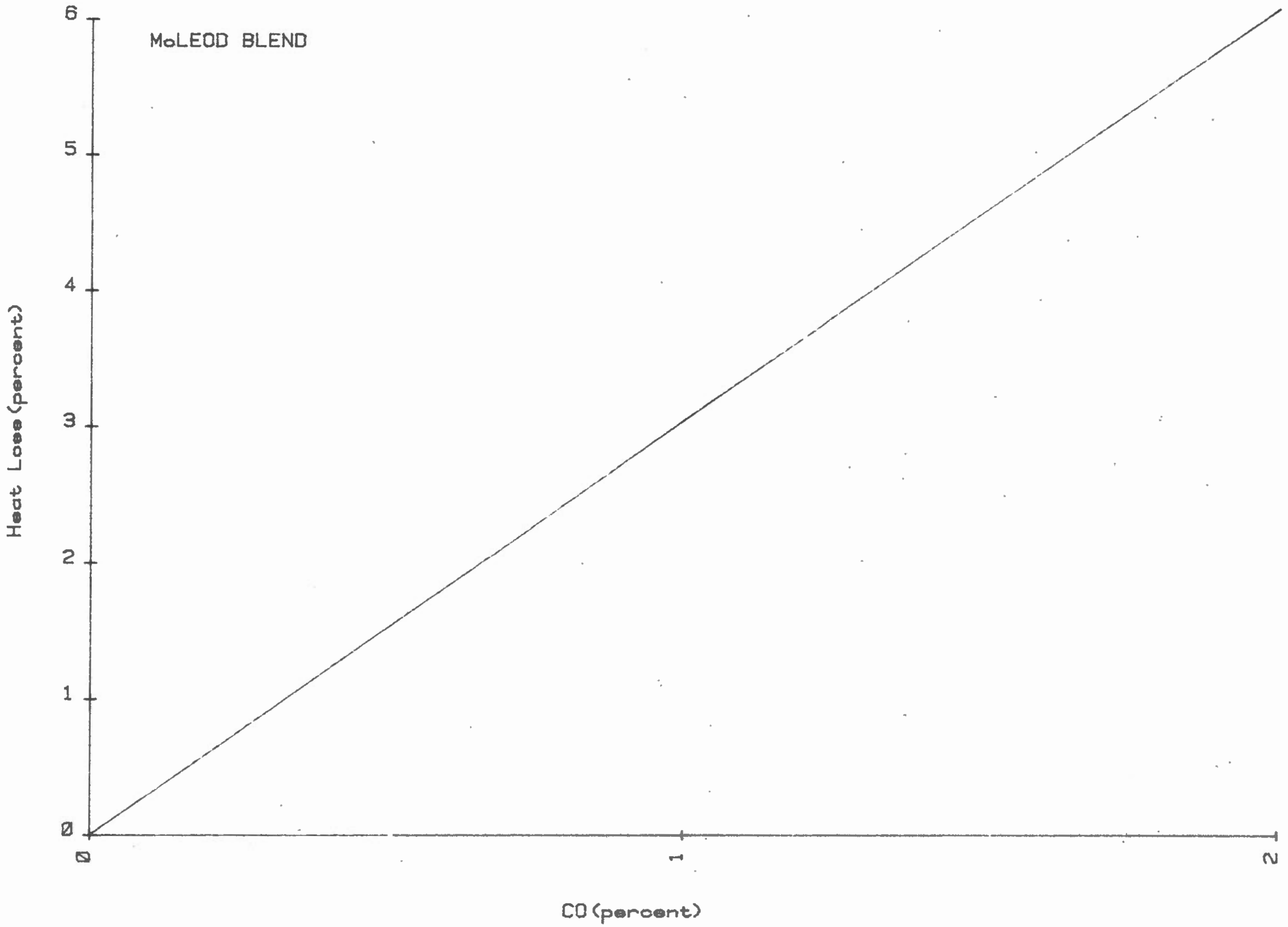


Fig. 6A - Heat loss for a range of CO concentration, assuming neglible excess air.

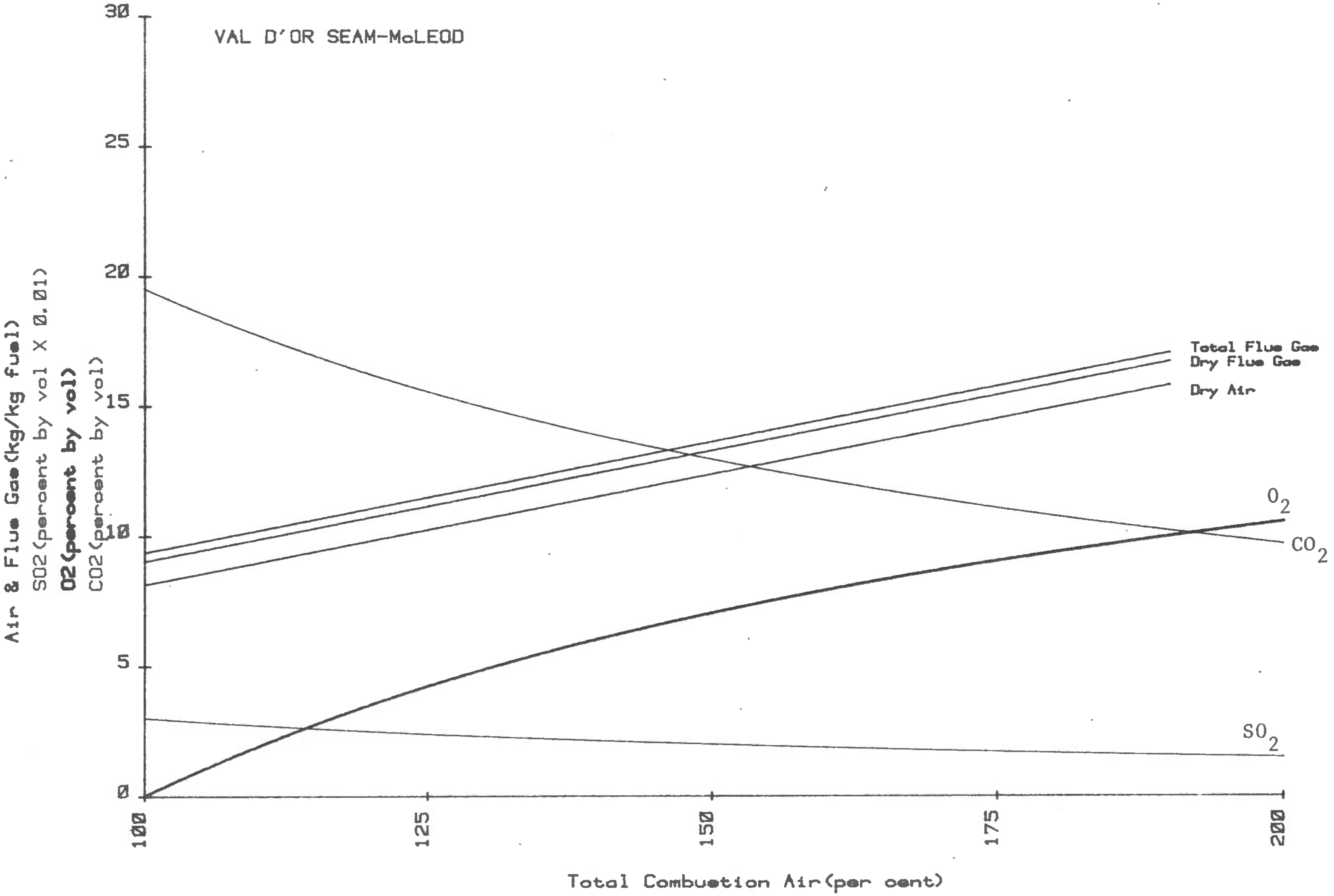


Fig. 7A - Combustion data, weight basis

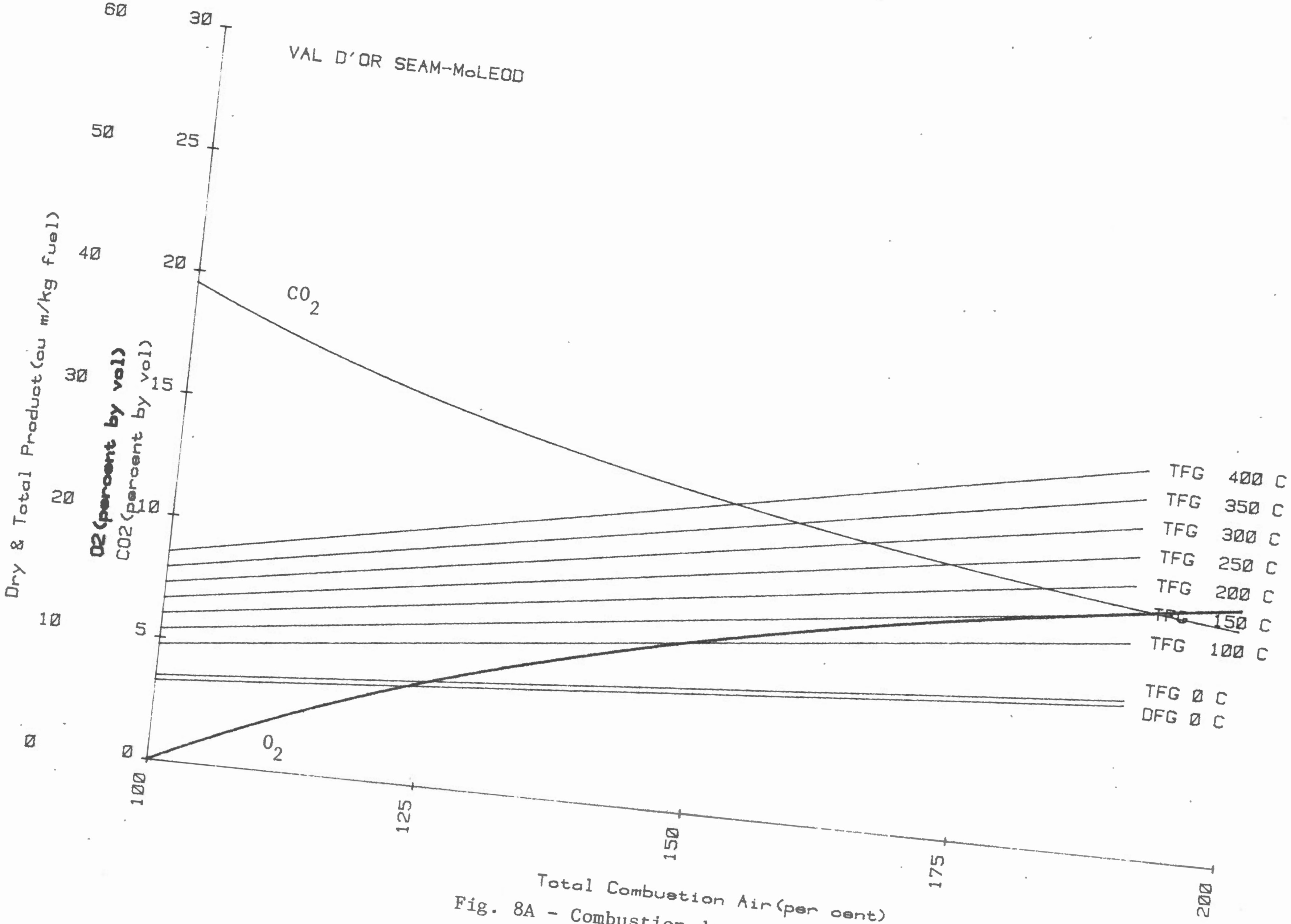


Fig. 8A - Combustion data, volume basis

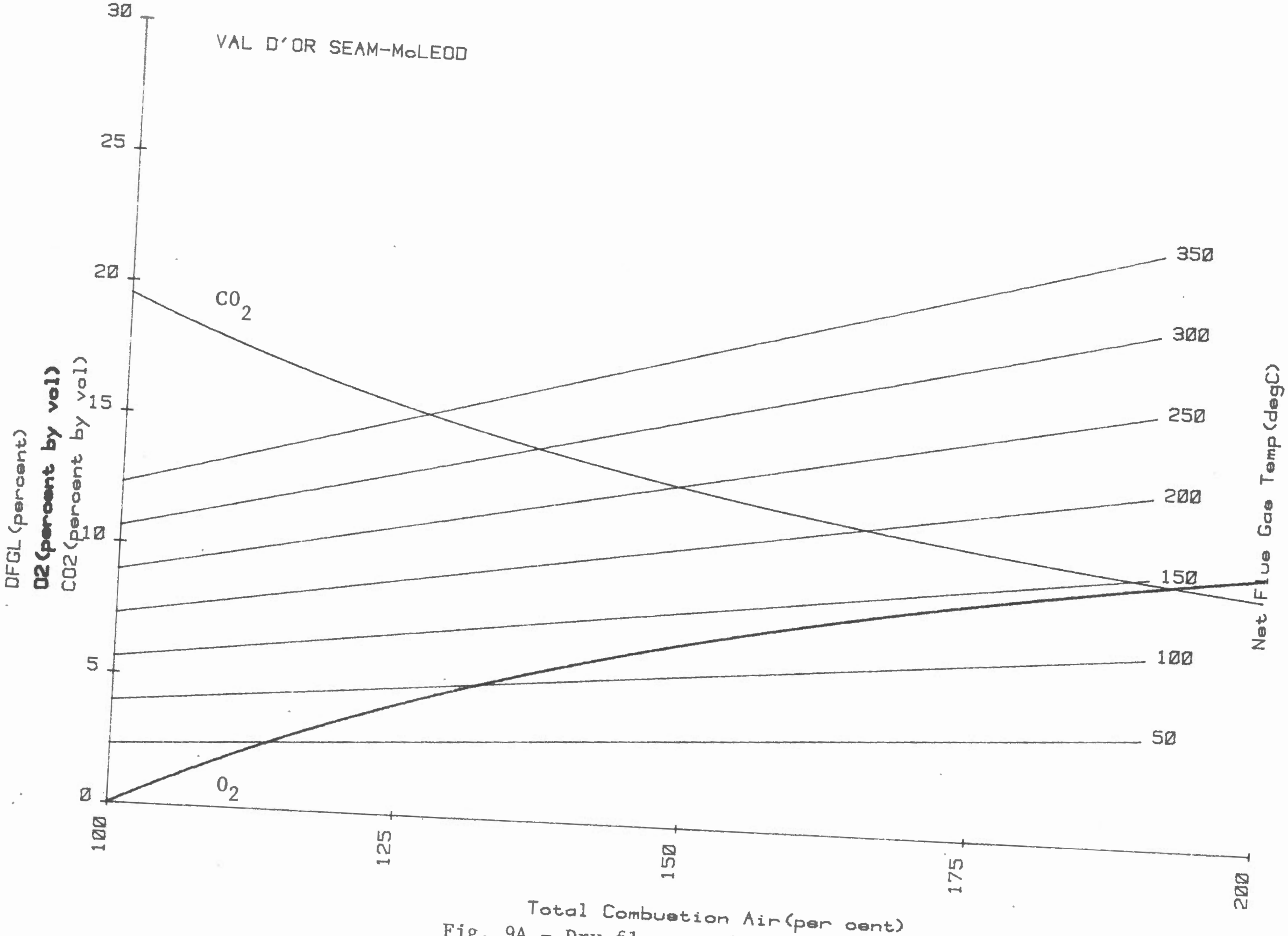


Fig. 9A - Dry flue gas loss for a range of temperature differentials.

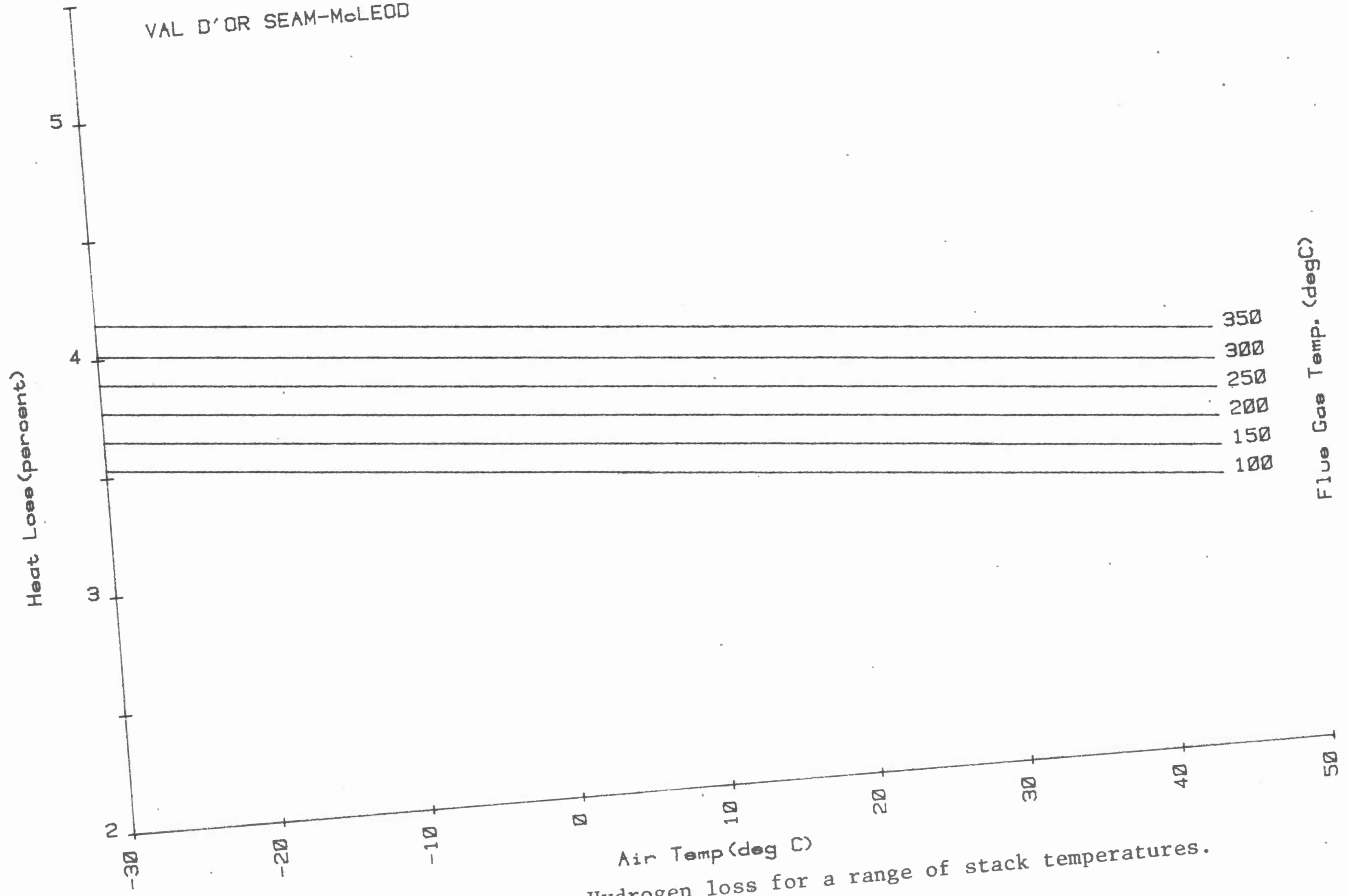


Fig. 11A - Hydrogen loss for a range of stack temperatures.

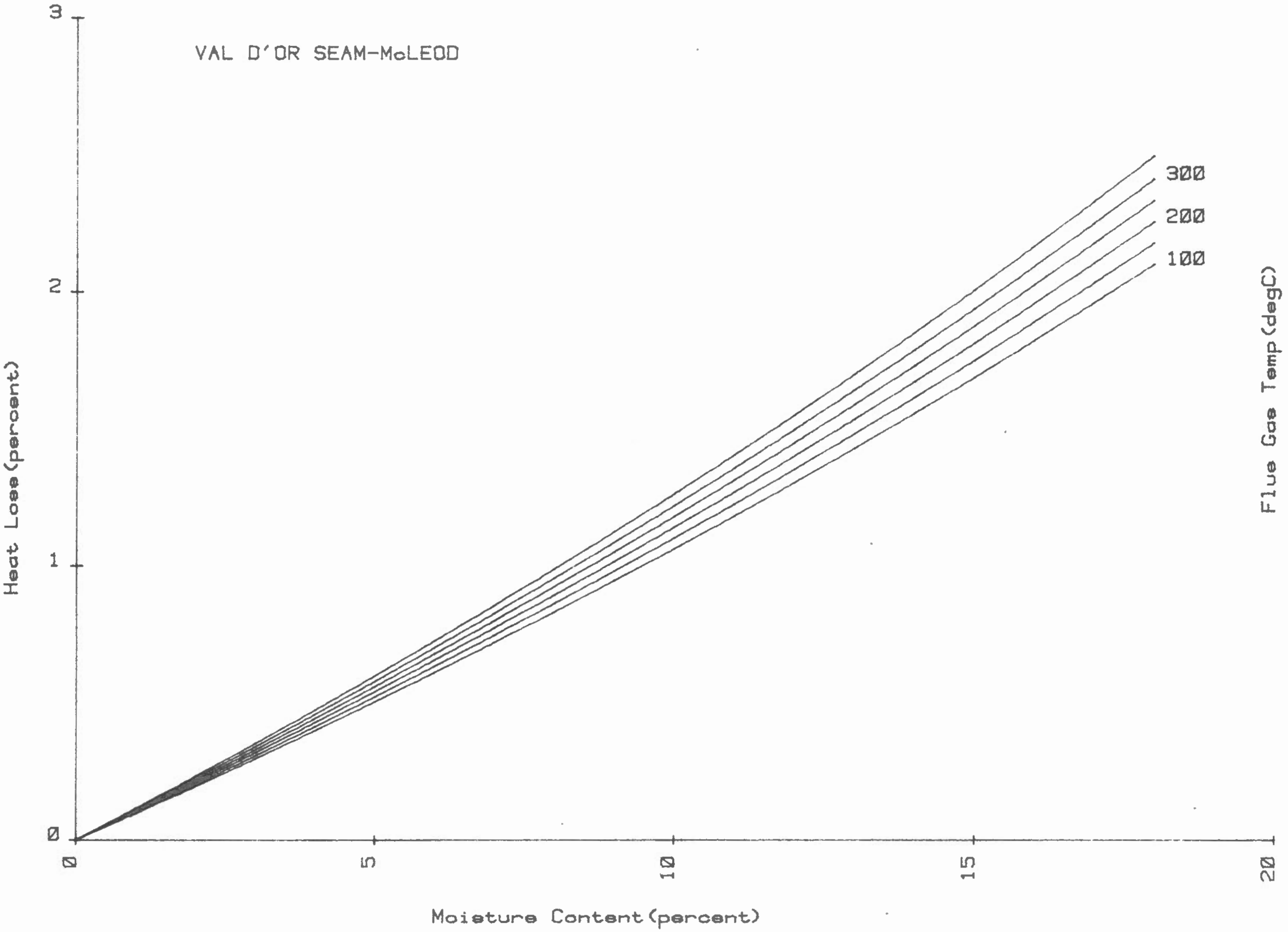


Fig. 12A - Heat loss due to moisture in coal at 20°C.

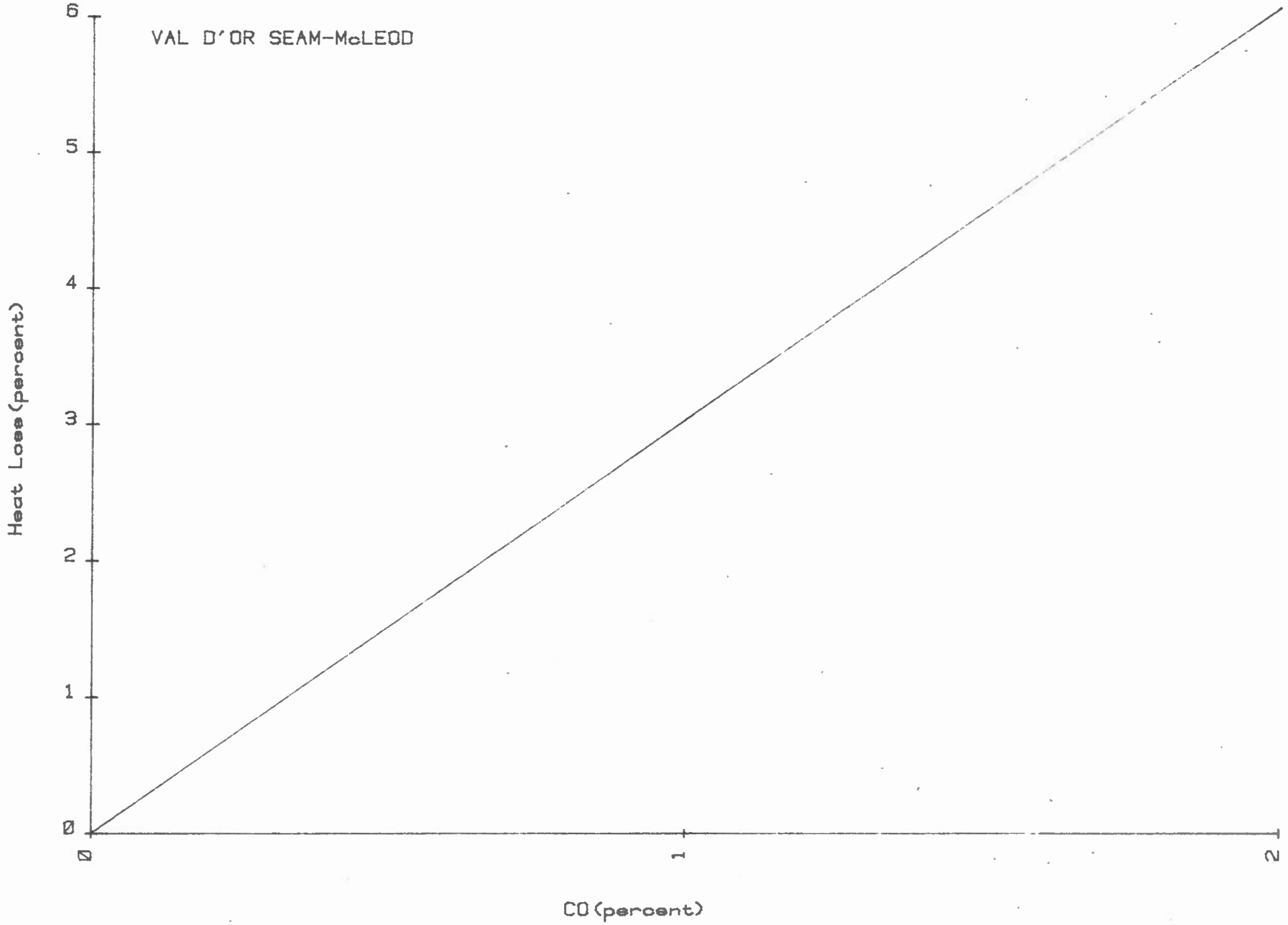


Fig. 13A - Heat loss for a range of CO concentrations, assuming neglible excess air.

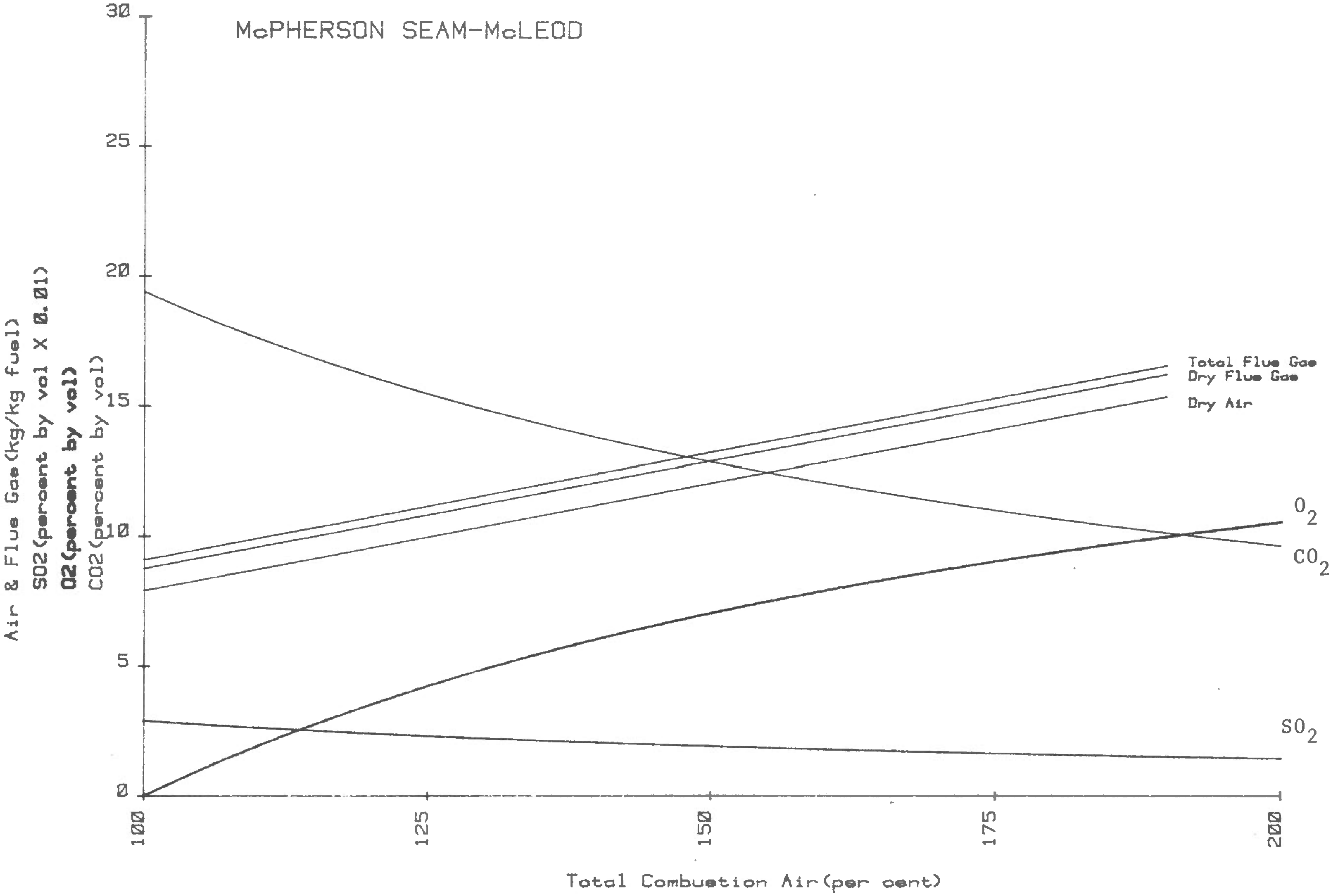


Fig. 13A - Combustion data, weight basis

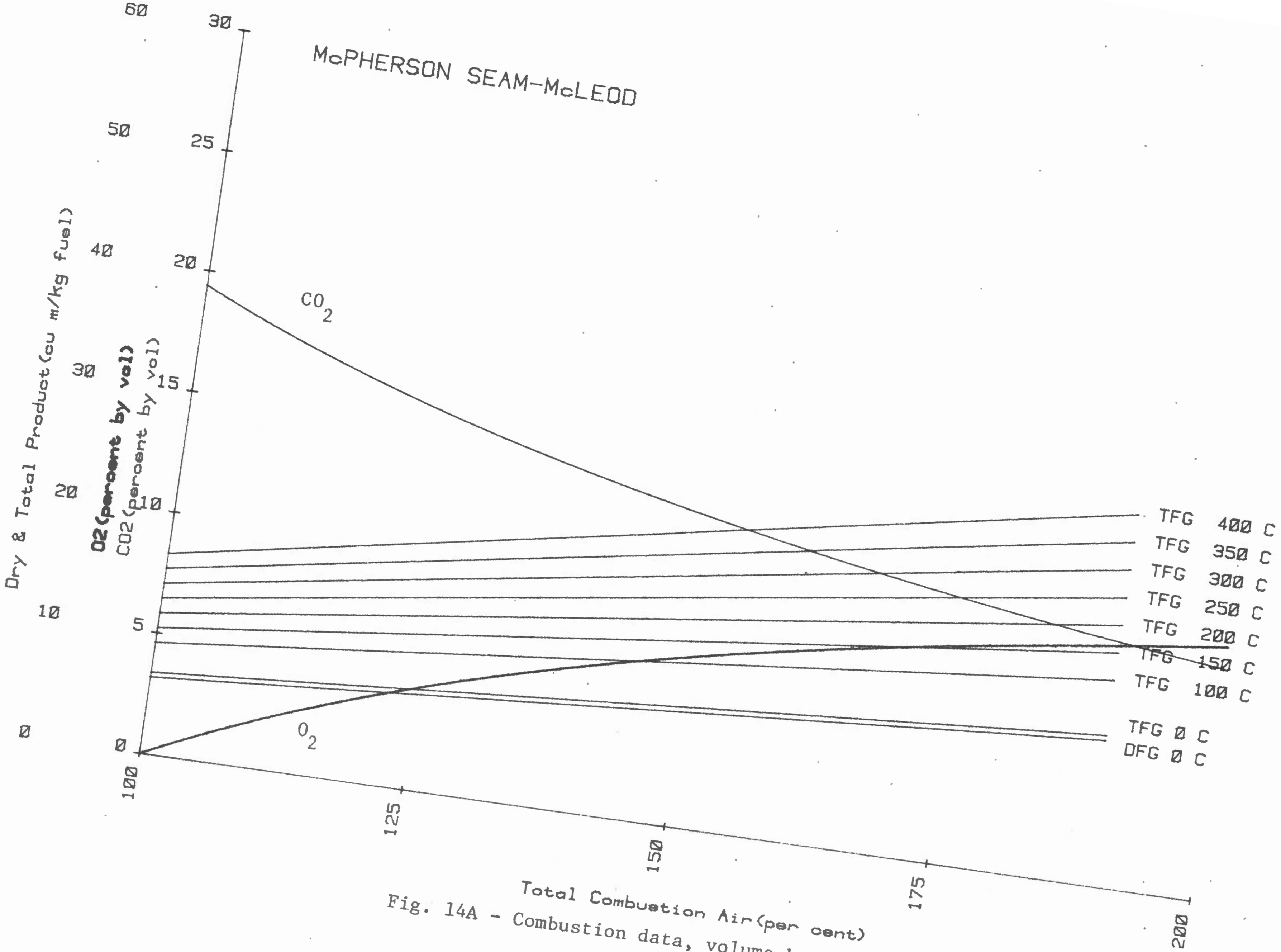


Fig. 14A - Combustion data, volume basis

Fig. 15A - Dry flue gas loss for a range of temperature differentials

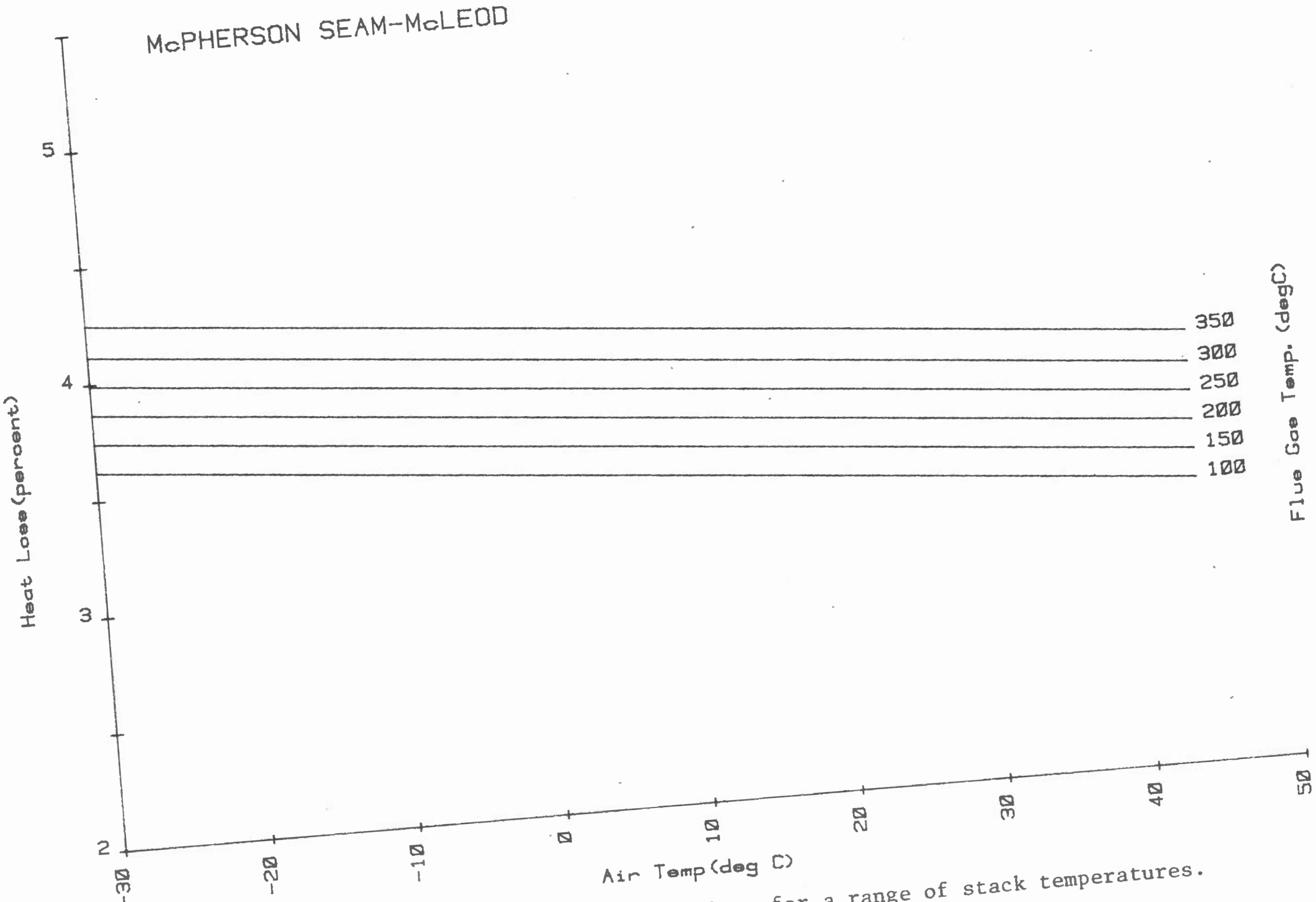


Fig. 16A - Hydrogen loss for a range of stack temperatures.

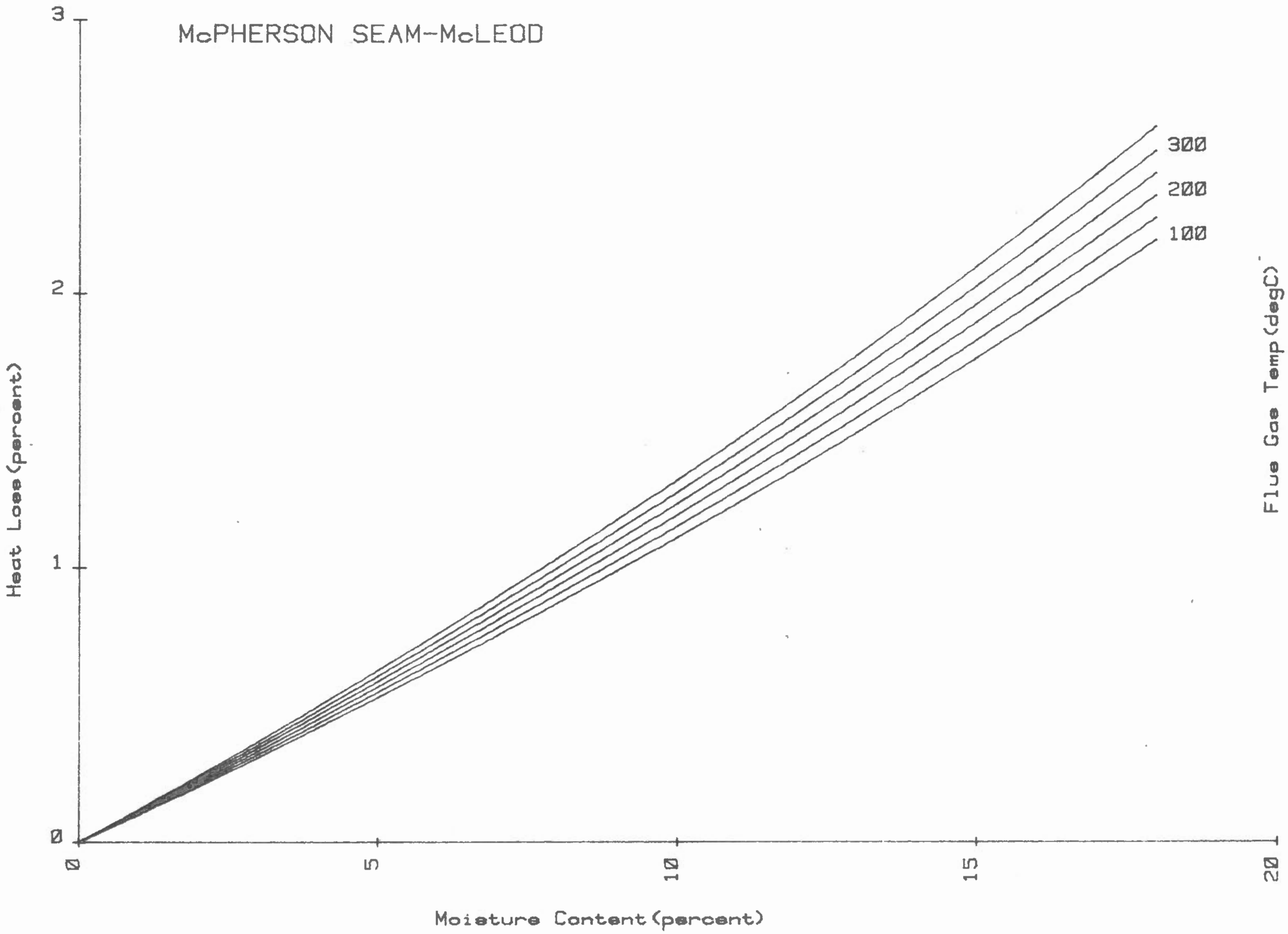


Fig. 17A - Heat loss due to moisture in coal at 20°C.

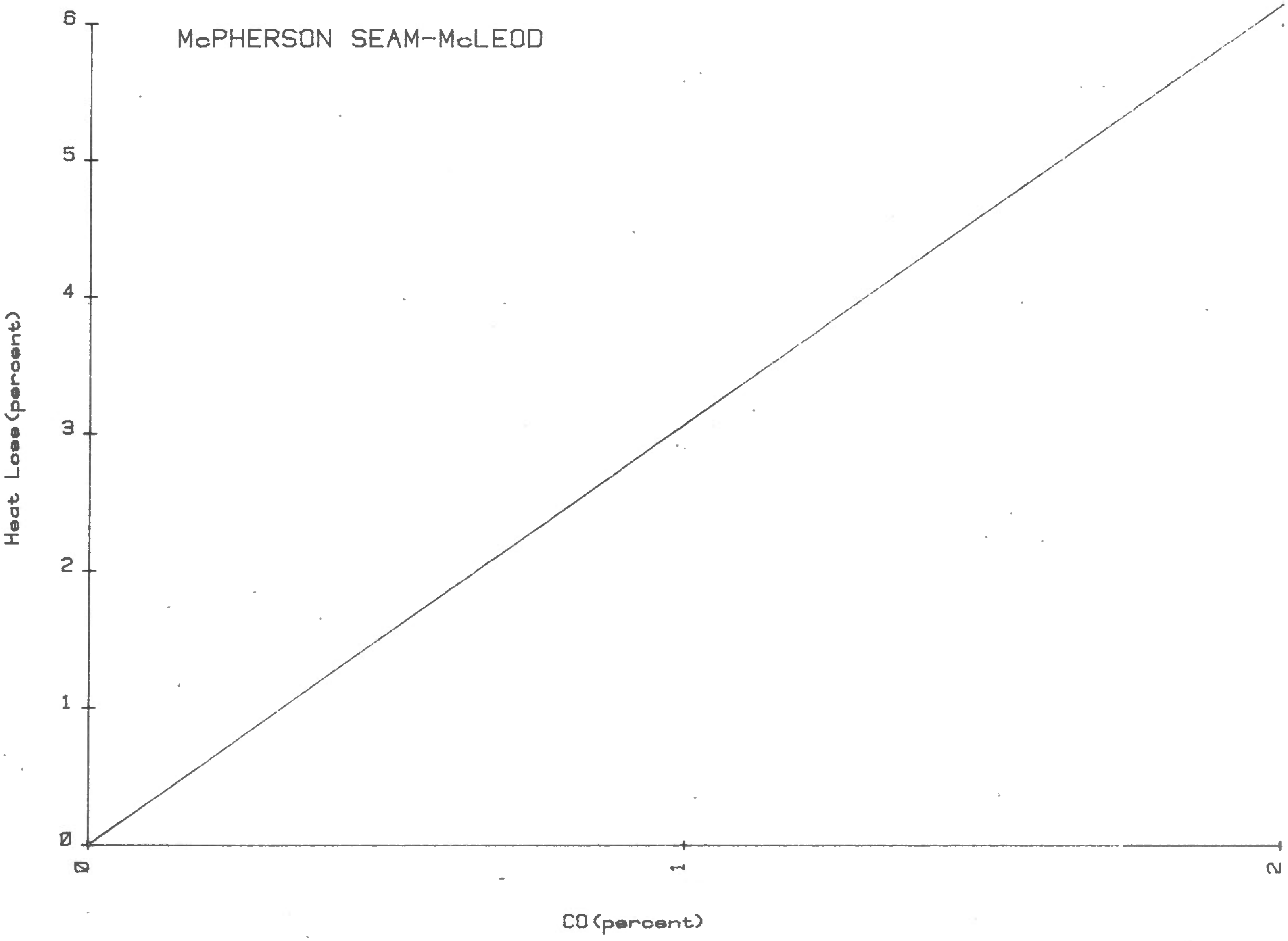


Fig. 18A - Heat loss for a range of CO concentration, assuming neglible excess air.