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COMBUSTION AND
FOULING CHARACTERISTICS
OF TWO CANADIAN LIGNITES

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Combustion and Fouling Characteristics of Two Canadian Lignites

The report describes combustion tests with Bienfait lignite from Saskatchewan and Onakawana lignite from James Bay. They were burned in a pilot-scale, pulverized-fired boiler primarily to study combustion performance and fireside fouling tendencies under slag-tap conditions. Flame stability and complete combustion were readily obtained, although satisfactory slag tapping was not achieved with either fuel. Fireside ash deposit samples, representing each fuel, were collected from various parts of the boiler and subjected to exhaustive analyses. The results indicate that, when burning Bienfait lignite, selective deposition of ash constituents takes place, resulting in a eutectic composition downstream of the furnace exit. In the case of Onakawana lignite, selective ash deposition did not occur. Deposit analyses, fusion temperatures, and enrichment ratios are given for both fuels.

Introduction

SASKATCHEWAN lignite, being an important Canadian energy resource, has been studied extensively by the Canadian Combustion Research Laboratory (CCRL), and in recent years research has been carried out on a pilot-scale, pulverized-fired steam boiler to study its combustion performance, air pollution emission, low-temperature corrosion potential, and fireside fouling tendencies under slag-tap conditions. Concurrently, similar research was carried out on Onakawana lignite from an undeveloped mine in the James Bay area.

The present report summarizes the results of combustion performance and fireside fouling for both fuels. Although of the same rank, these two lignites differ substantially in physical structure and, more important, in their fouling characteristics. Extensive analysis of fly-ash samples obtained progressively through the boiler system indicate that this may be due to selective deposition of certain ash constituents, leading to enrichment of others.

Pilot-Scale Research Boiler

The combustion research boiler, illustrated schematically in Fig. 1, is a pilot-scale, pulverized-coal-fired boiler that incorporates two opposed burners which tilt downward over a refractory slag chamber. The furnace is of membrane-wall construction and operates at a pressure of about 5 in. WG. The boiler generates 1600 lb/hr steam at 100 psig which is dissipated in an air condenser.

Crushed coal is supplied from a 5-ton hopper 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 450 deg F. If necessary, the pulverizer can be also swept and pressurized with a mixture of air and flue gas at any temperature up to 900 deg F. The pulverizer contains a motor-driven classifier for controlling coal fineness, and a simple splitter at the pulverizer outlet proportions the coal flow to each burner. Secondary air
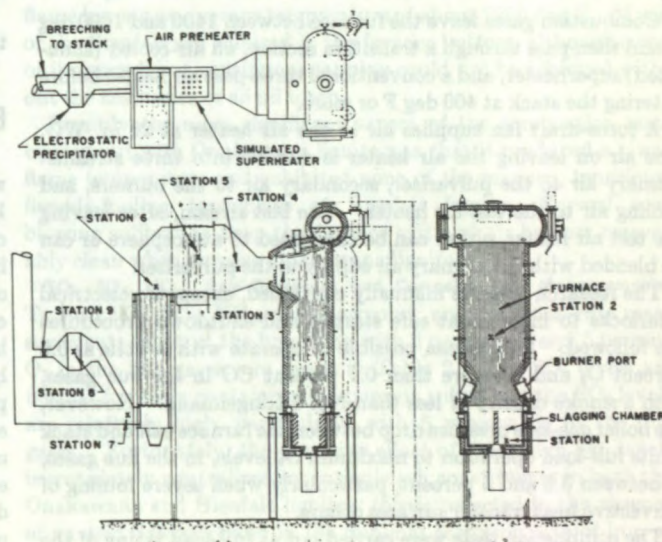

Fig. 1 Pilot-scale research boiler showing location of sampling stations
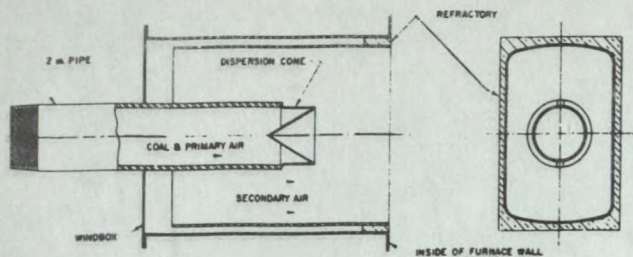
Fig. 2 Diagram of coal burner used during tests

Table 1 Lignite analytical data

Lignite	Onakawana		Bienfait	
	As Rec'd	As Fired	As Rec'd	As Fired
Proximate Analysis, %				
Moisture	48.13	26.67	35.85	20.91
Ash	6.78	16.50	6.24	8.79
Volatile Matter	21.44	26.60	27.11	32.52
Fixed Carbon (by diff)	23.65	30.23	30.80	37.78
Ultimate Analysis, %				
Carbon	33.26	42.48	43.45	51.35
Hydrogen	2.04	2.69	2.75	3.44
Sulphur	0.41	0.72	0.44	0.58
Nitrogen	0.55	0.72	0.73	1.01
Ash	6.78	16.50	6.24	8.79
Oxygen (by diff)	8.83	10.22	10.54	13.92
Equilibrium Moisture	35.17			
Gross Calorific Value, Btu/lb	5,340	6,790	7,110	8,440
Bulk Density (moisture-free basis),lb/cu ft	25		35	
Hardgrove Grindability Index	66 - 82		56	
Ash Fusibility, °F	Reducing	Oxidizing	Reducing	Oxidizing
Initial	1900	2020	1870	1910
Spherical Softening	1930	2100	2050	2260
Hemispherical Softening	2000	2110	2110	2280
Fluid	2100	2210	2150	2300
Ash Analysis, %				
SiO_2	48.85		26.57	
Al_2O_3	14.38		15.77	
Fe_2O_3	7.13		6.43	
TiO_2	0.97		0.58	
P_2O_5	0.30		0.74	
CaO	14.01		22.54	
MgO	3.82		4.13	
SO_3	10.22		14.13	
Na_2O	0.97		6.78	
K_2O	0.81		0.37	

can be supplied to the burners at any temperature up to 500 deg F.

Combustion gases leave the furnace between 1400 and 1600 deg F and then pass through a transition section, an air-cooled (simulated) superheater, and a conventional three-pass air heater before entering the stack at 400 deg F or more.

A force-draft fan supplies air to the air heater at 26 in. WG. The air on leaving the air heater is divided into three streams: 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, either can be exhausted to atmosphere or can be blended with the primary air supply to the pulverizer.

The research boiler is manually controlled, except for electrical interlocks to insure that safe startup and shutdown procedures are followed. It has been possible to operate with as little as 0.6 percent O_2 and no more than 0.1 percent CO in the flue gases, with a smoke density of less than No. 1 Ringelmann. However, the boiler gas-side pressure drop between the furnace exit and stack limits full-load operation to maximum O_2 levels, in the flue gases, of between 3.5 and 5 percent, particularly when severe fouling of convective heat transfer surfaces occurs.

The combustion tests were carried out at full-load rating of the research boiler, i.e., 2.5 million Btu/hr input, or a volumetric

Fig. 3 As-received sample of Onakawana

heat-release rate of 75,000 Btu/cu ft/hr, using two opposed inshot burners shown schematically in Fig. 2. Measurements of air pollutants, corrosion potential, and fireside deposits were carried out at excess-oxygen levels of 3 and 5 percent.

Test Measurements

The following are the principal parameters that were measured during the combustion performance tests with both Onakawana and Bienfait lignite. The stations at which the measurements were taken are designated by numbers as shown in Fig. 1.

1 Fuel and ash analyses, pulverizer inlet.
2 Fineness of coal grind, pulverizer outlet.
3 Flame temperature and length of flame; Station 2.
4 CO_2, CO, and O_2 by continuous monitor; Station 4.
5 Acid dewpoint by BCURA dewpoint meter; Station 7.
6 SO_3 by Shell-Thornton condensation method; Stations 2 and 7.
7 SO_2 by API Method 774-54; Stations 2 and 7.
8 NO_x by USBM Method 6970; Stations 2 and 7.
9 Rate of iron wastage by corrosion probe at 220 deg F; Station 7.
10 Particulate matter in flue gases by a combined cyclone-filter arrangement; Stations 4 and 7.
11 Particle-size distribution of fly ash; Stations 4, 7, and 8.
12 Chemical analysis, ash fusion determinations, X-ray diffraction and petrographic examinations of combustion residues; Stations 1, 3, 4, 5, and 6.
13 Efficiency of fly-ash collection by electrostatic precipitation; Stations 7 and 9.

Experimental Data

Combustion Performance. The analytical data for the Onakawana and Bienfait lignites, which were tested, are given in Table 1. In the as-received state, the Onakawana lignite resembled charred wood, as shown in Fig. 3. It was found to have an equilibrium moisture of about 37 percent and a total moisture content of about 48 percent. A preliminary trial showed that while the coal in this condition could be burned, passing it through the hammer-mill crusher was difficult. The crushed coal frequently hung up in the chute to the pulverizer, and even though the pulverizer was swept with air at about 500 deg F, the high moisture content delayed ignition to such an extent that the furnace and most of the test air heater were filled with a blue flame. However, after this experience the rest of the six-ton sample was air-dried to about 27 percent moisture, whereupon it crushed and pulverized readily, and burned more or less completely in the furnace. Drying the coal from 48 percent moisture to 27 percent

Table 2 Typical SO$_2$, SO$_3$, NO$_x$, acid-dewpoint and corrosion-rate measurements in flue gases from Onakawana and Bienfait lignite

Lignite	O$_2$ % vol	SO$_2$ ppm vol	SO$_3$ ppm vol	NO$_x$ ppm vol	Acid Dewpoint, °F	Corrosion Rate, μg Fe/sq cm/1/2 hr
Onakawana	3	411	17.9	414	Nil	0.05
	5	406	26.7	414	Nil	0.12
Bienfait	3	518	15.0	672	Nil	0.61
	5	157	26.0	743	Nil	0.21

Table 3 Chemical analyses of fly ash extracted from flue gases*

Lignite	Onakawana				Bienfait			
Sample Location	4		7		4		7	
Ash Composition, %	Water Extract	Residue	Water Extract	Residue	Water Extract	Residue	Water Extract	Residue
SiO$_2$ $\}$		60.7		63.9		3.1		4.3
Al$_2$O$_3$								
Fe$_2$O$_3$	0.1	11.3	0.1	9.7	0.1	15.9	0.4	0.9
CaO	0.2	4.1	0.5	3.4	0.1	3.9	2.0	4.8
SO$_3$	3.8		4.1		21.6		9.8	
Na$_2$O	0.2	0.8	0.2	0.9	3.4	1.6	3.6	1.2
K$_2$O	0.1	0.4	0.1	0.8	0.1	0.5	0.5	0.5
Solubility	3.2		6.8		33.1		18.2	
Loss on Ignition		12.0		8.7		25.2		12.5

*Data for 3% O$_2$ in flue gases.

Table 4 Collection efficiency of lignite fly ash in a small-scale electrostatic precipitator

Lignite	O$_2$ vol	Average Fly Ash Concentration in Flue Gases, gr/SCF			Electrostatic Precipitator Collection Efficiency, %
		Station 4 (Transition Section)	Station 7 (Precipitator Inlet)	Station 9 (Precipitator Outlet)	
Onakawana	3	8.62	6.04	0.03	99.5
Bienfait	3	0.60	0.48	0.01	98.0

Table 5 Physiochemical properties of fireside deposits

Lignite	Onakawana					Bienfait					
Sample Location	1	3	4	5 and 6	6	1	3	4	5(a)	5(b)	6	8
Ash Composition												
SiO$_2$	36.8	49.8	52.8	No Ash	57.3	29.5	27.8	32.7	29.0	32.0	22.4	38.8
Al$_2$O$_3$	16.4	15.6	13.8	Build-up	18.0	18.2	18.7	17.7	17.8	18.3	18.1	15.2
Fe$_2$O$_3$	10.9	6.9	7.9		10.2	14.0	6.9	7.7	8.9	8.1	5.7	5.3
TiO$_2$	0.8	1.1	1.0		1.1	0.7	0.6	0.6	0.6	0.7	0.5	0.8
P$_2$O$_5$	0.3	0.3	0.3		0.6	0.6	0.9	0.7	1.0	0.8	0.9	0.7
CaO	11.8	16.2	13.9		17.9	13.3	17.7	21.8	22.7	23.2	22.0	17.3
MgO	3.3	4.4	3.8		5.0	3.7	5.2	4.1	5.1	4.9	7.1	4.0
SO$_3$	-	3.7	4.1		7.2	0.1	6.9	9.3	10.2	8.3	15.6	15.0
Na$_2$O	0.9	0.9	0.8		1.3	3.2	6.0	4.8	6.3	6.0	7.6	11.0
K$_2$O	0.6	0.7	0.7		1.0	0.3	-	-	-	-	-	0.6
Combustible	-	0.2	0.5		9.8	-	0.9	0.2	0.1	-	0.1	4.3
Ash Fusion Temperature, °F												
Reducing Atmosphere												
Initial	1890	2000	2000	"	2000	1900	1970	1830	1990	1980	1880	1870
Hemispherical softening	2220	3080	2070		2080	2010	2200	2060	2100	2090	3040	1980
Fluid	2380	3170	2270		2270	2360	2250	2110	3130	2110	2220	2060
Oxidising Atmosphere												
Initial	1950	2050	3050	"	2050	3050	2120	1970	3040	2090	2170	2010
Hemispherical softening	2270	2130	2140		2130	3080	2220	2070	3130	2170	2270	2130
Fluid	2460	2360	2330		2360	3480	2290	2110	3160	2200	2210	2170
Particle-size Distribution, %wt												
+ 74μ	Glassy	28.0	27.7	No Ash	6.9	Glassy	89.4	30.4	37.6	23.1	71.7	79.8
44 x 74μ		18.7	14.4	Build-up	2.8		6.2	42.3	25.2	34.1	18.1	16.9
20 x 44μ		31.7	36.2		23.3		1.6	10.1	13.7	16.4	3.8	2.6
10 x 20μ		18.0	14.6		22.3		2.4	6.9	13.7	11.5	3.8	1.9
0 x 10μ		3.6	7.3		44.7		0.6	1.2	6.0	4.9	2.6	0.8

moisture represents a heat loss of about 4.3 percent of heat input. This loss would have to be accepted even if the coal were fired wet; hence it would seem better to predry the coal and gain the benefits from improved combustion and more economical furnace design.

In designing a large plant to burn Onakawana lignite, it would probably be advantageous to provide for much higher gas or air temperatures to the pulverizer. For example, boilers designed to burn German brown coal, which contains about 60 percent moisture, commonly use beater mills supplied with a mixture of air and furnace gases, at a temperature of about 1500 deg F.

To study the effect of fineness of grind on the combustion performance of Onakawana lignite, the classifier which is built into the pulverizer was adjusted to different speeds. At each speed the fineness of grind was measured and related by visual observation to length and stability of the flame. The optimum classifier setting produced a coal fineness of 72 percent through 200 mesh and resulted in a stable, fairly short flame with good burnout. Coarser grinds gave unsteady flames with large quantities of "sparklers" in the test air heater, while finer grinds reduced the capacity of the pulverizer. Stable flames with Bienfait lignite occurred at the same classifier speed but a substantially finer grind was produced.

The ring-and-roller pulverizer, which is rated at 400 lb/hr of Bienfait lignite, pulverized to 80 percent through 200 mesh, experienced no difficulty in pulverizing 450 lb/hr of Onakawana lignite to 72 percent through 200 mesh. The differences in grindability and combustion characteristics may be due to the unconsolidated structure and relatively low bulk density of the Onakawana lignite. Data from Hardgrove grindability tests on both lignites varied widely, particularly with Onakawana lignite. However, this was not unexpected because it is generally conceded that the Hardgrove index is not a reliable guide for the grindability of lignites that have widely varying organic constituents.

The low ash-fusion temperature of Onakawana lignite suggests that slag-tap operation may be feasible. However, when this lignite was burned in the research boiler, the average flame temperature did not exceed 2100 deg F and the slag was not rendered sufficiently fluid for continuous tapping. Much of the ash melted in the furnace bottom but it needed the higher temperature of an oil torch for period draining. Possibly in a utility-size furnace fired by conventional burners, slagging temperature could be achieved with Onakawana lignite at high loads but to maintain tapping at low loads supplementary oil flames would be needed. On the other hand, there is the possibility that either a unique combustion-chamber design could be developed for long residence time, or moisture-separating burners of a type used in Europe [1][1] could be adapted to overcome the low flame temperatures that seem to be an inherent drawback of high-moisture coals. Alternatively, the problem of low flame temperatures may be overcome by separating some of the moisture-laden air from the pulverizer and injecting it into the furnace downstream of the burners [2].

The Bienfait lignite had an as-received moisture content of 36 percent and was air-dried to 21 percent moisture during one year of storage. When direct-fired, it burned with a clean, stable flame having an average temperature of about 2250 deg F. Much of the Bienfait ash sintered in the furnace bottom, although some of it slagged, but continuous tapping could not be achieved without the assistance of an oil torch.

Possibly the most significant aspect of the combustion tests carried out with Onakawana lignite was that it produced a lower flame temperature and exhibited none of the massive, tenacious, fireside-fouling tendencies of Bienfait lignite. Normal soot blowing sufficed to keep the furnace exit and air heaters reasonably clean when burning Onakawana lignite.

SO$_2$, SO$_3$, NO$_x$, Acid-Dewpoint and Corrosion-Rate Measurements. Typical SO$_2$, SO$_3$, NO$_x$, acid dewpoint, and corrosion-rate measurements taken at the breeching with 3 percent O$_2$ and 5 percent O$_2$ in the flue gases, are given in Table 2. The SO$_2$ levels are normal for coals containing 0.5 percent sulfur but the SO$_3$ levels are relatively high, particularly with 5 percent O$_2$ in the flue gases. Fortunately, the corrosive effect of these high SO$_3$ levels is completely neutralized by cationic ash constituents in both the Onakawana and Bienfait lignites; this is reflected in the absence of an acid dewpoint and in the minimal corrosion rate of iron at

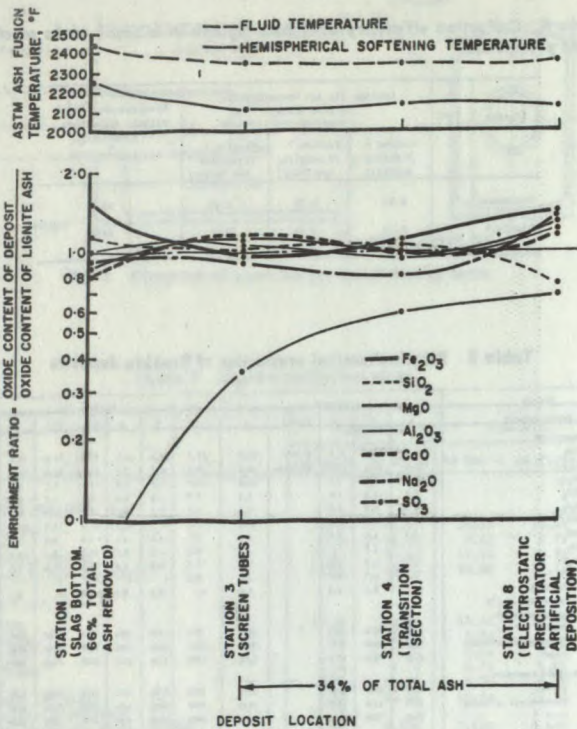---

[1] Numbers in brackets designate References at end of paper.

Fig. 4 Variation in enrichment ratio and ash-fusion temperature of fireside deposits with boiler location when burning Onakawana lignite

Fig. 5(a) Onakawana lignite

Fig. 5(b) Bienfait lignite

Fig. 5 Screen tube deposits; thin section × 37

220 deg F. The Onakawana lignite produced NO_x levels which were significantly lower than those produced by Bienfait lignite, presumably because low NO_x levels are consistent with low flame temperatures.

Fly Ash, Fireside Deposits, and Slag Characteristics. To assess the influence of flame temperature and ash properties on ash-fouling tendency, the combustion residues from Onakawana and Bienfait lignites were subjected to numerous physical and chemical tests, including chemical analyses, petrographic examinations, X-ray diffraction analyses, ash-fusion determinations, and particle-size analyses. The results of tests conducted on selected samples of fly ash, fireside deposits, and furnace bottom slag are discussed later.

Fly Ash. Typical chemical analyses of fly-ash samples extracted from flue gases containing 3 percent O_2 are given in Table 3. These analyses show that the Onakawana fly ash contains a low total alkali and a small amount of water-soluble sulfate whereas the Bienfait fly ash contains a relatively high total alkali and a large amount of water-soluble sulfate. It can also be seen that the ratio of water-soluble alkali to total alkali was only 0.2 for Onakawana fly ash but was over 0.7 for the Bienfait fly ash.

These analyses suggest that fireside fouling is directly related to the following three components of fly ash: (a) total alkali, (b) water-soluble sulfate, and (c) water-soluble alkali. Brown, et al., [3], stated that the sodium content of lignitic ash deposits is a prime factor in initiating but not in bonding the deposits, while Gronhovd, et al., [4], determined that the rate of fouling was a function of total sodium in the lignite ash.

Additional analytical work revealed that nearly all of the alkali was concentrated preferentially in the superfine particles of both Onakawana and Bienfait fly ash. In the case of Bienfait fly ash, the alkali content of the superfine particles was over 50 percent by weight. Thus superfine alkali ash particles appear to be the dominant bonding agent in the formation of massive deposit buildup.

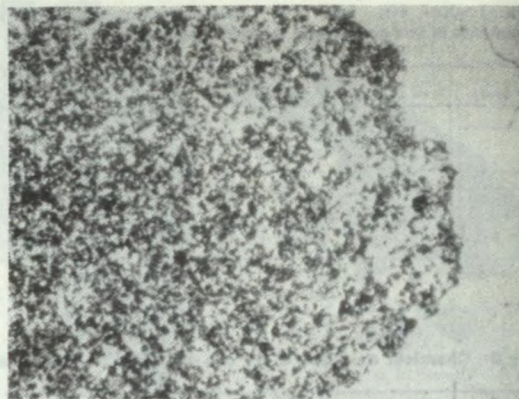Particle-size analyses, together with petrographic examinations

of fly-ash samples from Onakawana and Bienfait lignite, revealed that most of the $+74u$ particles were composed of char and that the size of the fly-ash particles became progressively smaller between the furnace exit and the breeching. The latter phenomenon suggests that the large particles are being progressively (a) reduced in size by delayed combustion of any unburned carbon, (b) removed from the gas stream by deposition on boiler surfaces, or (c) outnumbered by superfine alkali particles that sublimate from vapor phase.

In general, the combustion of high-ash, low-sulfur lignites in slag-tap boilers produces large concentrations of fine dust having a high electrical resistivity. This type of dust adheres to, and insulates, the collecting surfaces of electrostatic precipitators so that collection efficiencies are drastically reduced. However, German experience [5] with brown coals has shown that reasonably high collection efficiencies can be maintained if the electrostatic precipitator is designed with extra-large collecting surfaces and with particle migration velocities of less than 5 cm/sec.

Research work with a small-scale electrostatic precipitator at the CCRL confirms the German findings and, as shown in Table 4, the fly ash from Onakawana and Bienfait lignites was collected at efficiencies of 99.5 and 98.0 percent, respectively. The dust residuals, being only 0.03 grains/SCF or less, are well below rigid standards for air pollution control.

Fireside Deposits

Onakawana Lignite. The fireside deposits from Onakawana lignite were generally powdery and readily removed from the tube surfaces by periodic soot blowing. At the end of each test, the
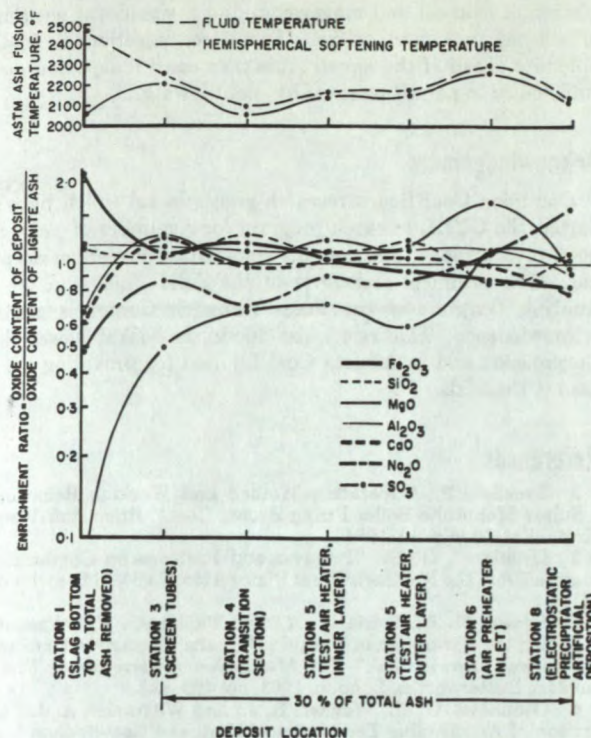
Fig. 7(a)   Onakawana lignite

Fig. 7(b)   Bienfait lignite

Fig. 6   Variation in enrichment ratio and ash-fusion temperature of fire-side deposits with boiler location when burning Bienfait lignite

Fig. 7   Slag tapped during lignite combustion tests.   Thin section $\times$ 37 under crossed polaroids

furnace walls and screen tubes were covered with about $1/4$ in. to $1/2$ in. of deposit, while the test air heater and the air heater were relatively clean.   The deposits contained mostly quartz, with small amounts of pyroxene and calcium sulfate.

The differences in chemical composition of the Onakawana ash deposits taken from the different locations in the boiler are shown in Table 5, and are plotted as a series of enrichment ratios in Fig. 4.   The enrichment ratio, which is defined as the ratio of the percentage elemental oxide in the deposit sample to the percentage elemental oxide in the lignite ash, shows that, with the exception of iron and sulfur, all deposits have essentially the same composition as the indigenous ash.   The relatively constant chemical and mineral composition of the deposits from different boiler locations suggests that the constituents of Onakawana ash do not readily volatilize or liquefy at the gas temperatures which prevailed downstream of the furnace throat, and that the fly ash passes through the boiler without selective deposition of mineral components.   This inference is supported by the powdery, friable nature of the deposits shown in Fig. 5(a) and by the fact that deposit buildup could be controlled by routine soot blowing.

Bienfait Lignite. The deposits from Bienfait lignite were relatively hard and so strongly sintered that they could not be dislodged by soot blowing.   Consequently, the gas passages through the screen tubes bridged rapidly and heavy ash deposits formed on the furnace walls, the tubes of the test air-heater and the air-inlet tube sheet of the main heater.

By X-ray diffraction, all of the Bienfait deposits were found to contain minor amounts of quartz, a number of unidentified complexes, and some amorphous matter.   The latter is probably a silicate glass, because the chemical analyses and the corresponding enrichment ratios, given in Table 5 and Fig. 6, respectively, show little change in silicon content with boiler location.   Table 5 also shows that the deposits from the test air heater contain more superfine dust particles than the deposits from other regions of the boiler.

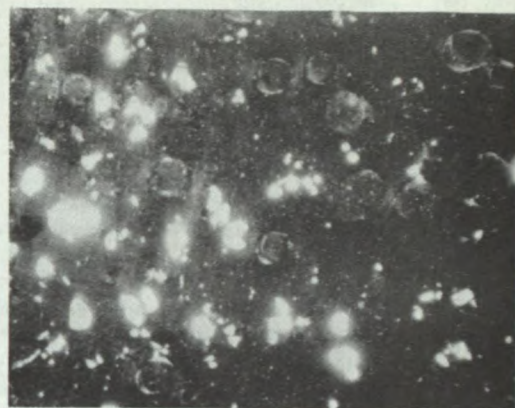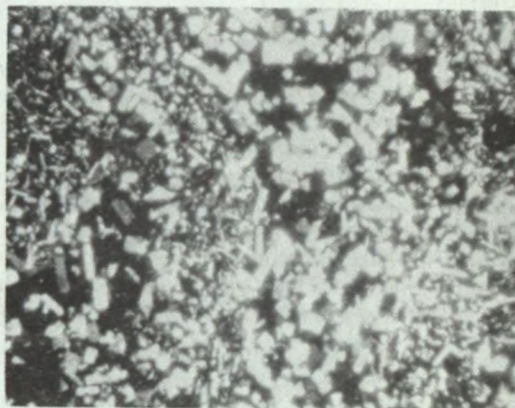Referring to Fig. 6 it can be seen that the ash deposited between the screen tubes and the test air heater is characterized by a eutectic which apparently results from a significant depletion of calcium and magnesium and a significant enrichment of silicon, iron, and sulfur.   Unfortunately, this eutectic occurs immediately downstream of the furnace exit and is, in all probability, mainly responsible for severe fouling of convective heat transfer surfaces.

The strong tendency of Bienfait lignite to form heavy deposits is evident from Fig. 5(b) which shows a microphotograph of an upstream edge of a deposit taken from the screen tubes.   The grey outer layer of this multilayered deposit is hard and dense, while the black interior core is lightly sintered; the white areas in the outer layer are voids.

The analytical work indicates that the severe fouling of tube surfaces by ash from Bienfait lignite is due to selective deposition of complex alkali sulfates and silicates on tube surfaces, particularly in the high-temperature region of the boiler.   Both of these alkali complexes, which are sticky above 1500 deg F, will effectively cement particles of ash into a bulky semifused mass on tube surfaces.   It is evident, therefore, that the thermal-physical properties of the ash, as deposited at specific boiler locations, have an overwhelming influence on ash-fouling tendencies.

Slag. During tapping of the furnace bottom with assistance from an oil torch, the Onakawana slag drained readily while the Bienfait slag drained slowly.   This difference in flowability is due to the amount and type of the mineral compounds produced in the slag melt and the rate of which these minerals cool.   Accordingly, petrographic examinations of slag from both Onakawana and Bienfait lignite were carried out to study its mineral and physical structure.

It was found that Onakawana slag contained from 12–18 percent silica and from 45–55 percent voids; the remainder of the slag was a glass with no identifiable phases. In Fig. 7(a), which shows a typical thin section of this slag, the white areas are grains of silica; the grey circular areas are voids, and the back background is glassy matter. The relatively uniform mineral structure suggests that the slag solidified gradually.

In contrast, the Bienfait slag had a silica content of less than 2 percent, a massive boxwork of small crystals, and some glassy matter. In Fig. 7(b) which shows a thin section of the slag, the small granular white areas are silica grains, the white rectangles are a spinel, and the black areas are glass; very few small voids were observed. These physical features indicate that the Bienfait slag solidified rapidly during tapping and that its apparent viscosity may be increased significantly by (a) the high percentage of dissolved silica and (b) the evolution of gases during cooling. As shown in Fig. 6, the Bienfait slag, being deficient in sodium, resulted in sodium-rich fly ash entering the air preheater.

Conclusions

The combustion of Onakawana lignite under slagging conditions produced friable deposits that were easily removed by routine soot blowing. In general, deposit buildup was not excessive and deposit composition, with the exception of sulfur, did not change appreciably with location in the boiler.

The combustion of Bienfait lignite under slagging conditions produced strongly bonded deposits that were rich in water-soluble alkali sulfates in the high-temperature region of the boiler. These deposits, particularly at the furnace exit where a eutectic composition occurred, were difficult to remove by soot blowing. The eutectic composition apparently resulted from a significant de-

pletion of calcium and magnesium and a significant enrichment of silicon, iron, and sulfur. Therefore, injection of MgO or dolomite ahead of the screen tubes may control deposit structure sufficiently to permit removal by soot blowing.

References

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