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REVIEW

THE CHATHAM CFB BOILER FOR A WIDE SPECTRUM OF FUELS AND SOME PROBLEMS OF ESTONIAN OIL SHALE COMBUSTION IN CFB SYSTEMS

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Mode of operation of a circulated fluidized bed boiler for combustion of oil shale, coal, hardwood and petroleum coke is described. The possibility of producing energy at combustion of Estonian oil shale in these boilers is discussed.

In 1991, Finnish efforts in the field of oil shale combustion in circulated fluid(-ized) bed (CFB) boiler are described in [1]. However, the first CFB boiler for combustion of oil shale was installed in Canada [2, 3].

The 20 MWe Chatham CFB boiler was started up in 1986. It is designed by Combustion Engineering Superheater Co., Lurgi Canada/Lurgi GmbH and Combustion Engineering Inc. Today these companies are presented by **ABB Combustion Systems Combustion Engineering Inc. (ABB-CE, Windsor, Connecticut, U.S.A.)** and **Lurgi Reheat Facilities.**

The unit is designed to produce 26 kg/s steam at 62 bar and 482 °C on the New Brunswick Electric, Chatham, New Brunswick, Canada. It was planned for combustion of a wide spectrum of diverse fuels. There have been commercially fired such fuels as New Brunswick oil shale, bituminous and sub-bituminous coal, hardwood with biomass and petroleum coke. Data on the commercially fired fuels is presented in Table 1.

The fuel handling system comprises storage for coal and oil shale for approximately 30 hours full-load operation. Two 245 t storage bins were provided for shale and one 273 t capacity bin for coal. The fuel is nominally 6.4 mm top size and is discharged by gravimetric feeders to the combustor. Limestone for sulfur capturing is supplied in powder form (less than 0.79 mm) to a separate 255 t hopper, and is pneumatically fed to the lower part of the combustor at either of two parts. Coarse limestone can also be fed from either oil shale silo and mixed with the coal prior to the feed bin. The plant is equipped to receive fuel and limestone by road, rail or water delivery.

The principal components of the boiler are illustrated in Figure 1 and comprise combustor, cyclone, external fluid-bed heat exchanger (FBHE or EFBHE) and backpass. Combustion takes place in a bed of material under mildly oxidizing conditions. Primary air is introduced through a grid of nozzles in the base of the combustor and the secondary air through multiple ports along the walls.

The oxidizing atmosphere, coupled with relatively low combustion temperature of approximately 860 °C, reduces the risk of fouling and slagging. The upper combustion chamber is cooled by waterwalls of the boiler using standard membrane wall construction. In operation, the entire combustion chamber is filled with a mixture of moving solid particles in a flue gas/air stream, having no specific solid separation layer and a maximum density at the bottom of the bed. The combustion chamber measures 3.2 m by 3.2 m and is 24.38 m high.

Gases and solid particles pass from the combustor to the refractory lined cyclone, where the majority of solid particles are separated, while ash is returned to the combustor directly of routed to the external FBHE through a plug valve.

The FBHE is a bubbling-bed heat exchanger with fluidizing air being supplied by a 3.54 kg/s capacity blower. Twenty-four double "U" tube banks or water-cooled tubes provide steam-generating surface, with the cooling capacity being taken from the centre downcomer to the

Table 1. **Data on Commercially Fired Fuels**

Fuel	Bituminous coal	Sub-bituminous coal	Wood/biomass	Petroleum coke	Oil shale (New Brunswick)
HHV (GJ/t)	26.1-30.3	20.0	12.6-19.8	32.3-32.8	2.72
Proximate analysis(wt. %)					
FC	44.8-54.8	32.6	8.8-14.8	78.2-81.5	0.0
Volatiles	26.0-36.0	35.1	44.9-58.3	12.5-17.4	21.5
Ash	7.3-18.2	4.3	0.4-3.6	0.4-1.3	73.2
Moisture	6.5-8.7	28.0	10.8-45.7	0.7-7.5	5.0
Ultimate analysis(wt. %)					
Oxygen	2.1-10.8	13.5	27.8-41.7	0.1-1.3	8.9
Hydrogen	3.7-4.7	3.6	3.8-6.0	1.7-3.7	1.3
Nitrogen	0.9-1.7	0.7	0.1-0.8	1.7-1.9	0.7
Sulfur	0.6-6.5	0.2	0.0-0.2	4.4-6.0	0.7
Carbon	62.1-71.5	49.7	31.6-54.5	82.0-88.2	10.2
Ash composition(wt. %)					
SiO_2	35.5-51.4	30.8	5.2-27.5	11.1	47.4
Al_2O_3	11.8-23.1	15.7	1.2-6.6	6.1	19.5
TiO_2	0.5-1.3	1.2	0.0-0.8	0.1	—
Fe_2O_3	1.3-36.6	4.7	2.1-5.8	10.4	7.3
CaO	1.4-5.1	21.6	27.0-50.3	0.0	14.9
Na_2O	0.2-0.6	1.7	0.1-3.6	0.2	3.3
MgO	0.6-1.6	5.0	5.7-6.7	0.3	—
K_2O	0.2-2.5	0.6	5.7-18.2	0.2	2.1
SO_3	1.1-2.2	16.4	1.4-30.0	0.2	—
P_2O_5	0.1-0.6	0.7	2.4-6.7	—	—

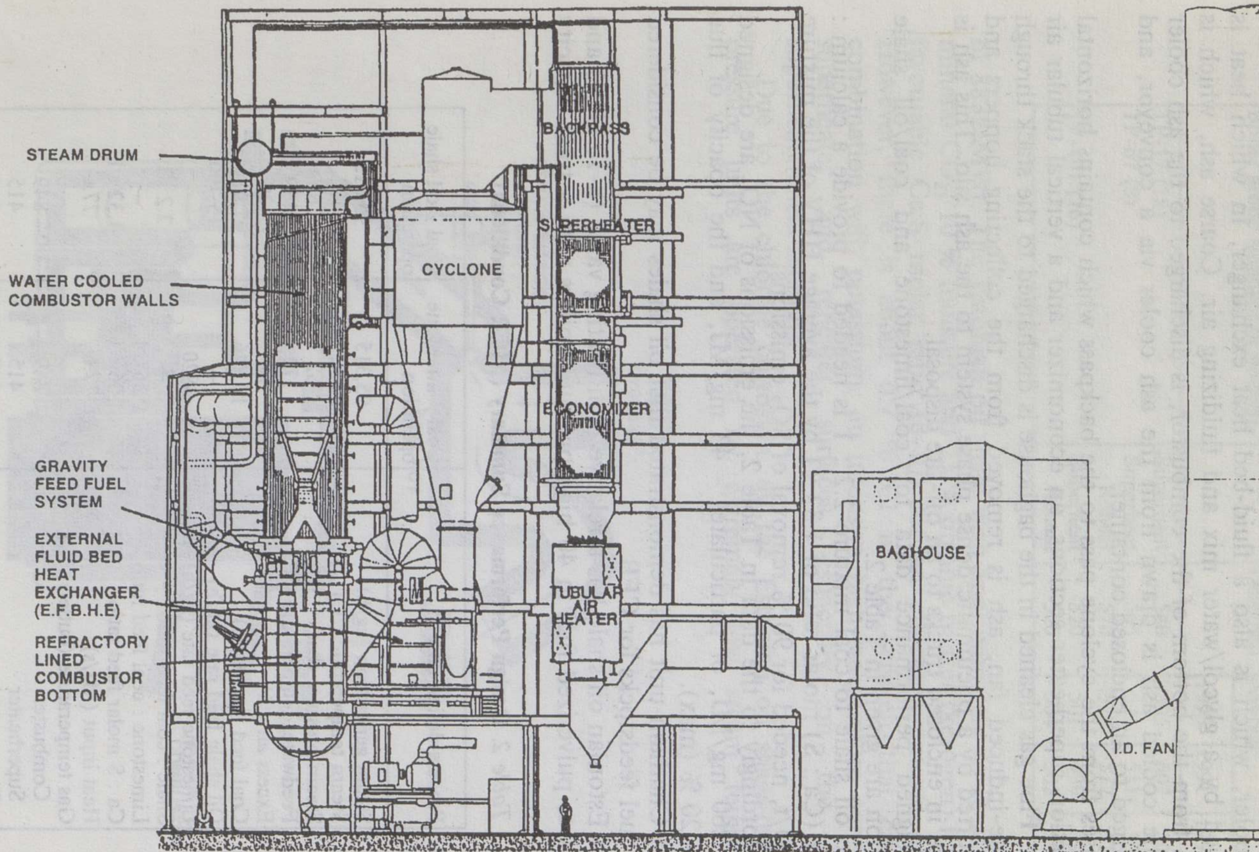

Fig. 1. Chatham, New Brunswick circulating fluid bed boiler

water-cooled walls of the backpass through a 0.526 l/s circulating pump, which also provides assisted circulation to the water-cooled walls of the backpass. No combustion is excepted in the FBHE.

Ash from the FBHE is returned into the combustor or directed to the ash cooler, which is also a fluid-bed heat exchanger, in which heat is removed by a glycol/water mix and fluidizing air. Coarse ash, which is drawn from the bottom of the combustor, is discharged to the ash cooler and the cooled ash is drawn from the ash cooler via a conveyor, and discharged to an enclosed container.

Gases from the cyclone pass to the backpass which contains horizontal convection superheater sections, an economizer and a vertical tubular air heater. Flue gas cleaned in the baghouse is discharged to the stack through a single-induced fan, ash is removed from the collecting hoppers and transported by a pneumatic dense phase system to the ash silo. This ash is trucked in enclosed trucks to an off-site disposal.

Designed performance data for coal/limestone and coal/oil shale operation are given in Table 2.

The oil shale to coal mixture 2.2 : 1 is needed to provide a calcium : : sulfur (Ca : S) molar ratio of 1.32 : 1 by the average HHV of the mixture 11.8 GJ/t, needed for 90 % removal of SO_2 emissions.

Accordingly to the data in Table 2, the emissions of NO_x are designed to be 260 mg/MJ, of particulates - 43 mg/MJ, and the opacity of flue gases - 20 % (max).

The Chatham unit has demonstrated that oil shales may be considered viable fuel feedstocks for CFB.

The Estonian oil shale has a relative high heating value (8-10 GJ/t) and is fired as pulverized fuel in 40 high-pressure boilers with a total capacity

Table 2. **Design Performance Summary (MCR Conditions)**

Process design criteria	Coal / limestone operation	Coal / oil shale operation
Steam generation (kg/h)	95,315	95,315
Steam temperarure (°C)	482	482
Steam pressure (bar)	62	62
Feedwater temperarure (°C)	179	179
Excess air (%)	20	20
Coal feed rate (kg/h)	10,846	7,914
Oil shale feed rate (kg/h)	—	15,700
Limestone feed rate (kg/h)	3820	—
Shale : coal feed ratio	—	2.2 : 1
Limestone : coal feed ratio	0.35 : 1	—
Ca : S molar feed ratio	1.35 : 1	1.32 : 1
Heat input (MJ/s)	77.6	77.6
Gas temperarure (outlet) (°C):		
Combuster	849	849
Superheater	415	415
Economizer	246	246
Air heater	177	177
Plant turndown ratio	3 : 1	3 : 1
Carbon combustion efficiency (%)	97.7	99.0
Boiler efficiency (%)	87.42	88.22

Table 3. **Designed and Actual Superheat and Reheat Temperatures (°C) on Estonian Oil-Shale-Fired Pulverised Fuel Combustion Boilers**

Boiler group (number of boilers)		Designed	Average		
			1990	1991	1992
TP-17 (18)	Superheat	540	505	507	509
TP-67 (8)	Superheat	565	521	511	503
	Reheat	570	528	517	510
TP-101 (16)	Superheat	520	501	499	499
	Reheat	525	504	503	503

of 8832 MWt. The Estonian oil shale with approximately 45 % ash, 20 % mineral CO_2, 10 % moisture and 25 % organic matter (kerogen) has a very favourable Ca:S molar ratio (8-10) for an effective removal of sulfur. However, there is about 0.7 % Cl in the kerogen that causes, in combination with potassium, an intensive high-temperature corrosion of superheater and reheater surfaces, especially on the finishing superheat/reheat sections.

Due to the chlorine corrosion, all the Estonian oil shale-fired high-pressure units are operated by extremely low steam temperatures,

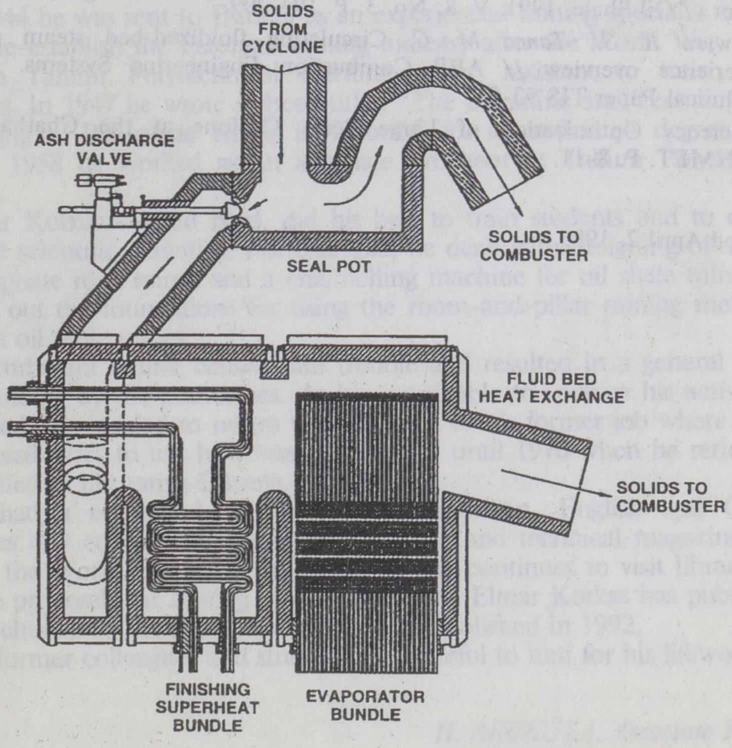

Fig. 2. Seal pot, ash discharge valve and fluid bed heat exchanger

as demonstrated in Table 3. It results in a loss of power generating efficiency - approximately 3-6 %.

The latest CFB boilers with higher superheat and reheat temperatures are designed with external FBHE where the finishing superheat and reheat bundles are placed as effective and well-controllable boiler elements (Fig. 2), as, for example, on AES Thames CFB boilers (2 × 101 kg/s, main and reheat temperatures 540 °C), at Montville, Connecticut, U.S.A., visited by the author.

Taking in account, that the corrosive active superfine particles theoretically may pass cyclone, the coarser ash, separated into the external FBHE, must loss the corrosive activity typical of the oil shale fly ash. This phenomenon must be investigated by testing the combustion of Estonian oil shale in CFB systems. It must be taken into account that the investigation of the corrosive activity is needed for determination of potential maximum temperatures of main and reheat steam, as well as for calculation of the thermal efficiency of a new plant equipped with CFB boilers.

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