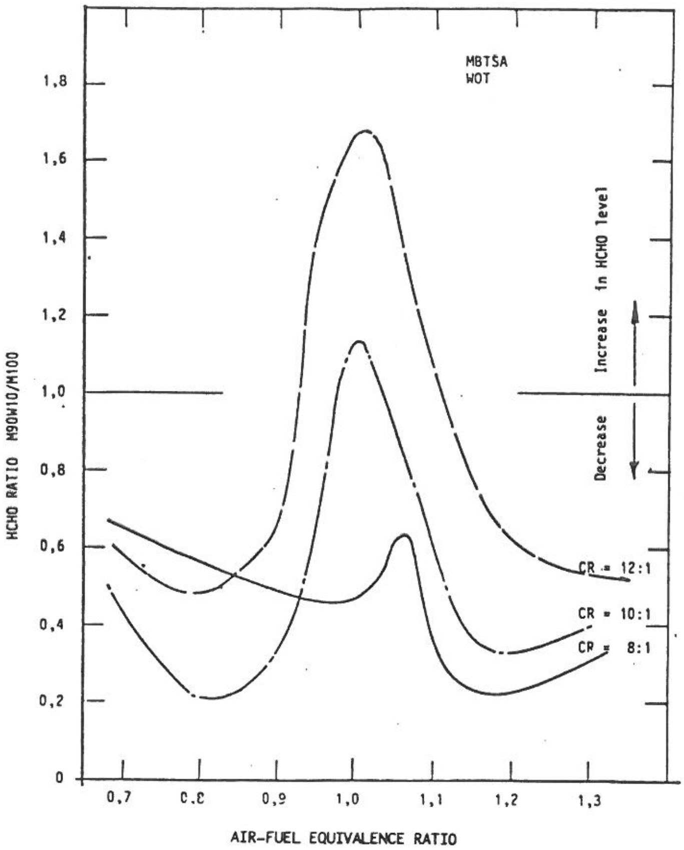

FIGURE 7: EFFECT OF ADDING 10% WATER TO METHANOL (M90W10 BLEND) ON HCHO EMISSIONS FROM A RICARDO E6 ENGINE

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THE BURNING OF INFERIOR COALS IN FLUIDIZED BEDS -

THE NATIONAL FLUIDIZED BED COMBUSTION BOILER

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1 INTRODUCTION

The new methods of mining coal and the continuous demand for good quality coals for the local and export market has left South Africa with increasing quantities of discard and duff coal. These inferior coals, which are currently stockpiled, are unsuitable for steam raising in existing boilers.

In South Africa, over 25m tonnes of discard coal have been accumulated over the years and this is increasing at a rate of 7m tonnes per year. The accumulated duff coal is in excess of 2m tonnes and is increasing at a rate of 1,2m tonnes per year.

In order to utilize the inferior coals and reduce the demand for better quality coals, the Department of Mineral and Energy Affairs has allocated the sum of R2,2m for the construction and operation of a National Fluidized Bed Combustion Boiler (NFBC Boiler). Its prime objective would be to demonstrate the reliability of this process, over long periods of operation, burning both discard and duff coal.

The combustion of inferior coals is not without problems particularly since these coals are associated with high ash, high sulphur and high percentage of fines. The reduction of pollutants eminating from a fluidized bed, when burning inferior coals, becomes therefore a serious problem.

In this paper, fluidized bed combustion systems in general, and the NFBC Boiler in particular, are discussed within the context of pollution.

2 THE CHOICE OF FBC TO BURN INFERIOR COALS

Probably the most important feature of and FBC is that it can handle all grades and sizes of coal, provided that the combustion process is autogenous. In brief, the reasons which favour fluidized bed combustion technology for the combustion of inferior coals are given below:

(i) Conventional boilers cannot burn coal efficient= ly if it contains a high ash fraction or has a high concentration of fines. The reason for this is that, the combination of high ash (in excess of 35%) and low volatiles cannot sustain combustion. On the other hand, commercial FBCs currently operate on coals with up to 70 per cent ash content [1,2].

(ii) FBCs offer a higher boiler efficiency, if compa= rison is made with conventional boilers. FBC companies guarantee efficiencies of between 80 and 83 per cent. The reasons for this are, better reaction kinetics and bed heat transfer rates, which are attributed to the good solids mixing, and the continuous ash removal from the burning coal particles. For the same reason, FBCs with inbed tubes require a smaller heat transfer surface area if compared with conven= tional boilers of the same steam output.

(iii) FBCs operate at temperature of 800 to 950°C which are below ash fusion temperatures. Further, the problem of deposition of alkali metals on the tubes encountered in conventional boilers does not occur in FBCs.

(iv) The low FBC combustion temperature results in low nitrogen oxides (NO_x) emissions as discussed in the following section. Dolomite or limestone can be added to the fluidized bed together with the coal to remove sulphur oxides (SO_x). This method eliminates the use of flue gas scrubbers. With regard to emission of particulates, the FBC offers no advantage over conventional combustion systems.

A closer look at the pollution aspects of FBCs is given in the following section.

3 FLUIDIZED BED COMBUSTION AND POLLUTION

In an FBC, coal is burnt in a bed of suspended inert particles. These particles, generally ash or sand, size less than 3 mm, are kept in suspension (fluidized) by the upflow of air which also supplies oxygen for the combustion of coal. The mean density of the fluidized bed is similar to the density of the coal particles, hence the good mixing of coal in the bed. To burn coal in an FBC an internal heater is used which brings the combustor up to temperature, approximately 650°C (depending on the type of coal). When burning low ash coal, the ash is removed by attrition within the bed and elutriation. However, when burning coal with ash in excess of 40 per cent, the ash which remains in the combustor is removed by using a bed overflow facility. In this way, there is no ash accumulation within the combustor and the FBC maintains its fluidization characteristics.

Most of the research work on pollution aspects of FBCs is concentrated on the emission of particulates, nitrogen oxides (NO_x) and sulphur oxides (SO_x).

(i) Emission of Particulate Matter

FBCs in general, produce higher concentrations of particulates if compared with most conventional combustion systems. This is characteristic of this type of operation and is due to the scouring effect and attrition within the fluidized bed which produces fine coal particles and ash.

The problem of coal/ash elutriation from the combustor becomes serious if inferior coals are burnt. Investigations into the elutriation of coal/ash particles from combustors have shown, as can be expected [3,4,5] that the weight of carbon/ash losses increase with the fluidizing velocity, the coal loading and with the reduc= tion in coal feed size. Measurements of elu= triated particles carried out at the combustor exit gave, for atmospheric FBCs, concentrations in the region of 2 000ppm. Emission from pressurized FBCs are of the order of 10 000ppm [6]. These figures are high and they indicate that flue gas clean-up equipment are necessary for the operation of FBCs. Cyclones, baghouses and electrostatic precipitators can reduce stack emissions to internationally specified levels. Partial or total recycling of particulates leav= ing the combustion chamber is widely employed. This increases combustion efficiency to over 99 per cent and reduces the amount of carbon in the ash product.

(ii) Emission of Sulphur Oxides

The removal of SO_x (in general 99% SO_2, 1% SO_3) is affected by design and operating parameters such as, the fluidized bed operating conditions, bed height and Ca/s molar ratio. The Ca/s ratio is very important due to its economic implica= tions. Both limestone and dolomite are used for sulphur retention. There is, however, a prefe= rence for dolomite for pressurized FBCs and limestone for atmospheric FBCs (Figure 1). The effect of temperature on sulphur capture is also shown on Figure 1. Although, at temperatures above 820 - 840°C there is a distinct reduction in the sorbent activity of atmospheric FBCs, this does not occur in pressurized systems.

(iii) Emission of Nitrogen Oxides

The nitrogen oxides in the flue gas of most com= bustion systems are in the form of nitrogen dioxide (NO_2) and nitric oxide (NO) which, at the emission point, has a concentration of over 90 per cent. Nitric oxide is converted in the atmosphere to nitrogen dioxide which is the reason why some regulations on NO_x emissions give figures in terms of NO_2 equivalent weight. In an FBC, almost all the nitrogen of NO_x originates from the coal, whereas in a Pulverized Fuel Combustor more than half of the emitted NO_x originates from the nitrogen in the combustion air. Typical ranges of NO_x concentrations emina= ting from coal fired power plants are given in Table 1.

Although the excess air has no significant effect on sulphur capture [9], NO_x emissions increase with percentage excess air (Figure 2). The same applies for increases in combustion temperatures (Figure 3). The improved reduction in NO_x emissions offered by pressurized combustion is shown in Figure 4.

THE NFBC BOILER

This boiler was designed based on Tavistock duff but it will also be capable of handling discards. Typical chemical and physical properties of these two types of coal are given in Table 2.

Table 3 gives a list of design parameters for the NFBC Boiler.

To enable the efficient combustion of both discard and duff coal and reduce pollution, special features have been incorporated in the design of the boiler. These features are described below:

(i) Both inbed and overbed coal feeders are provided to investigate the effect of their position on the elutriation of coal (Figure 5). It is be= lieved that better combustion efficiencies will be achieved if the duff coal is fed into the fluidized bed.

(ii) The boiler utilizes a single pass convection bank positioned in the upper section of the furnace (Figure 5). The rear wall tubes form a furnace exit screen and a water-cooled collector where particulate matter is dropped out of the flue gas leaving the furnace and returned to the bed by gravity. Further control and reinjection of par= ticulates is accomplished through two stages of cyclones. A portion of the ash is recycled back to the boiler from the primary cyclones with the remainder being removed by the secondary cyclone and sent to the ash disposal bin. Although cyclones may reduce particulate emission levels to the specified 150ppm when burning good quality coals, it is believed that for the combustion of discard and duff this specification may not be met. For this reason, an alternative route for the flue gas passes through a baghouse instead of the cyclones (Figure 6).

In addition to the facilities described above for the removal of ash from the flue gas, a rock removal system is also incorporated in the fluidized bed. This is particularly essential when burning discard coal.

(iii) It is intended to use limestone for inbed removal of sulphur. The boiler is designed with a mini= mum of 75% sulphur capture using up to 4 : 1 Ca/s ratio based on stoichiometry.

Typical NO_x and SO_x emissions obtained during the ope= ration of a similar FBC boiler are given in Figures 7 and 8. This boiler rated at 11 000 kg/h steam burning anthracite culm (approximately 70% ash) was designed and built by a consortium of companies with funds from the Department of Energy (USA). The company that managed this project is the technology supplier for the NFBC Boiler.

Work on construction of the NFBC Boiler plant at the NICR Pilot Plant area in Pretoria West has already begun and commissioning trials are scheduled for March, 1984. Handover date is May, 1984. In addition to con= tinuous operation runs of the boiler burning duff and discards, other types of coal will also be combusted to gain expertise and report on the combustibility of a wide spectrum of South African coals.

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TABLE 1

TYPICAL NO_x CONCENTRATION RANGES IN FLUE GAS(7,8)

TYPE OF FIRING		TYPICAL NO_x CONCENTRATION ppm
Pulverized Coal Fired	:	500 - 700
Spreader Stoker	:	400 - 470
FBC		
Atmospheric	:	200 - 700
Pressurized	:	100 - 200

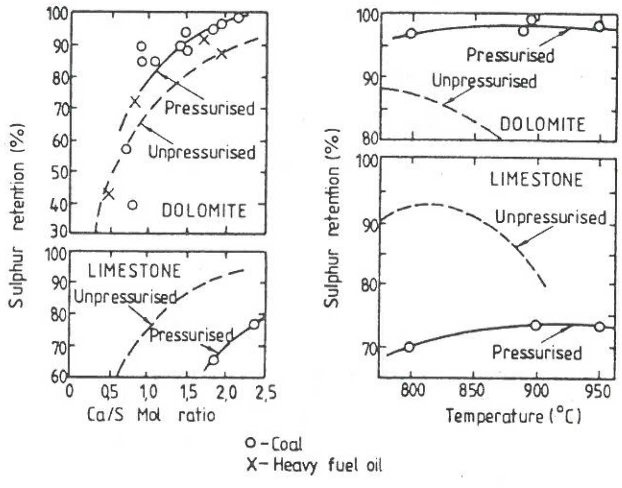

FIGURE 1 :- EFFECT OF Ca/S MOL RATIO & TEMPERATURE ON SULPHUR RETENTION (7)

TABLE 2 DATA ON DUFF AND DISCARD COAL

ANALYSIS OF RAW COAL (AIR DRY BASIS)			SIZE ANALYSIS PERCENTAGE LARGER THAN SIZE		
COMPONENT	DUFF COAL	DISCARD COAL	SIZE mm	DUFF COAL	DISCARD COAL
Water	2,9	1,6	31,2		0
Ash	17,8	62,7	25,4		29,2
Volatiles	26,4	16,1	19,1		47,9
Fixed Carbon	52,90	19,6	12,7	0	61,5
Sulphur	1,4	3,2	6,3	18,1	79,2
			3,1	47,0	87,1
Calorific Value:			1,6	68,9	92,4
Duff Coal : 25,7 MJ/kg			-1,6	31,1	7,6
Discard Coal : 9,3 MJ/kg					

TABLE 3 NFBC BOILER DESIGN PARAMETERS

Steam Flow (Natural Circulation)	12 000 kg/h
Steam Conditions:	
Pressure	1,50 Mpa
Temperature	255 °C
Superheat	50 °C
Bed Dimensions (square)	9,3 m^2
Bed Height	0,68 - 1,5 m
Fluidizing Velocity:	
Duff Coal	1,7 m/s (max)
Discard Coal	2,0 m/s (max)
Sulphur Capture	75% (min)
Turndown	4 to 1

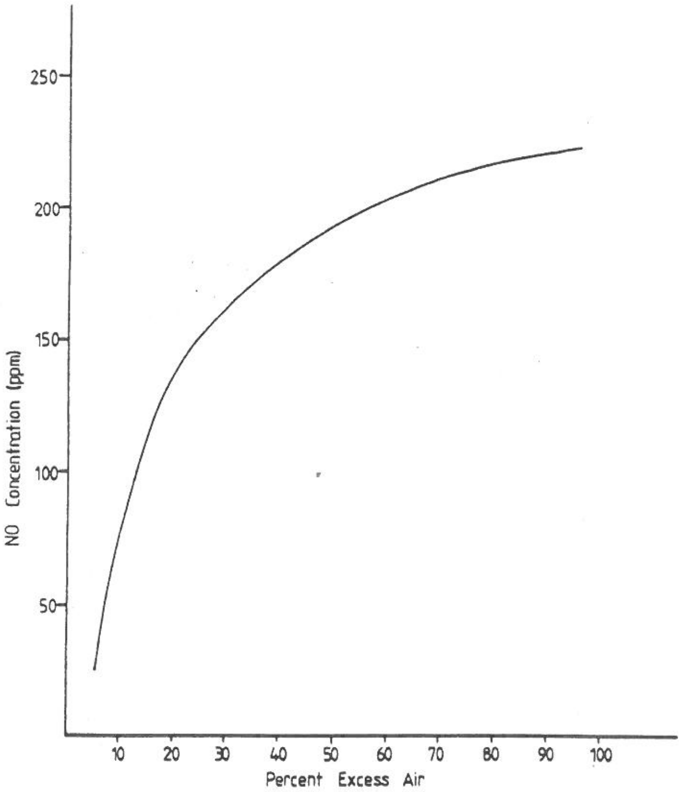

FIGURE 2 :- EFFECT OF EXCESS AIR ON NO EMISSIONS AT 600 KN/m^2 (7)

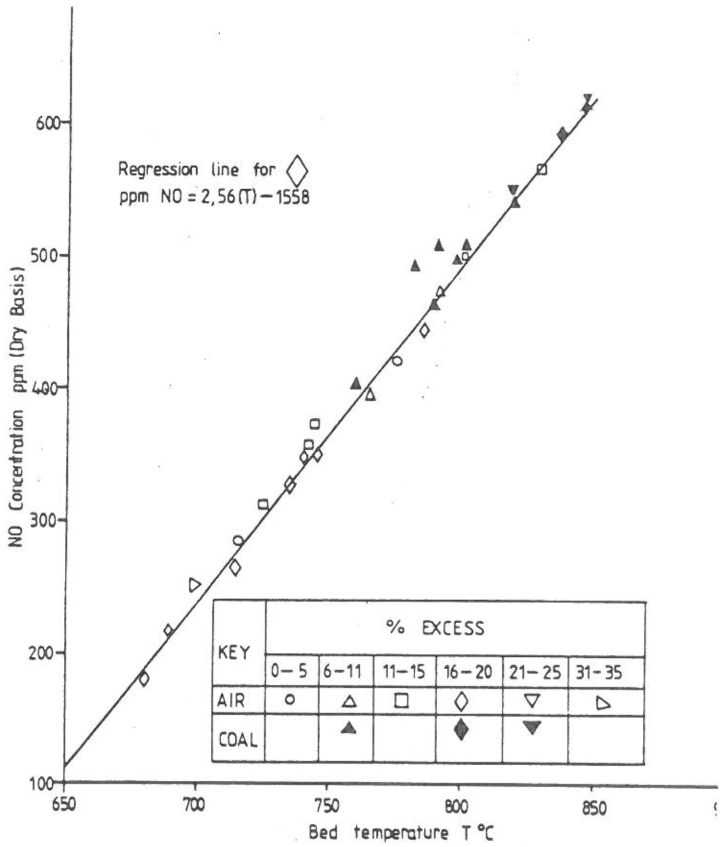

FIGURE 3:- NO EMISSION AS MEASURED AGAINST BED TEMPERATURE & STOICHIOMETRY (10)

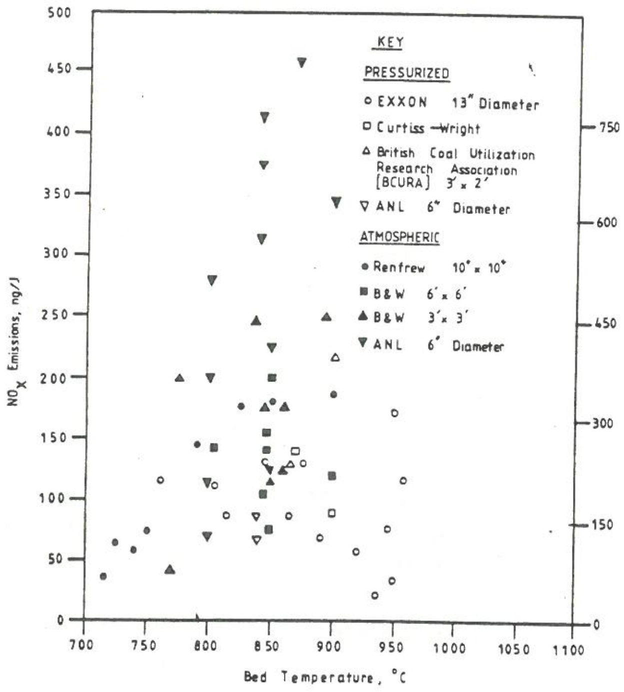

FIGURE 4 :- NO_x EMISSIONS FROM FBC BOILERS [11]

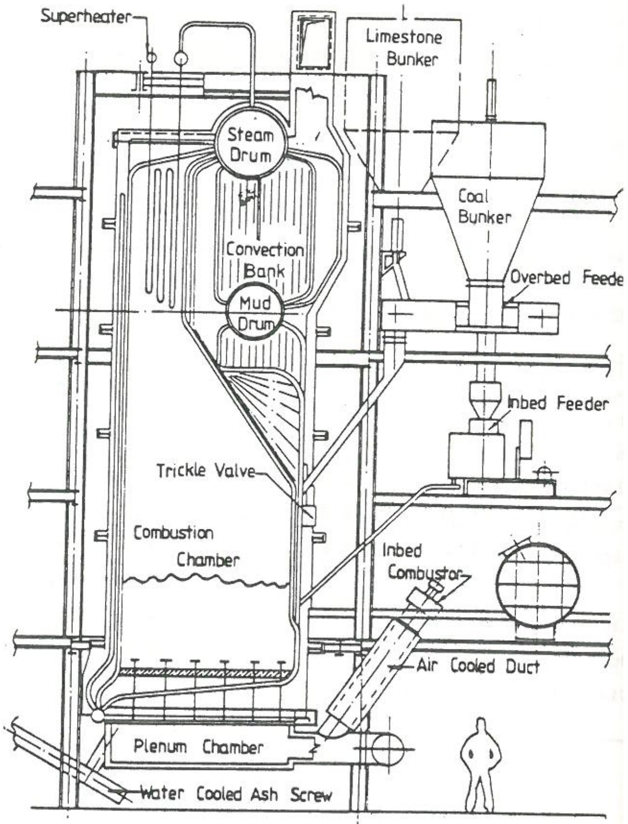

FIGURE 5 :- SECTION SIDE ELEVATION OF NFBC BOILER

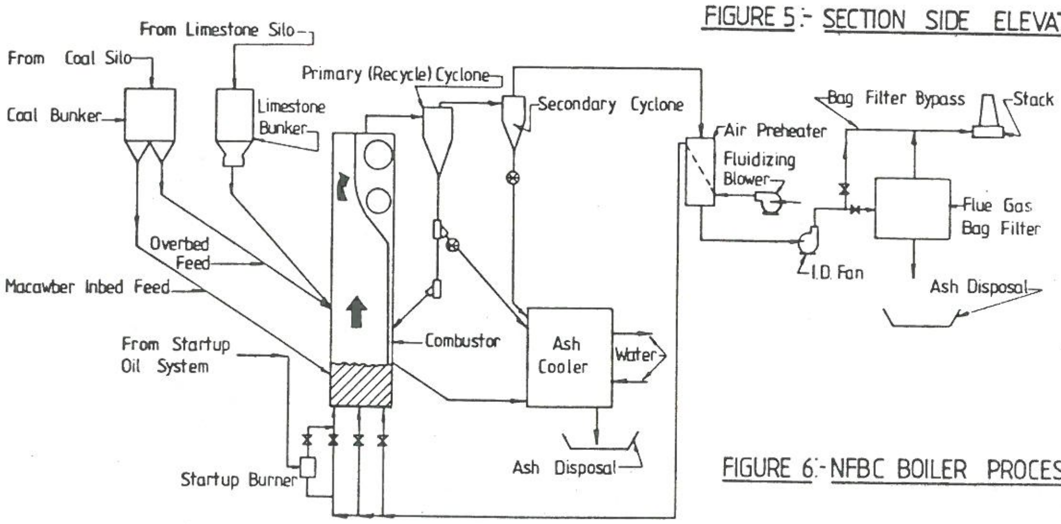

FIGURE 6 :- NFBC BOILER PROCESS SCHEMATIC

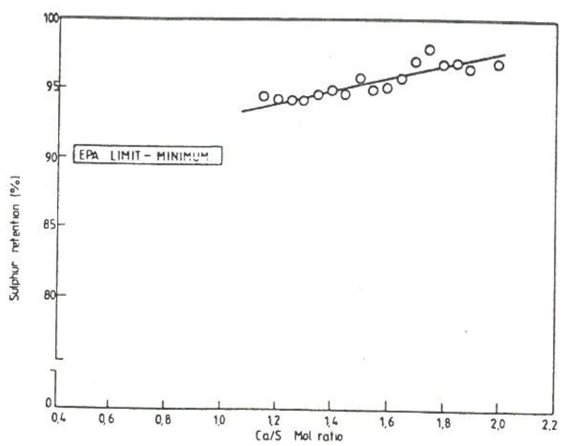

FIGURE 7 :- EFFECT OF Ca/S MOL RATIO ON SULPHUR RETENTION

(SHAMOKIN FBC BOILER)

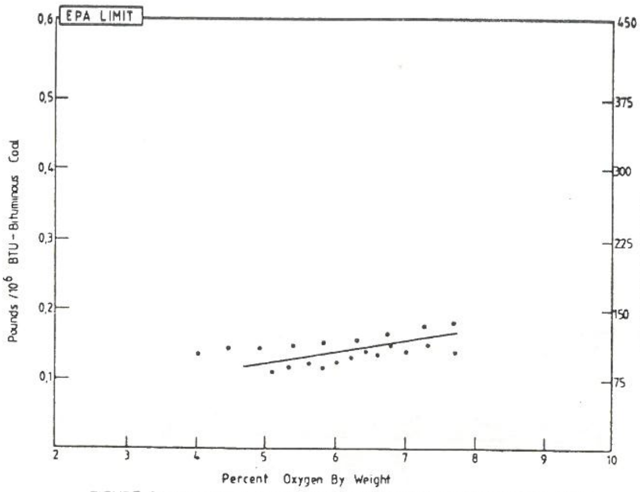

FIGURE 8 :- NO_x CONCENTRATION & PERCENT OXYGEN IN FLUE GAS

(SHAMOKIN FBC BOILER)