1. Introduction

1.1 About NTPC and the Study

NTPC Limited (previously known as National Thermal Power Corporation Limited) is an Indian Central Public Sector Undertaking (CPSU) under the Ministry of Power, Government of India, engaged in the business of generation of electricity and allied activities. It is a company incorporated under the Companies Act 1956 and a "Government Company" within the meaning of the act. The headquarters of the company is situated at New Delhi. NTPC's core business is generation and sale of electricity to state-owned power distribution companies and State Electricity Boards in India. The company also undertakes consultancy and turnkey project contracts that involve engineering, project management, construction management and operation and management of power plants. It is the largest power company in India with an electric power generation capacity of 45,548 MW. Although the company has approximately 16% of the total national capacity, it contributes to over 25% of total power generation due to its focus on operating its power plants at higher efficiency level. In May 2010, NTPC was conferred “MAHARATNA” status by the Union Government of India. It is ranked 424th in the Forbes Global 2000 for 2014.

Coal is a very important and an integral part in coal fired NTPC plants. The complete coal handling plant contributes to between 10 to 20% of the investment cost of a coal plant. Cost of coal is more important in terms of operating cost; about 30% of the operating cost of an NTPC plant goes to cover the procurement, transport and handling cost of coal. Under such a situation having a good idea about the loss of calorific value of coal due to stack piling is highly necessary.

The operational excellence of the company depends much on the quality of coal at firing-producing thermal energy in the boiler. Thermal energy from coal is represented in the two terms: Gross and Net Calorific Value (GCV and NCV). There is an interest in GCV because this is the most commonly used measure for purchasing energy that is used for producing steam for driving turbines. The value determined for GCV can affect the values calculated for the plant heat rate and for the plant total energy efficiency: (Babcock & Wilcox, Steam, 40th edition).Two terms are important in the understanding:

$$\textbf{Net Plant Heat Rate (NPHR)} = \frac{\textbf{Total fuel heat input (BTU)}}{\textbf{Net power leaving the plant (kWh)}}$$

kWh = BTU/kWh per unit time (The NPHR typically varies with plant load)

$$\textbf{Plant total energy efficiency (E)} = \frac{\textbf{3412 BTU/kWh}}{\textbf{NPHR}} \times \textbf{100\%}$$

1.2 About NTPC Kahalgaon

Kahalgaon Super Thermal Power Station is located in Kahalgaon in Bhagalpur district of Bihar. The power plant is one of the coal based power plants of NTPC. The coal for the power plant is sourced from Rajmahal coalfield of Eastern Coalfields Limited. Source of water for the power plant is Ganga River. The total installed capacity of the plant is 2340 MW.

Fig. 1: View of NTPC Kahalgaon Power Plant

2. Objectives

IIT Kharagpur was given to work as per the discussion in the meeting held between IIT Kharagpur team and the NTPC team at NTPC Farakka on 29th August 2015; the main objectives for the study decided are as follows:

a) Identification of location of stockpiles and establishment of the stockpiles in the plant area
b) To collect and prepare the coal samples from the same stockpiles in every trimester for laboratory analysis
c) To conduct proximate analysis on the samples of NTPC Kahalgaon to determine their total moisture content, volatile matter, ash content and fixed carbon
d) Completion of four trimesters sampling and completion of sample analysis

e) Results and Discussions
f) Inferences and Recommendations

3. Materials and Methods

3.1 Sample Collection

Sample collection has been done four times in NTPC Kahalgaon during the period from 24th December 2015 to 5th November 2016. The sampling dates were selected for every trimester all-round the year which are given in the Table 1.

Table 1: Sampling dates at NTPC Kahalgaon

S. No.	Sampling No.	Sampling Date
1.	First trimester	24th December, 2015
2.	Second trimester	27th April, 2016
3.	Third trimester	15th July, 2016
4.	Fourth trimester	5th November, 2016

In December 2015 a coal stackpile of particular source was prepared with a height of 12 ft. The coal samples were collected from three different heights: bottom, middle and top of the stack. A sampling grid (Fig. 2 and 3) was drawn over the stack by 3/3 horizontal and vertical line. Each of the samples was to be collected from total intersecting grid points (total 12). 10 kg of sample was collected from those selected 12 intersecting points (Fig. 4). After collection, proper mixing and size reduction (-72 mesh), 5 kg of two replicate samples were prepared.

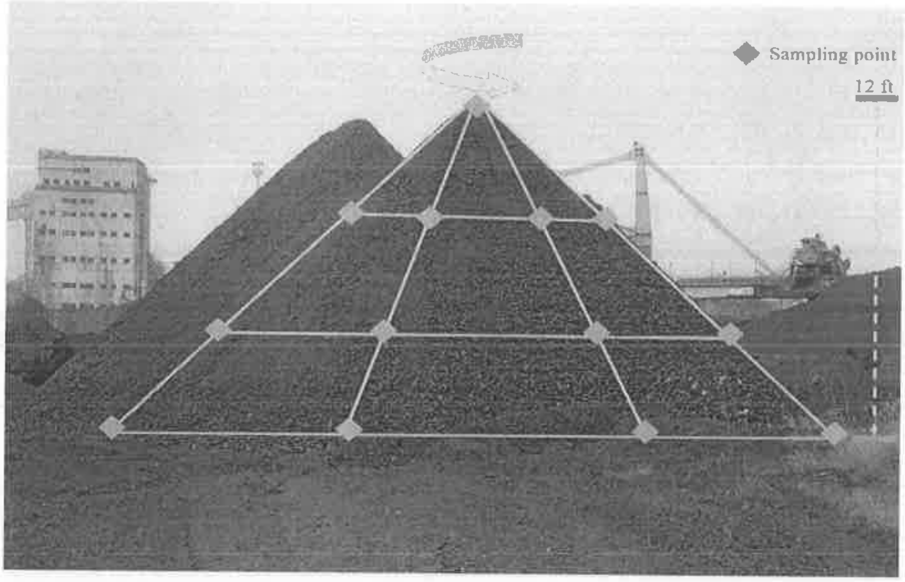

Fig. 2: Picture of stockpile depicting points of cross-sectional areas from where samples were collected

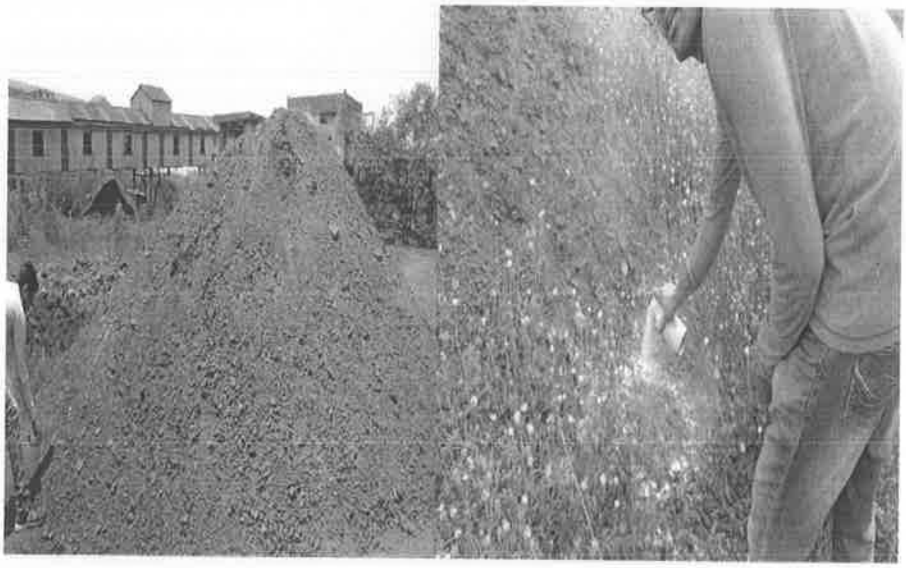

Fig. 3: Marking the cross sectional area for the sample collection

Fig. 4: Sample collection from the stackpile

3.2 Methods of Sample Preparation

3.2.1 Coning and Quartering

Coning and quartering is a method used by analytical chemists to reduce the sample size of a powder without creating a systematic bias. The technique involves pouring the sample so that it takes on a conical shape, and then flattening it out into a cake.

The coal samples were flattened in the form of cake and then divided into 4 quarters; two diagonally opposite quarters were randomly selected and discarded, while the other two were combined and constitute the reduced sample. The same process was continued until an appropriate sample size remains. All the coal samples after coning and quartering were brought to the site based sample preparation laboratory to carry out the further procedures of sample preparation.

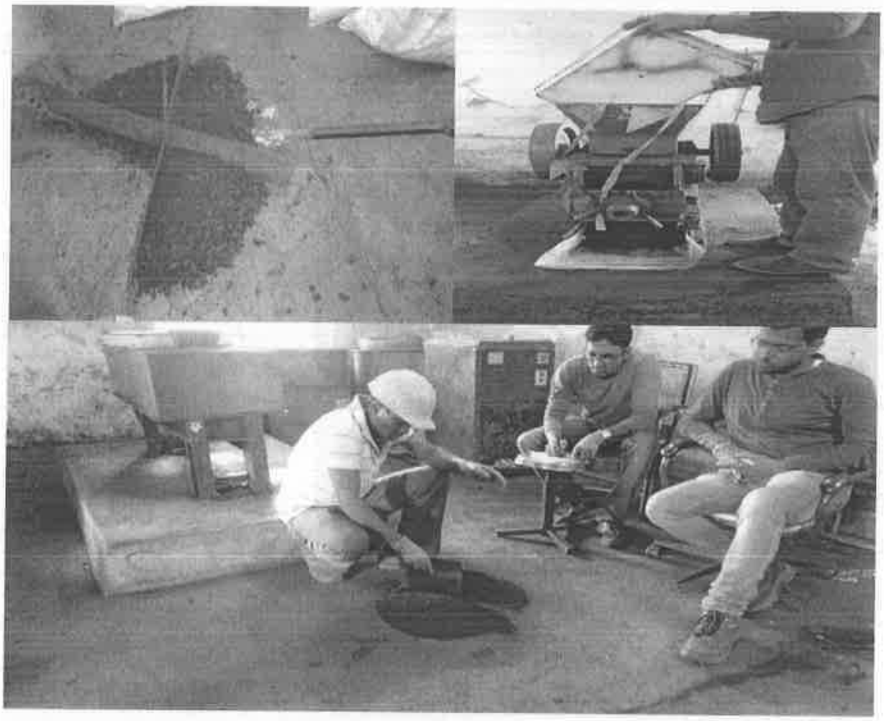

Fig. 5: Sample preparation at NTPC Kahalgaon laboratory

3.2.2 Crushing

Crushing reduces the overall top size of the run-off mine coal so that it can be more easily handled and processed within the Coal preparation plant (CPP). Crushing requirements are an important part of CPP design and there are a number of different types of crushers.

All the coal samples that were brought to the laboratory were crushed in three stage crusher, in order to reduce the coal size before its processing in the pulverizer unit. A roll type coal crusher of feed input (-) 12.5 mm, final output size (-) 3.35 mm with a capacity of 250 kg/hr was used. It utilized power of about 3 HP, 440 V, 50 Hz, AC to provide the coal size of 3.35 mm after crushing.

3.2.3 Pulverizing

A pulverized coal-fired boiler is an industrial or utility boiler that generates thermal energy by burning pulverized coal (also known as powdered coal or coal dust since it is as fine as face powder in cosmetic makeup) that is blown into the firebox. All the coal samples after crushing were brought to pulverizing unit to pulverize them to powder form for final GCV and proximate analysis. The basic idea of a firing system using pulverized fuel is to use the whole volume of the furnace for the combustion of solid fuels. Coal is ground to the size of a fine grain, mixed with air and burned in the flue gas flow. Biomass and other materials can also be added to the mixture. Coal contains mineral matter which is converted to ash during combustion. The ash is removed as bottom ash and fly ash. The bottom ash is removed at the furnace bottom. Pulverized coal provides the thermal energy which produces about 50% of the world's electric supply.

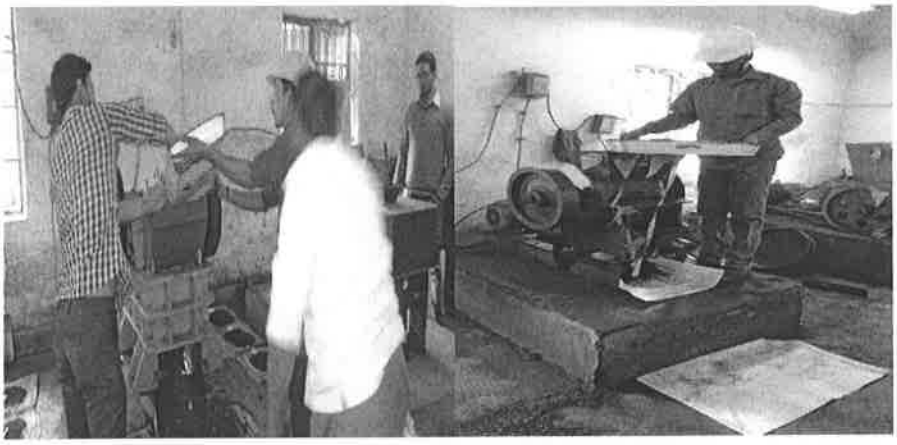

Fig. 6: Size reduction of the coal sample using roll crusher

Fig. 7: Pulverization of the coal sample by pulverizing unit

4. Determination of the parameters

It is expected that coal being a carbonaceous material is prone to spontaneous oxidation. The oxidation starts on the surface, resulting in carbon loss. This in turn, sets off weathering and disintegration that leads to weight loss. All these and the effects can be captured by the two tests:

a) Standardized Methods of Calculation of Gross Calorific Value
b) Standardized Methods of Proximate Analysis

4.1 ASTM D 5865-02, Standard Test Method for Gross Calorific Value of Coal and Coke

3.1.4 Clause: Gross Calorific Value (Gross heat of combustion at constant volume), Q_v (gross)—the heat produced by complete combustion of a substance at constant volume with all water formed condensed to a liquid.

3.1.7 Clause: Net Calorific Value (Net heat of combustion at constant pressure), Q_p (net)—the heat produced by combustion of a substance at a constant pressure of 0.1 MPa (1 atm), with any water formed remaining as vapor.

In its simplest form, the GCV is the maximum amount of energy that could be extracted from the coal under controlled conditions, e.g., as determined in a laboratory bomb calorimeter. Likewise, the NCV is the maximum amount of energy that could be extracted from the coal at the conditions at which the power plant is operated (i.e., with the generated steam being released to the atmosphere, without benefit of recovering the latent heat of condensation). NCV is smaller than GCV.

Proximate analysis has long been used to determine the rank of coals by separating volatile components, fixed carbon and inert components. Because of the wide ranging quality of coal products and the commercial value of ranking these products the need for good methods is obvious. To meet these needs there are ASTM® tests to perform these separations separately using specialized industrial equipment. When using the ASTM® methods, these tests are carried out with gram sized samples to reduce the effort required to get a representative, smaller sample.

The analytical requirements for proximate testing by TGA are modest: the ability to accurately record the weight of a sample as it is heated over a temperature range and held isothermally at designated temperatures, then change the sample's environmental atmosphere from inert to oxidizing. The instrument used has accurate temperature and gas control, a balance with microgram sensitivity, and software to facilitate and automate the analysis.

5. Results and Discussions

After reaching from NTPC station to IIT Kharagpur samples were tested for GCV analysis and proximate analysis. The studies were done at IIT Kharagpur immediately after bringing the samples to IIT Kharagpur. ASTM standard procedures were followed. Each sample was studied five times. The mean value was tabulated and is presented in the Table 2.