



## Non-Recovery Coke Ovens For North-East Indian Coals: An Attempt For Energy Utilization

**Nilakshi Kakati**

Coal Chemistry Division ,CSIR-North East Institute of Science &  
Technology, India

**Jayanta J Borah**

Coal Chemistry Division ,CSIR-North East Institute of Science &  
Technology, India

**Tonkeswar Das**

Coal Chemistry Division ,CSIR-North East Institute of Science &  
Technology, India

**Binoy K Saikia**

Coal Chemistry Division ,CSIR-North East Institute of Science &  
Technology, India

### **Abstract:**

*Demand for coke is on the rise and is predicted to go up further in the years to come. As on today, among the various commercially established coke making technologies, non-recovery/heat recovery ovens are established to be the sustainable ones. It has been investigated that the north eastern region (NER) of India has a number of coke ovens which are non recovery types and without heat recovery systems. Huge volume of coke oven gases released from these ovens which have high calorific values and contribute to major environmental degradation. In this paper, an attempt has been made for maximum utilization of these coke oven gases (COG) for heat recovery. The modern heat recovery ovens which are environmentally sustainable and have ease in operation have minimized the stringent environmental issues. This non-recovery/heat recovery coke making technology developed for high sulphur, high volatile coals of NER India for caking coals will be a promising technology for future, particularly in developing countries that are facing power and coke shortages.*

**Keywords:** *Non-recovery/heat recovery; high sulfur coals; coke oven gases; energy recovery*

### **Introduction**

Coke making in beehive ovens is quite advantageous for NE coals which exhibit special features i.e. high volatile matter and high caking index etc. A number of commercial firms have successfully commissioned carbonization batteries in the NE region and are producing quality cokes which find ready market specially by the electrode industries [1]. However, with the increasing number of such units there is a strong possibility of increased environmental pollution in and around the coke oven sites. The present project aims at developing suitable strategy to combat such pollution in commercial perspective.

Coke is manufactured conventionally by two methods i.e. by direct heating and indirect heating. In indirect heating, coal is pyrolysed in absence of air indirectly. Heat is supplied to the coal bed by some external source created by burning fuel gas in the combustion chamber adjacent to the coking chamber. The volatile matters come out of the coal bed after attaining the required temperature which subsequently cooled at different stages to collect various products. The coke ovens which are based on this technology are known as by-product oven [2]. The heat generated by the combustion of volatiles is then penetrated into the bed after radiating from oven top and also by conduction. The flue gas coming out of the oven carries a significant quantity of sensible heat in addition to some combustibles. As nothing other than coke is recovered it is called non-recovery coke oven and its potential of making power is utilized by generating electricity, it may be called heat recovery oven. Coke making started with the beehive ovens, which were later enhanced to non-recovery type of coke ovens. The by-product ovens because of the value addition due to the recovery of coal chemicals were preferred over non-recovery ovens as a more viable and profitable investment. The stringent pollution laws and the high cost involved in the installation of pollution control equipment led to many by-product coke oven plants to face closure in the 80's and 90's. This led to the revival of interest in the non-recovery coke oven technology as it was realized that it could be used with minimum investment and complied with the pollution control regulations [3]. Non-recovery coke ovens are used for production of coke, whereby products are not recovered. Power can be generated by means of waste gas heat recovery. In this way waste can be converted to wealth. Hence non-recovery type of coke oven is energy efficient and environment friendly. The northeastern region of India has a substantial deposit of

high sulphur, caking coals. Assam, Meghalaya, Arunachal Pradesh and Nagaland are the four coal producing states of the region. Unlike most of the Indian coals, these coals are of low ash content, high volatile matter, high sulphur, highly caking and friable. These coals normally belong to the tertiary age [4]. The sulphur content in these coals is in the range of 2-7% in general and majority of the sulphur is in organic matrix, which is not easily removable. Because of the sulphur content, these coals do not find easy in-take in the industries for stringent environmental regulations. However, these coals have found applications in brick, cement, ferro silicon, ferro alloys, tea garden etc. The production of coke from these coals in non-recovery coke ovens has been established as a viable proposition and has been found to be appropriate in the cement making by VSK technique.

The newly constructed oven specially for NE coals is provided with sufficient free space between the oven top and the coal bed where the volatile matters coming out from the coal charged during carbonization get combusted. The adequate free space as well as controlled supply of air ensures efficient combustion of the hydrocarbons present in the volatile matter [5-7]. The unburnt volatiles along with the hot flue goes to the sole via volatile chamber provided at the side walls of the oven where secondary air is injected to facilitate the complete combustion of the remaining hydrocarbons. The burning of the volatile matter in the sole increases the temperature of the coke oven bed that increases the efficiency of the coke oven. Also an additional combustion chamber has been provided for complete combustion of volatiles and settling down of particulate matters. All the above mentioned pollution control devices are inbuilt in the oven system. The clean flue gas can also be utilized in heat recovery units.

Here in this paper utilization of high sulphur coals of north-eastern region, non recovery and heat recovery ovens for maximum utilization of these coals, temperature profile across the reactor, composition of flue gases with respect to time, quality of cement clinkers produced using these cokes and also maximum recovery of COG for heat recovery are discussed.

### **Experimental**

The experimental results in the non-recovery set-up for NE coals for conventional and sole heating are compared in Table 2. The temperature profile inside the reactor using

NE coals is given in the Figure1, and average temperature attained during the carbonization period for various batches is given in Figure 2.

The overall material balance across the reactor for conventional ovens in terms of weight % during coking period is given in Figure 3 and rate of computed gas production in each hour based on material balance is given in Figure 4. Coking coals from NECL, Margherita, Assam and Meghalaya are collected and their physico-chemical characteristics evaluated as per standard methods are given in Table 1.

The process developed at NEIST, Jorhat for highly caking, low ash, high volatile and high sulphur coals of NE region has been found to yield good quality coke suitable for cement industries adopting vertical shaft technology. Coke samples have been prepared, homogenized and nodulised. The nodules were then used for clinkerisation under simulated condition as has been followed in VSK technology. The physico-chemical properties show that good quality cement clinkers (as per standards) are produced. The chemical composition of the clinkers obtained using NR cokes and standard cement clinkers and coke ash are given in Table 3.

Sl. No.	Coal Samples	Moisture	Ash	Volatile Matter	Fixed Carbon	Carbon	Hydrogen	Sulphur	Calorific Value
		%	%	%	%	%	%	%	Kcal/Kg
I	Assam Coal	2.3	4.99	41.35	51.4	75.9	5.45	2.24	8000
II	Meghalaya Coal	2.2	10.8	38.4	48.6	65	5.2	2.31	7780

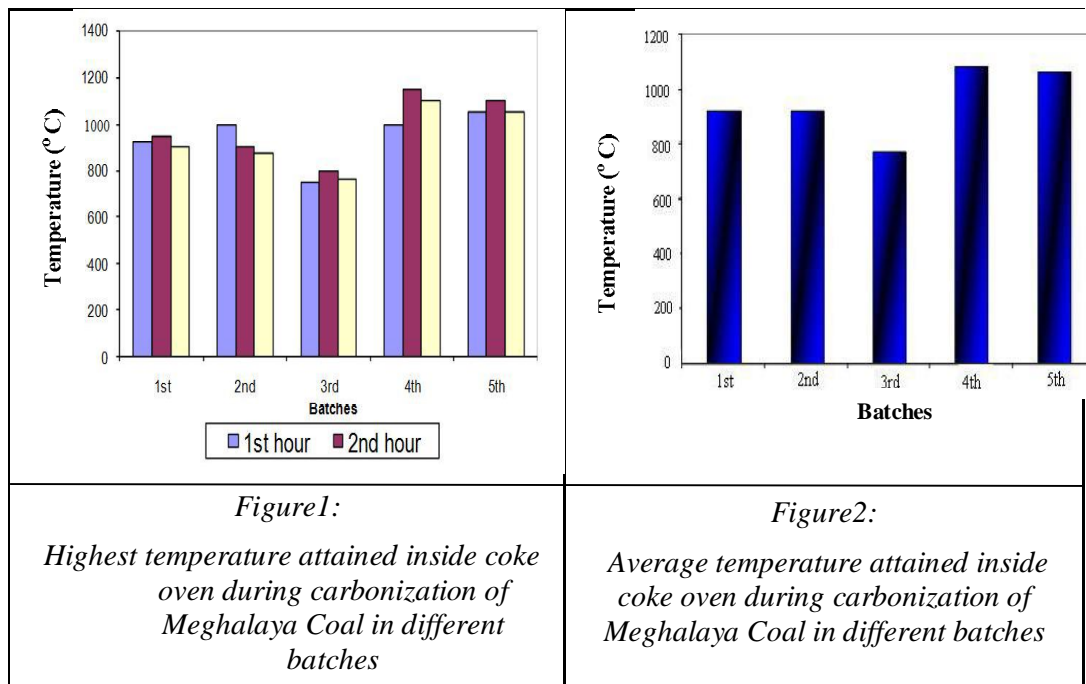
Table 1

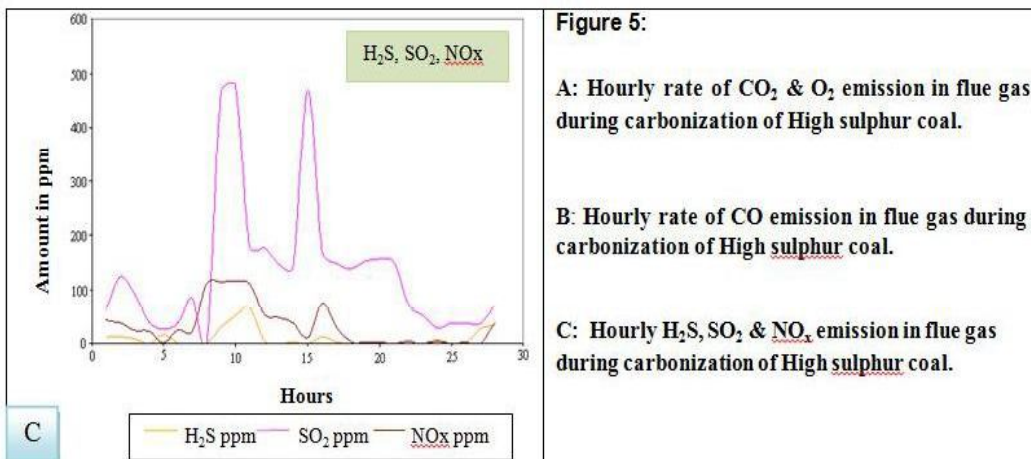
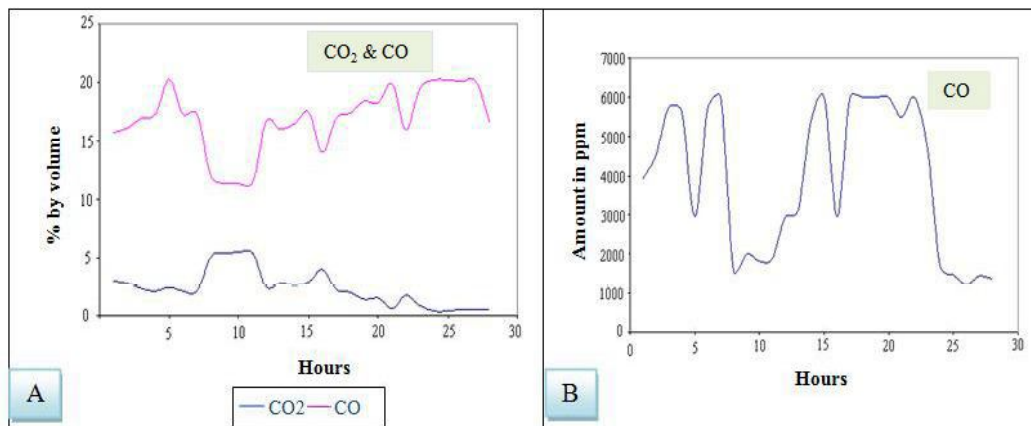
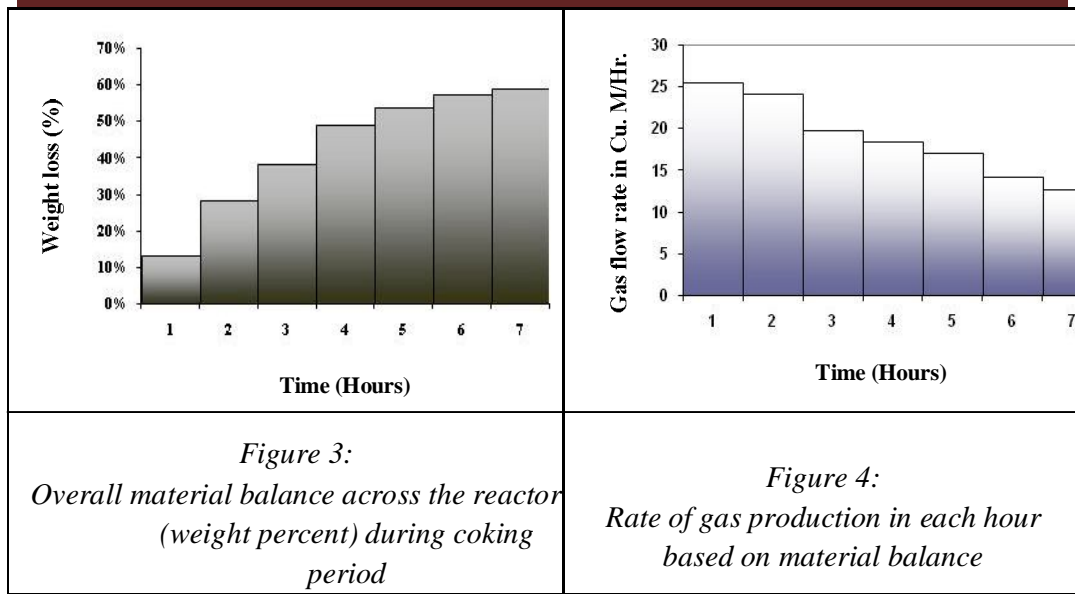
Type of Oven	Yield of coke	Temp of Discharge	Time of carbonization	Sulphur	Moisture	Ash	Volatile matter	Fixed Carbon	Calorific Value
	(%)	°C	hrs	(%)	(%)	(%)	(%)	(%)	Kcal/Kg
Conventional	40-43.3	800-1000	35-40	1.5-1.76	1.8-5.5	6-8.5	2-7	85-89	6390-7220
With sole heating	50-58	≥ 1000	24-26	1.5	1.82	10.45	2.7	85	6670-7220

Table 2

Constituents	Clinker using NR coke (%)	Standard Clinker (%)	Composition of coke ash used in Cement clinkers	
			Assam Coke	Meghalaya Coke
LOI	3.58	0.75	--	--
SiO <sub>2</sub>	19.88	22.38	49.80	49.50
Al <sub>2</sub> O <sub>3</sub>	6.87	6.10	17.10	27.07
Fe <sub>2</sub> O <sub>3</sub>	3.98	4.10	18.60	18.99
CaO	63.30	65.80	5.90	1.20
MgO	1.86	1.37	3.40	0.90
SO <sub>3</sub>	--	--	4.40	--
Alkalis	--	--	0.80	--
<b>Total</b>	99.39	100.50	100.00	97.66

Table 3





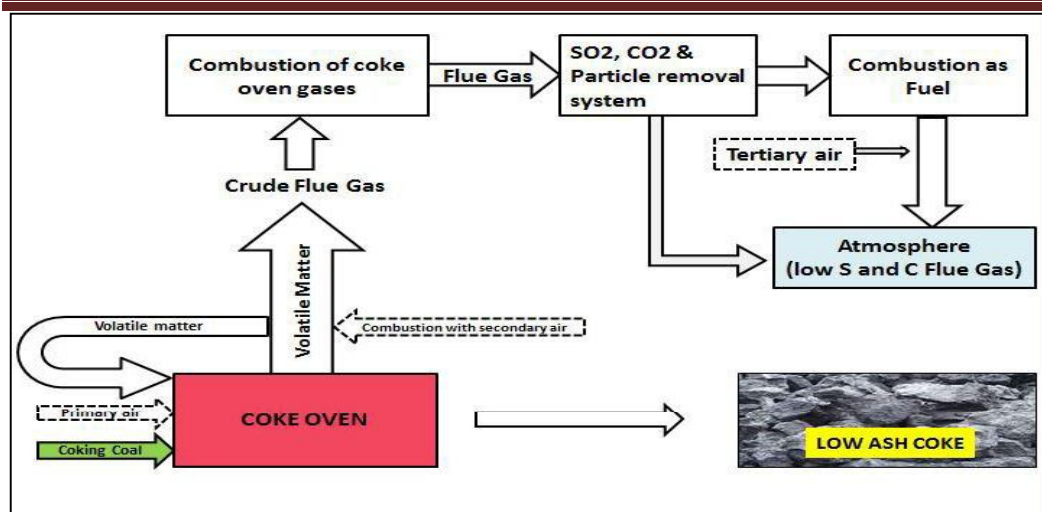


Figure 6: Flow sheet for Non-recovery Coke Oven for NER Coals.

## Results And Discussion

It has been found that yield of coke has been found to improve in sole heating systems for high volatile NE coals. The coking period has been found optimum at 24-26 hours in the pilot plant scale (kg/batch). The temperature profile across the reactor has been found to improve with continuous operation of the coke oven, which is more than 1000°C. The average sulphur retention value has been found to be 65%-70% in cokes. The yield of CO<sub>2</sub>, O<sub>2</sub>, CO, sulphurous (SO<sub>2</sub>, H<sub>2</sub>S) and NO<sub>x</sub> has been shown in the figure (A-C). The rate of evolution of sulphurous gases during 24 hours coking period has shown that critical period of S-evolution starts after 8 hours of coking time. The overall material balance across the reactor for conventional reactor shows lower yield of coke than newer type of oven with sole heating facility. The final weight loss corresponding to % of coke produced in non-sole heating system is shown in Figure 3. The computed rate of gas production per hour is given in Figure 4.

Some experiments were conducted on absorption of sulfurous gases on zinc oxide and other mixed oxide pellets prepared in the laboratory. The metal oxides i.e., zinc oxide (ZnO), Zinc ferrite (ZnFe<sub>2</sub>O<sub>4</sub>), Copper ferrite (CuO + Fe<sub>2</sub>O<sub>3</sub>) with 5% binder was used for making the sorbent pellets. The sintered pellets were used to absorb H<sub>2</sub>S at 550°C – 600°C at reduced atmosphere and were found to desulphurize COG's. A new process has also been developed for further reduction of sulfurous gases and volatiles i.e., an additional combustion chamber is constructed in the flue tunnel where sufficient space is provided for flue gas combustion with additional air supply. For



further reduction of sulphurous gases and volatiles, an additional combustion chamber is constructed where sufficient space is provided for flue gas combustion with additional air supply. The aqueous leaching of combusted flue gases can remove sulfurous and carbonaceous gases from COG's.

### **Conclusion**

Good quality cement can be manufactured using coke produced from high sulphur coal and of North-east region of India by Vertical Shaft Kiln process. Sulphur content in the coke ultimately improves strength of produced cement due to improvement in burnability of cement raw mix and the solid state reaction. These cokes are also used in foundry and metallurgical industries. The non-recovery coke making process developed for NER coals is a sustainable technology with low sulphur and carbon emissions.

### **Acknowledgement**

The authors are thankful for the financial grants of Ministry of coal and CSIR, New Delhi.

**Reference**

1. Beehive coke oven. (1984). A project report: Regional Research Laboratory, Jorhat.
2. Hazra, S.K. Non- recovery/heat recovery coke ovens: Design considerations and methods of heating. Book published during workshop on HR Coke-2005 (held at CFRI, Dhanbad during 26<sup>th</sup> -28<sup>th</sup> Feb 2005), pp 33-36; published by CFRI, Dhanbad.
3. Desulphurization of flue gas generated in beehive coke oven, (1987). A project report: Regional Research Laboratory, Jorhat.
4. Baruah, B.P., Bora, J.J., Bordoloi, D.K., & Rao, P.G. Utilization of coals from Northeast India. In: Proceedings on International Conference on Coking coals & Coke making: Challenges & Opportunities; Published by Viva Books Private Limited, held at Ranchi, India on 12<sup>th</sup> -14<sup>th</sup> Dec, 2005, pp 67- 75.
5. Baruah, B.P., & Khare, P. (2007). Pyrolysis of high sulphur coals. *Energy & Fuels*, 21(6), 3346-3352.
6. EPA. (2001). National Emissions Standards for Hazardous Air Pollutants (NESHAP) for Coke Ovens: Pushing, Quenching, and Battery Stacks — Background Information for Proposed Standards. Final Report. EPA-453/R-01-006. Research Triangle Park, NC: U.S. Environmental Protection Agency.
7. Barkakati, P., Bordoloi, D., Bandyopadhyay, S., & Borah, U.C. (1993). Physico-chemical characteristics of cement produced using sulphur bearing fuels in the black meal process for cement manufacture. *Cement and concrete research*, 23, 1185-1194.