

# HIGH TEMPERATURE CARBONIZATION OF COAL

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## INTRODUCTION

It is defined as heating the coal in absence of air to a final solid mass temperature of 900 degree Centigrade and above. It is the only method of producing hard coke from coking coal with better size consistency, hardness and richer in fixed carbon content to cater the needs of the blast furnace, foundry, and chemical industry.

The process started at the beginning of the 18<sup>th</sup> century by carbonizing good quality coking coal in heaps on the ground, which subsequently led to the development of beehive ovens of different shapes and sizes to meet the increasing demands of hard coke for iron smelting. Demand of coke followed by economic consciousness prompted scientist & technologist to introduce rectangular ovens having horizontal flues with complete by-product recovery system, which is followed by mechanization of charging and discharging system. Installation of high capacity blast furnaces compelled to develop modern high capacity coke ovens capable of producing harder coke of superior quality using coals of varying coking characteristics. Novel features of the modern ovens are faster coking rate, electronic control system, stamp charging of coal, dry quenching of coke, mechanized coal and coke handling system, pollution control devices in all allied units along with safety devices for men and machines.

## THERMAL BEHAVIOR OF COAL

When coal is charged into coke ovens after crushing, at a temperature around 1000 degree Centigrade, the reactive particles starts fusing and finally forms a vertical plastic layer along each heating wall which gradually moves towards the centre of the coal mass leaving behind a layer of semi-coke which in turn is converted into coke. The carbonization is said to be complete when these layers meet at the centre raising the coke mass temperature around 1000 degree Centigrade. The effects of heat on coal are as follows:

PRIMARY CARBONIZATION		SECONDARY CARBOIZATION	
330-380 deg C	Softening Temperature	500-650	V.M goes out & contraction starts
380-460 „	Plastic Range	650-700	Evolution of hydrogen& contraction
470-500 „	Resolidification	700-800	Major hydrogen& compactness starts
		>800	Hydrogen, Carbon Monoxide, low evolution, compactness and increase in strength

It takes about 16 hrs. in 400 mm wide coke oven to reach the coke mass temperature of 1000 deg. During the process of carbonization, volatile matters pass through the free space of the oven and finally goes to the bye product separation plant for collection of gas, tar, ammonia, benzol etc. Gas after purification is collected in gas holders, 40% of which is consumed to maintain the oven temperature and the balance is utilized in other plants.

#### BASIC ASPECTS OF HIGH TEMPERATURE CARBONIZATION

All coals right from lignite to anthracite are believed to be genetically related. It is the extent of metamorphosis and chemical changes which actually describe the rank evolution, the status and the position of coal in the long march of its coalification. It is seen that all kinds of caking coal, known in India, as prime, medium and semi to weakly caking coal are bounded by two carbon planes, i.e. 83.5 and 91.8 per cent in the coalification path. Beyond the limits on either sides, all other coals are virtually non-caking, and are outside the purview of coke making. In the metamorphic path of coal genesis when decarboxylation and dehydroxylation reactions are largely completed, and the atomic H/C ratio appears to fall due to commencement of dehydrogenation and demethylation reactions the caking property begins to develop in coals marked by about 84% carbon, reaches maximum at 90.5% carbon and there after shows a decreasing tendency. One of the prime requisites of metallurgical grade coal required for high temperature carbonization is the caking property which is structure oriented phenomenon, confined in limited reserves of coal.

When coal is heated in an inert atmosphere to a temperature of 350-450 degree Centigrade, certain coals soften and become deformable. Coals exhibiting this property are called plastic coal. Due to viscous nature of coal particles in their plastic states, they can coalesce or agglomerate to form a cake. Hence plastic coals are referred to caking coals. The plastic state is a transient phenomenon and the agglomerated mass eventually

solidifies into a semi-coke. Only those caking coals which can produce blast furnace grade coke are called prime coking coal. Plasticity is exhibited by exinite and vitrinite macerals only.

At the initial stage of heating during carbonization, kinetic energy of coal substance increases, as a result the aligned molecular coal species loosen themselves and become mobile. With further rise in temperature bond rupture may take place before general softening begins, then the free radicals produced would simply polymerize in a random fashion, even attacking other coal molecules forming bigger molecules and the chance of plastic deformation will be completely lost. Hence in order to achieve plasticity, the loosened coal fragments must be solvated as soon as they are formed and also stabilized, if present in free radical forms, by some low melting hydrogen rich bodies such as bitumen or exinites. Herein lies the importance of presence of such plastic-aiding materials in caking coals. Once the coal actually begins to melt, then the free radicals produced, would be stabilized by the donor hydrogen of the hydro-aromatic structure and the original bitumen would be of less consequence. Without the initial vehicle there would be no plasticity, no cake formation. It is the plastic mass which covers the entire thermally degraded coal substance and then solidifies as hard coke.

## HIGH TEMPERATURE COKE OVENS

- (i) Non-Recovery Ovens
- (ii) By-Product Ovens

**Non-Recovery Ovens :** They are normally known as bee-hive ovens. These ovens are suitable for operations to meet the sudden fluctuations in demand of hard coke. These ovens need less capital investment compared to by-product ovens. The coal bed is heated directly by the heat generated by burning the volatile matters inside the ovens on the bed top. Starting up and closing down of the ovens are much easier than that of by-product ovens. By-products of carbonization are burnt inside the oven there by causing less pollution. Now a days developed countries are preferring modern non-recovery coke ovens with the aim of generating less pollutants and more economy. There are mainly two types of bee-hive ovens i.e. circular base bee-hive ovens and rectangular base bee-hive ovens. Circular base ovens do not permit mechanical devices for quick discharging of coke from the ovens thereby increasing the coking times. On the other hand The rectangular base ovens can be mechanized to a considerable extent and can quickly discharge the product thereby reducing the coking time. Technologies are being developed for improving the performance of rectangular type non-recovery coke ovens to the extent possible.

By- Product Ovens : In this type of ovens the coal is heated indirectly in absence of air and the constituents of volatile matters evolved, are separated by cooling at different stages and further processed as per requirement of the end products. The fuel gas generated is cleaned and reused partially for heating the ovens from both the sides. The process yields very high quality coke suitable for blast furnace use. The process is highly capital intensive. This type of oven has mainly five important sections i.e. coking chamber, heating system, by-products and gas collecting systems, charging and discharging of ovens, coke quenching and handling. Various technologies for these sections have been developed . Some of these technologies are shown below.

## TECHNOLOGICAL INNOVATIONS

The physical and chemical properties of coke produced by high temperature carbonization of coal is primarily (about 70%) <sup>depends</sup> on the constituents of coal and remaining (about 30%) on the other factors i.e. operating conditions/technology etc. Some of the technologies are shown below :

### (A) Pre-Carbonization Technology

- (i) Coal beneficiation
- (ii) Coal crushing
- (iii) Coal blending
- (iv) Methods of charging
- (v) Inclusion of additives
- (vi) Partial briquette blending
- (vii) Pre heating of coal charge

### (B) Carbonization Technology

- (i) Control of flue temperature
- (ii) Changing the thickness of the wall
- (iii) Changing the dimension of the oven
- (iv) Adjustment of the pressure

(C) Post-Carbonization technology

- (i) Changing the method of quenching
- (ii) Stabilization of coke through sizing

**COMPARATIVE ECONOMICS OF CARBONIZATION BETWEEN BP AND BH OVENS**

Basis : One million ton of coke per year

Sl.No.	Particulars	Non-Recovery Ovens		By-product ovens
		Imp.BH	Old BH	
(i)	No. of Ovens	30	50-60	35
(ii)	Capital Rs./t/yr.	800-1000	500-700	4000-10000
(iii)	Operational Rs./t	300-400	300-450	750-900
(iv)	Cost of Production (coal sensitive)	2200-2800	2100-2700	2600-3200
(v)	Thermal Efficiency %	65-80	40-60	80-87
(vi)	Specific Energy MJ/kg	6-10	12-20	2.3-2.5
(vii)	Coke Yield %	70-80	55-65	72-76
(viii)	Coking Time (hr.)	24-40	48-72	14-18

## COST COMPARISON BETWEEN NON-RECOVERY AND BY-PRODUCT COKE OVENS

Sl.No.	Particulars	BH:BP
(i)	Capital Cost	1 : 4
(ii)	Operational Cost	1 : 2.5-3.0
(iii)	Maintenance Cost	1 : 5-6
(iv)	Construction Period	1: 3-4
(v)	Interest on Capital	1 : 5-6
(vi)	Return ( DCF Rate )	1.5 : 1

## WASTE HEAT RECOVERY IN NON-RECOVERY COKE OVENS

Attempts have been made by the designers to utilize the heat being wasted by the flues in various ways i.e. by heating the primary and/or secondary air ,drying the coal,making steam and generating power. It has been reported that the factors of uncontrolled generation of waste gases and small capacities may make the operation inefficient. The approximate estimates of power generation and the capital cost of such facility may be recorded as below :

	A	B	C	D
(i) Plant Capacity (t/a)	38000	67000	115000	230000
(ii) Power Generation (MW)	0.75	1.5	2.5	5.0
(iii) Cost of Facility (Rs. Million)	30	60	90	180