How is Crude Coal Tar Derived?

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INTRODUCTION

Crude Coal Tar is a by product of the Coking process. Coking is the process of heating coal in coke ovens to drive volatile matter from it.   Metallurgical Coke is used as a fuel and reducing agent in the production of iron, steel, ferro-alloys, elemental phosphorus, calcium carbide and numerous other processes. It is also used to produce carbon electrodes and to agglomerate sinter and iron ore pellets.

COKE PRODUCTION

The coke making process involves carbonization of coal to high temperatures (1100°C) in an oxygen deficient atmosphere in order to concentrate the carbon. **The commercial coke making process can be broken down into two categories: a) By-product Coke making and b) Non-Recovery/Heat Recovery Coke making**. A brief description of each coking process is presented here.

a) By-product Coke Production:

The majority of coke produced in the United States comes from wet-charge, by-product coke oven batteries (Figure 1). The entire coke making operation is comprised of the following steps: Before carbonization, the selected coals from specific mines are blended, pulverized, and oiled for proper bulk density control. The blended coal is charged into a number of slot type ovens wherein each oven shares a common heating flue with the adjacent oven. Coal is carbonized in a reducing atmosphere and the off-gas is collected and sent to the by-product plant where various by-products are recovered. **The modern by-product coke oven recovers volatile chemicals in the form of coke oven gas, tars, and oils.** Hence, this process is called by-product coke making.

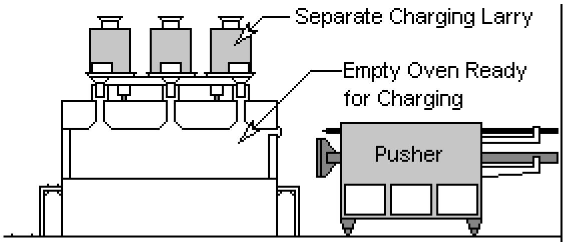
Figure 1: "Coke Side" of a By-Product Coke Oven Battery. The oven has just been "pushed" and railroad car is full of incandescent coke that will now be taken to the "quench station".

Figure 2: Incandescent coke in the oven waiting to be "pushed".

The coal-to-coke transformation takes place as follows: The heat is transferred from the heated brick walls into the coal charge. From about 375°C to 475°C, the coal decomposes to form plastic layers near each wall. At about 475°C to 600°C, there is a marked evolution of tar, and aromatic hydrocarbon compounds, followed by re-solidification of the plastic mass into semi-coke. At 600°C to 1100°C, the coke stabilization phase begins. This is characterized by contraction of coke mass, structural development of coke and final hydrogen evolution. During the plastic stage, the plastic layers move from each wall towards the center of the oven trapping the liberated gas and creating in gas pressure build up which is transferred to the heating wall. Once, the plastic layers have met at the center of the oven, the entire mass has been carbonized (Figure 2). The incandescent coke mass is pushed from the oven and is wet or dry quenched prior to its shipment to the blast furnace.

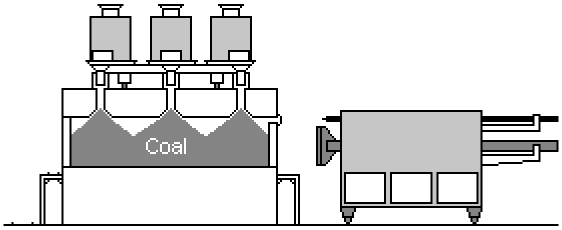
Process Flow Diagram:

Coke Oven Operation



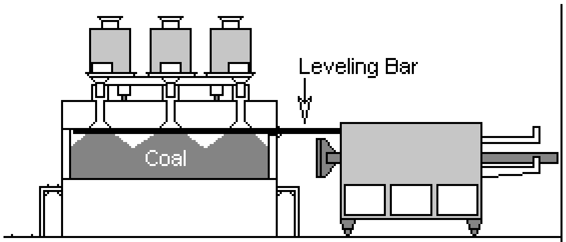
The charging larry, with hoppers containing measured amounts of coal is in position over charging holes from which covers have been removed. The pusher has been moved into position.

First Step



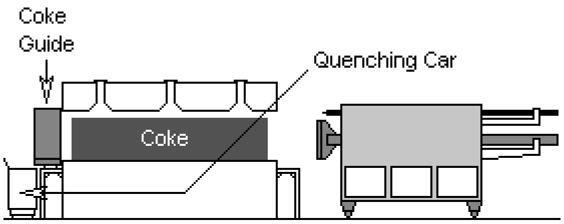
The coal from the larry hoppers has dropped into the oven chamber, forming peaked piles.

Second Step



The leveling door at the top of the oven door on the pusher side has been opened, and the leveling bar on the pusher side has been moved back and forth across the peaked coal piles to level them. The bar next is withdrawn from the oven, the leveling door and charging holes are closed, and the coking operation begins.

Third Step

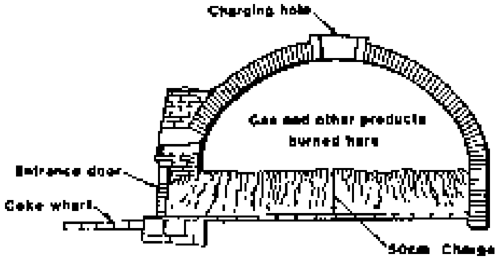


Coking of the coal originally charged into the oven has been completed (in about 18 hours) and the oven is ready to be "pushed". The oven doors are removed from each end, and the pusher, coke guide and quenching car are moved into position.

Fourth Step

b) Non-Recovery/Heat Recovery Coke Production:

In Non-Recovery coke plants (originally referred to as beehive ovens) the coal is carbonized in large oven chambers (Figure 3). The carbonization process takes place from the top by radiant heat transfer and from the bottom by conduction of heat through the sole floor. Primary air for combustion is introduced into the oven chamber through several ports located above the charge level in both pusher and coke side doors of the oven. Partially combusted gases exit the top chamber through "down comer" passages in the oven wall and enter the sole flue, thereby heating the sole of the oven. Combusted gases collect in a common tunnel and exit via a stack which creates a natural draft in the oven. Since the by-products are not recovered, the process is called Non-Recovery coke making. In one case, the waste gas exits into a waste heat recovery boiler (Figure 3) which converts the excess heat into steam for power generation; hence, the process is called Heat Recovery coke making.



Generalized cross-section of a beehive coke oven with a charge of coal (Roger 1998)

Here is a picture from 1974 of the extractor pulling coke from an oven and loading it into rail cars. A flume on the machine catches the "dribble." (Public domain photo by William Barrett, HAER (Historical American Engineering Record)

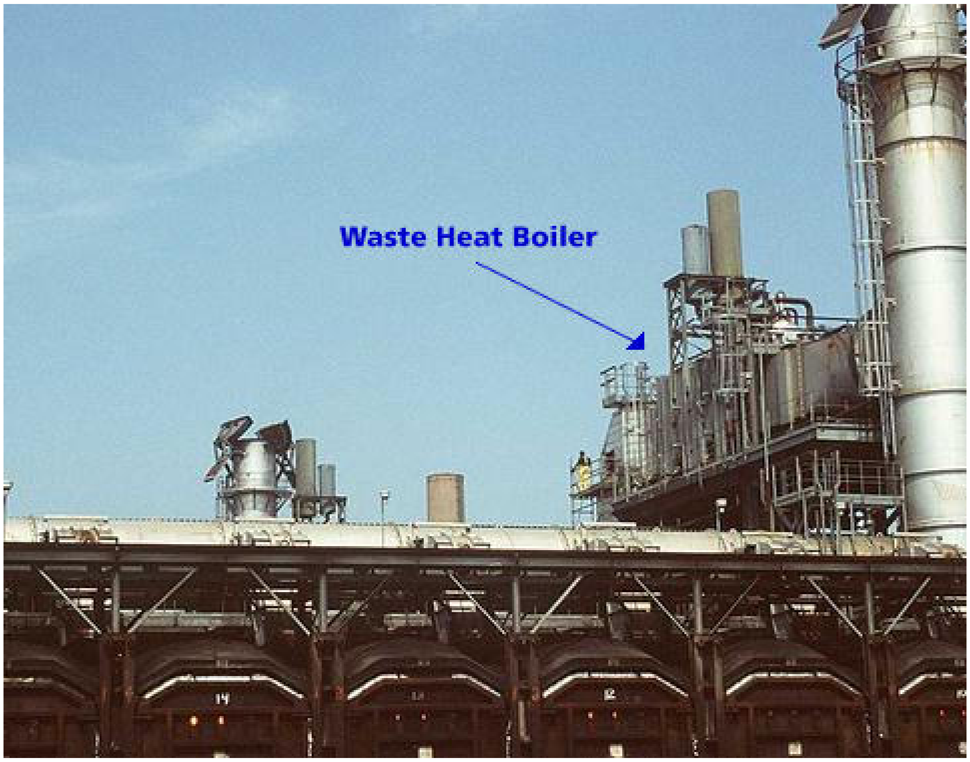


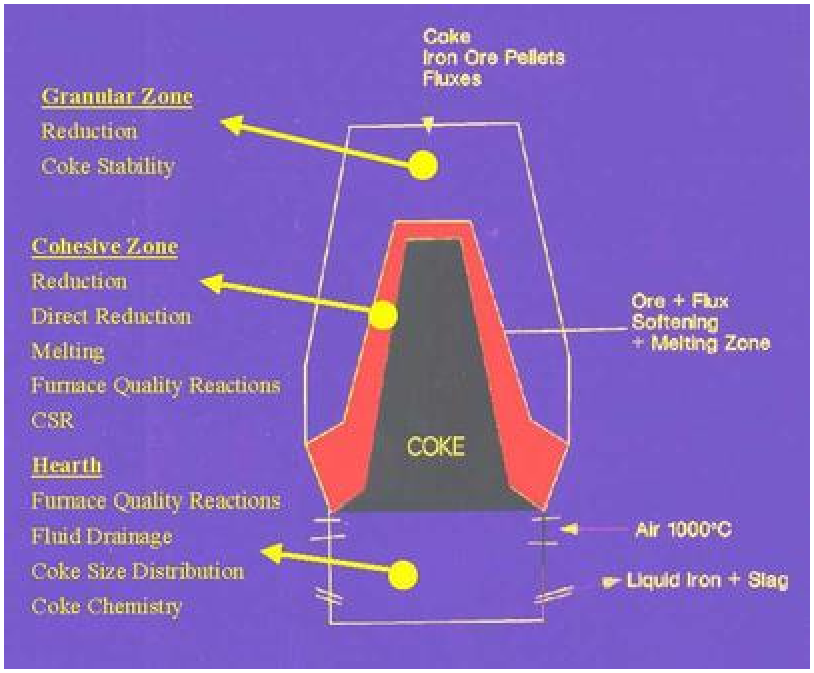
Figure 3: Heat Recovery Coke Plant.

COKE PROPERTIES

High quality coke is characterized by a definite set of physical and chemical properties that can vary within narrow limits. The coke properties can be grouped into following two groups: a) Physical properties and b) Chemical properties.

a) Physical Properties:

Measurement of physical properties aid in determining coke behavior both inside and outside the blast furnace (Figure 4). In terms of coke strength, the coke stability and Coke Strength After Reaction with CO_2 (CSR) are the most important parameters. The stability measures the ability of coke to withstand breakage at room temperature and reflects coke behavior outside the blast furnace and in the upper part of the blast furnace. CSR measures the potential of the coke to break into smaller size under a high temperature CO/CO_2 environment that exists throughout the lower two-thirds of the blast furnace. A large mean size with narrow size variations helps maintain a stable void fraction in the blast furnace permitting the upward flow of gases and downward of molten iron and slag thus improving blast furnace productivity.



Blast Furnace Operating Zones and Coke Behavior.

b) Chemical Properties:

The most important chemical properties are moisture, fixed carbon, ash, sulfur, phosphorus, and alkalis. Fixed carbon is the fuel portion of the coke; the higher the fixed carbon, the higher the thermal value of coke. The other components such as moisture, ash, sulfur, phosphorus, and alkalis are undesirable as they have adverse effects on energy requirements, blast furnace operation, hot metal quality, and/or refractory lining. Coke quality specifications for one large blast furnace in North America are shown in Table I.

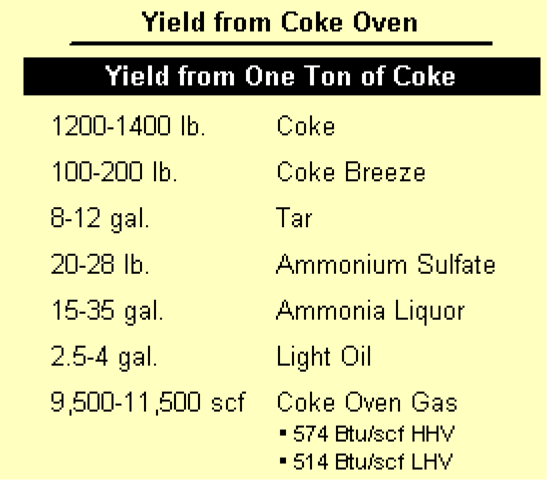
Table I. Coke Quality Specifications:

Physical: (measured at the blast furnace)	**Mean**	**Range**
Average Coke Size (mm)	52	45-60
Plus 4" (% by weight)	1	4 max
Minus 1"(% by weight)	8	11 max
Stability	60	58 min
CSR	65	61 min
Physical: (% by weight)		
Ash	8.0	9.0 max
Moisture	2.5	5.0 max
Sulfur	0.65	0.82 max
Volatile Matter	0.5	1.5 max
Alkali (K_2O+Na_2O)	0.25	0.40 max
Phosphorus	0.02	0.33 max

FACTORS AFFECTING COKE QUALITY

A good quality coke is generally made from carbonization of good quality coking coals. Coking coals are defined as those coals that on carbonization pass through softening, swelling, and re-solidification to coke. One important consideration in selecting a coal blend is that it should not exert a high coke oven wall pressure and should contract sufficiently to allow the coke to be pushed from the oven. The properties of coke and coke oven pushing performance are influenced by following coal quality and battery operating variables: rank of coal, petrography, chemical and rheologic characteristics of coal, particle size, moisture content, bulk density, weathering of coal, coking temperature and coking rate, soaking time, quenching practice, and coke handling. Coke quality variability is low if all these factors are controlled. Coke producers use widely differing coals and employ many procedures to enhance the quality of the coke and to enhance the coke oven productivity and battery life.

Typical Coke Oven Yield



Yield from Coke Oven

Yield from One Ton of Coke

1200-1400 lb.	Coke
100-200 lb.	Coke Breeze
8-12 gal.	Tar
20-28 lb.	Ammonium Sulfate
15-35 gal.	Ammonia Liquor
2.5-4 gal.	Light Oil
9,500-11,500 scf	Coke Oven Gas ▪ 574 Btu/scf HHV ▪ 514 Btu/scf LHV

References:

1. Website:
http://www.energysolutionscenter.org/HeatTreat/MetalsAdvisor/iron_and_steel/process_descriptions/raw_metals_preparation/coking/coking_process_description.htm

2. Website:
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7. Website:

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