Effect of coke properties on cupola furnace operation and performance of FOUNDRY COKE

There are at present no reliable quantitative relationships regarding the effect of coke properties on furnace operation. In spite of this, there is qualitative and in some instances, semi quantitative which indicates that coke properties can significantly affect cupola furnace operation. This is, of course, consistent with the cupola furnace as well as in the maintenance of acceptable fluid dynamic conditions. Specifically, coke must provide the following chemical and physical functions:

1. Chemical – Combine with oxygen to provide the following white simultaneously minimizing the introduction of sulfur and slag components which adversely affect furnace efficiency:
   a) The heat required for reducing iron oxide and melting slag and iron.
   b) The CO required to reduce iron oxide.

2. Physical – Provide adequate permeability within the burden so that a counter current movement of hot reducing gases and molten slag and iron is maintained.

From the combustion point of view, coke is relatively inert and requires relatively high temperatures to initiate a reaction with oxygen that is sufficient to provide the heat necessary for reducing iron oxide and for melting slag and iron. To a good first approximation, this occurs in the immediate vicinity of the furnace tuyeres, where ambient or heated air (greater than 1000°C) reacts with hot coke to produce a temperature sufficient for furnace operation greater than 1400°C). Thus, to provide the maximum benefit as a fuel, the amount of contained carbon in the coke should be maximized and hence the ash content minimized. After taking this constraint into account, there are no limitations on coke as a fuel source other than the obvious criterion that the bulk of it survives the passage through the furnace at the tuyeres.

Foundry Coke

Coke is the fuel used for melting iron in the cupolas of foundries. A cupola consists of a vertical, cylindrical, steel shaft, lined with fire-clay brick. It is provided with a door near the top for introduction of the charge, which consists of alternate layers of coke, limestone, pig iron, and scrap. Air that is not pre heated is introduced into the cupola through tuyers evenly spaced around the 'circumference near the bottom. The coke burns in the blase of air, and the heat generated is sufficient to melt the iron, which trickles down to the base of the cupola. The upper portion of the cupola is termed the "Stack". The combustion products leaving the charge pass through the stack to the atmosphere. Below the molten iron periodically. The whole furnace is supported above floor level on pillars. The arrangement of a cupola is attached as Sketch-1.

Cupola of moderate size with a diameter of 54in. Inside the lining will melt 11.5 tons of iron per hour with a 10:1 iron-to-coke ratio. The height of the bed above the tuyeres may be 45 to 51in., and 5200 cubic feet of air per minute is blown in with a normal pressure of 18oz in the windbox located around the tuyeres. Melting temperatures are usually in the range 1370 to 1600°C (2500°F to 2900°F), depending on the kinds of iron produced.

A cupola furnace is not adapted to controlling or altering the composition of the iron appreciably. The composition of the cast iron will be close to the average composition of the charge of pig iron and scrap. The combustion gases ascending through the charge are slightly oxidizing in character, and oxidize small amounts of silicon, manganese, iron, and carbon, as well as sulfur and phosphorus. The oxides of iron, silicon, and manganese, as well as sand, dirt, and oxides associated with the charge and
the ash of the coke, are fused with the limestone at the cupola temperatures to form the slag.

Considerable disagreement has also arisen as to the most desirable properties in a foundry coke; in general, operators agree to the following characteristics.

1. The pieces should be large in size. The structure should be dense with small cells, thick cell walls, and porosity below 50 percent.
2. The coke should have a high ignition temperature and a high reactivity with oxygen to produce carbon dioxide. The heating value, carbon content, graphite content, strength, hardness, and apparent and true specific gravities should also be high.
3. The reactivity of the coke with carbon dioxide to produce carbon monoxide should be low. In addition, the moisture, ash, volatile, sulfur, and phosphorus contents should be low.

Foundry coke usually ranges in size 2 to 5 in (i.e. to 125mm) larger. In general, the larger sizes are preferred by foundry operations. Small coke tends to fill voids in the charge, a condition which increases the blast temperature. The tendency of the coke to react both with carbon dioxide and oxygen is increased by decreases in size, because of the greater surface exposed. A relationship between coke size and cupola diameter may possibly exist, and it has been suggested that the maximum coke size be one-twelfth of the cupola diameter.

The structure of the coke is important because of its influence on its strength and on its reactivity of the dense coke is believed to be low. High strength in a foundry coke is necessary so that it will resist without excessive breakage the harsh treatment it receives in handling and charging, and the weight of the charge above it.

When coke burns completely to carbon dioxide, the maximum amount of heat is released. The temperature in the cupola are, however, high enough for the carbon dioxide to react with more coke with formation of carbon monoxide, in accordance with the reaction: \( \text{CO}_2 + \text{C} = 2\text{CO} \). Carbon monoxide is not desirable, in the cupola. The reaction by which it is created proceeds with absorption of heat, thus reducing the thermal efficiency of the process. Moreover, carbon monoxide is a reducing gas, and by its presence the coke with carbon dioxide to form carbon monoxide in increased by increasing the surface of the coke exposed to the gases, by use of either small sizes of coke or a coke with an open structure. A coke which has been thoroughly in the oven, so that the volatile matter is very low or graphitic carbon has formed on the surface, is less reactive with carbon dioxide than a less completely carbonized coke, and for this reason is preferred.

Volatile matter is driven off from the coke at the cupola temperatures, and the heat unites which it represents will not be utilized in the melting process. Consequently the volatile-matter content, which also serves as an index of the completeness of carbonization, should be low.

Sulfur and phosphorus are picked up from the coke by the molten iron. A high sulfur content tends to make an iron which is brittle when hot. The characteristic is commonly termed "hot-shortness". Phosphorus increase the brittleness of cold metal, and this characteristic is termed "cold-shortness". Each element should be, present in the coke in only a low concentration.

Ash serves no useful purpose in the cupola but reduces the fuel value of the coke. It is one of the sources slag. Heat is consumed in raising its temperature, and any increase raises the amount of fluxing materials required in the charge. It usually between 8 and 12 percent.