THE
EFFICIENT USE OF COKE

PRODUCING QUALITY IRON FROM LOWER QUALITY COKE

LEARNING TO LIVE WITH HIGHER SULFUR AND ASH COKE THAT HAVE LOWER STRENGTH AND FIXED CARBON

by

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INTRODUCTION: Worldwide energy use is forecast to double in the next 20 years. The U.S. uses 25% of the world's energy supply. Burning coal generates 52% of the U.S. energy. Coal reserves in the U.S. are gigantic, however, most of the coal contains high sulfur which, when burned, is the cause of air pollution and acid rain. The air pollution can be significantly reduced by burning low sulfur bituminous coal. This type of coal is also the primary raw material for producing coke and in demand by large electrical generating plants that need to reduce pollution.

All coke is made from coal but not all coals can be used to make coke. Blast furnace coke can be made from a greater variety of metallurgical coals than foundry coke. **Foundry coke must be made from low volatility, low sulfur coals. These coal types are in very short supply.** Many mines have closed because of economic problems, EPA action or because the sources have been depleted. New sources of low volatility, low sulfur-coal have not been developed. They may not exist. Lesser quality coals will have to be utilized in the future to produce foundry coke. This will result in higher sulfur and ash contents in the coke with lower fixed carbons and strength. Coal costs will only increase in the future. Supply interruptions may occur and coke prices will increase. This problem will not go away any time soon, if ever, therefore, the cupola iron foundry is challenged to efficiently use the coke available to produce iron that must increasingly meet tighter specifications.

Simultaneous with the lack of availability of high quality coke, the quality of scrap streams has likewise deteriorated over the years. **When the elevated sulfur and ash levels stemming from poor quality coke, coupled with the slag-promoting characteristics of sub-standard scrap, are merged together in a cupola, reduced cupola melting efficiency, reduced metal quality and slag buildup in downstream metal holding vessels will become very troublesome.**

DISCUSSION:

The discussion portion of this paper reviews time proven methods of how to operate a cupola more efficiently and possibly, burn less coke.

A cupola should run in a reasonably controlled fashion. Do not put up with consistently occurring problems – the bottom will not drop, the bottom leaks through, the front slagging dam fails every few days, the refractory repairs do not last, etc. If the recurring problems cannot be solved, obtain expert advice. Some is free (from suppliers) and some has to be paid for (consultants) but all is worth the price if the problem is eliminated.

There are a number of things that a foundry can do to better confront the problems associate reduced coke quality. They are important for good operation under current conditions but critical with the use of poorer coke quality. They will require considerable effort but little, if any, expenditure. They are listed as follows:

- Coke bed – unless the bed is properly put in, there will be problems during the entire campaign. There should be written procedures and checklists for this operation.
- Refractory repair – after the bottom is dropped the lining must be cleaned and repaired. Unless the lining is properly repaired, operational problems will occur. Unfortunately, the repairs are done when there is little or no supervision. This operation should be covered by written procedures and proper training.
- Coke – keep it dry! Wet coke makes calculation of the correct charge weight difficult. Over-coking or using extra bumps to compensate occurs. This increases the coke consumption.
- Do not charge dirt, small metallics, rust, etc. Screen the charge over a ½ inch screen. Keep the screen clean and in good repair. This will reduce the requirement for additional limestone or supplemental fluxes, decrease refractory attack and avoid excessive back pressure.
- Do not charge thin, leafy (tin cans) steel. It oxidizes quickly and readily picks up sulfur. Do not charge railroad tie plates, spikes, etc., because they are usually highly oxidized. Highly oxidized scrap, regardless of price, is very expensive! Dirty, rusty scrap will increase slag generation and reduce overall metal handling efficiency.
- Do not charge very large pieces of metallics, i.e. over 1/3 the cupola diameter. These pieces disrupt the entire operation of the cupola. Very large pieces are an invitation to disaster!
- Avoid coke breakage – easy to say but hard to accomplish. Coke will be weaker in the future! Rough handling will cause serious breakage.
- Coke size is important. Larger is not always better. Coke size should be 1/10 – 1/12 the diameter of the cupola when it is added at the charge door. Buying large size coke knowing some will up as fines during handling creates a mixture of large and small sizes, reducing combustion efficiency.
- Screen out the ½ inch x down coke fines and consider injecting them through the tuyeres using a BRI gun or suction tuyere.
- If the bottom is dropped everyday consider going to longer campaigns. Refractory suppliers can be of considerable assistance.
- Water leaks from the shell or tuyeres cause serious problems. Fix the leaks ASAP
- Keep the cupola full – no excuses!
- Use more oxygen. The objective is to use less coke.
- Determine the ideal melting rate for your cupola. This is calculated by determining the cross sectional area of the tuyeres, the hearth and the blast rate. If the foundry cannot do the calculations there are consultants available who can assist. If the numbers indicate an imbalance, they should be corrected. This may require a larger blower, different diameter tuyeres, etc., but making the changes will increase the efficiency of the cupola. The sales department should be aware of the ideal number. This figure is as important as the ideal production of molds per hour, the core making capacity, etc.
- New and better refractories come on the market every day. Do not live with refractory problems. Refractory companies can be a valuable asset in solving these problems.

- Water-cooled steel shells with no refractory linings consume more coke than lined shells. Consider lining the shell if this is not the current practice.
- Fluxes -"if they are so cheap they can't be important!" **Coke ash, oxidation products, dirt, iron oxide, fluxed refractory lining, etc., all combine to form slag.** This highly acidic slag must be fluxed by adding basic constituents such as high calcium limestone or dolomite.

  Without proper fluxing the slag will coat the coke, preventing combustion and bridge in the areas chilled by air from the tuyeres. Good slag quality is evidenced by how easily it flows from the cupola. When the slag flow is sluggish, it tends to build up to the point of clogging the tuyeres, causing serious problems. Bridging is also a condition resulting from poor slag fluidity. Large cupolas use 2.0 to 4.0 percent of the metallic charge, usually in the form of limestone, and smaller cupolas commonly employ 3.0 to 7.0 percent of the metallics as limestone. Another rule is to use 20 to 25 percent of the weight of the charged coke as limestone. If the coke ash increases, more limestone may be required. Poor fluxing can result in lower carbons and temperatures, reduced melt rates and increased oxidation. There should be a specification for the flux that includes chemistry and size. **Supplemental flux additions of soda ash or fluorspar will reduce the viscosity of limestone slags and improve their performance.**

  Limestone suppliers should submit an analysis of the material at least every 6 months! The limestone flux should be sized 2 inch x ½ inch. Fines will blowout and large lumps do not properly calcine. If the standards for the limestone flux stone are not set, the supplier may ship substandard material that will affect the operation!
- The flux should be evenly distributed through out the charge. Do not put it in one side of the bucket. Ever wonder why the charges tend to always hang up in the same location? This could be due to charging limestone flux and fines in the same location with every charge. As coke quality drops, fluxing will take on a new importance!
- **A supplemental flux addition such as fluorspar or a newly developed, proprietary sodium oxide based briquette, available from ASI International (www.asi-alloys.com) will significantly reduce the melting point and viscosity of the slag generated from limestone, flush coke ash from the surface of the burning coke, allowing it to burn more incandescently, resulting in hotter iron and improved carbon recoveries. It should be noted that fluorspar produces undesirable fluorine emissions.**

METALLURGICAL CONSIDERATIONS: An iron containing 0.15 percent sulfur and 0.80 percent manganese has been observed to form manganese sulfide related porosity when poured below 2460°F. Reducing the manganese to 1.7 times percent sulfur plus 0.30 will result in a manganese of 0.56 percent and will lower the critical pouring temperature. Excess manganese contents can be lowered to 0.20 percent without any metallurgical problems if adequate controls and accurate analyses are available. The minimum manganese for cupola-melted iron is 0.45 percent. This level will help prevent oxidation. High sulfurs have been associated with increased chilling tendencies. There is, however, a small bright side to the higher sulfur content. Gray irons with high levels of manganese sulfide inclusions have been shown to have better machining properties.

Lime spar desulfurization vessels function well producing ductile iron base. Sulfurs can easily be reduced from 0.10 percent to under 0.01 percent. A modified vessel could be developed for gray iron.

Soda ash, a powder, has been used as a flux and a desulfurizer. It can cause severe refractory attack, very fluid slag and air pollution in the highly concentrated form. There is a new, modified soda ash-based briquette available today that contains 1/3 the soda ash and other ingredients that is said to overcome most of these problems. This could be of significant importance if it can be used in the cupola to lower iron sulfurs without the other problems. This could be a simple solution to a serious problem!

Almost all the sulfur in the metallic charge is recovered. Steel is the preferred addition because of its low sulfur content, although more coke is consumed when using this material.

Avoid purchased cast iron scrap. A major gray 1ron foundry reduced its iron sulfur 0.015 percent by replacing 10 percent of purchased cast with steel scrap.

Returns are a major source of sulfur and are accepted as a given by most foundries. A small reduction in returns and substitution of steel in the charge can have a significant effect on final sulfurs. Every effort should be put forth to increase casting yield. Review all gating and risering (do not over riser). Direct pouring using Kalpur sleeves significantly increases yields.

When the sulfur input and output of a cupola is in equilibrium the sulfur content of the iron stays reasonable constant. A very slight increase in input will tend to increase the metallic sulfur due to the compounding effect of the returns. Conversely, a slight decrease in sulfur input over time will effect sizable reductions.

CAPITAL EXPENDITURES: One of the best innovations introduced into cupola melting in recent years is the automatic tuyere blast control, produced by Foxboro Corporation. It automatically opens or restricts the blast flow to each tuyere so the same volume of air is blown through each tuyere. It was reported, in one installation, that this system resulted in a reduction of coke usage by 7 percent and a 75°F increase in iron temperature. Bridging was virtually eliminated and there were no hang-ups. Good refractory wear patterns were also reported. This reduced repairs, labor and cost. Installation of an automatic tuyere blast control costs about $15,000 per tuyere. This capital expenditure can reportedly be recovered in less than six months!

Recuperative hot blast systems have been proven to greatly improve melting temperatures and consequently, carbon and silicon recovery. Coke consumption is significantly less. Capital costs for these systems; however, are high. Equipment manufacturers and consultants can be of great help.
Microwave gauges are available to measure the height of the charges in the cupola. They avoid the regulatory requirements of radiation instruments.

Supersonic injection of oxygen through the tuyeres has shown much better results than low velocity methods. The "coherent jet" is the latest development in this area. It creates higher temperatures in the cupola center.

Tuyere injection of coal or coke fines offers a potential solution to the problems of coke supply. The systems can be simple and inexpensive for intermittent operations or more extensive for continuous operation. The supply of acceptable carbonaceous material can be a problem.

SUMMARY: Iron cupola foundries are now faced with a new challenge. This is a two-part problem. They must try to economically produce iron with lower quality coke at the same time attempting to keep iron sulfurs at 0.15 percent maximum with higher coke sulfur levels.

The desire to meet the coke challenge must come from the top down! A 1ist of suggestions pertaining to more efficient cupola operations have been made. This will require increased effort on the part of operating personnel to implement. Significant improvements can be achieved by capital expenditures if the financing can be arranged.

There is help available from suppliers and consu1tants. Foundries have met the challenges over the years and the strong, determined and dedicated have survived. It will be so again.

Footnote: Mr. Haley has graciously granted ASI permission to use this paper for our web site and approved the some slight modifications that were made to his original manuscript.