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Western Canadian Coal vs. USA Coal

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SUBJECT: C LIN PAPER--ABSTRACT

ADDITION OF WESTERN CANADIAN COAL AND PETROLEUM COKE INTO A PREDOMINATELY U.S ORIGIN COAL BLEND.

THIS PAPER WILL ILLUSTRATE HOW A METALLURGICAL COKE PRODUCER HAS INCORPORATED THE USE OF WESTERN CANADIAN COAL AND PETROLEUM COKE INTO THEIR COAL BLEND PREVIOUSLY COMPRISED OF U.S. ORIGIN COALS.

FACED WITH A SET OF CIRCUMSTANCES RELATED TO PREVIOUS REPAIR METHODS AND BATTERY AGE, THIS COKE PRODUCER SOUGHT TO FIND AN ECONOMICALLY FEASIBLE COAL BLEND TO MAXIMIZE PRODUCTIVITY AND COKE QUALITY WHILE STRIVING TO PRESERVE THE LIFE EXPECTANCY OF OVEN CHAMBERS.

THE AUTHOR WILL DEMONSTRATE HOW THE ADDITION OF WESTERN CANADIAN COAL AND PETROLEUM COKE HAS SUCCESSFULLY MET ALL OBJECTIVES.

Abstract

ACME Steel Company has a mid-age coke plant and would like to push 19 hour coking-time, top-notch quality coke, and use as much U.S. Coals as possible. This task is not easy, because U.S. Coals are famous for their high coking pressure, high coke reactivity + low shrinkage during actual oven practice. However, it is accomplished by including Western Canadian Coals plus petroleum coke

Western Canadian Coals —

Why they are good in Cokemaking.

Abstract

ACME Steel Company has a mid-age Coke Plant and would like to push 19 hour Coking-time top-notch quality coke. This task is not easy. However, it is accomplished by using Western Canadian Coal plus petroleum Coke.

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50 WORD ABSTRACT

I. Introduction

ACME Coke Plant located at South East Side of Chicago City. It has two 50 oven double divided Wilputte underjet batteries. These batteries were Constructed in 1956-57 and were through-wall repaired in 1978-79, replacing all 102 heating Walls. Maximum Coking Capacity is 123 ovens/day (19 hour Coking Time) at 18.4 ton Wet Coal charged into the 701 Cuft working Volume. ~~Some defects pre-existe or developed on these re-Conditioned ovens after years usage. Some walls are not straight any more (bowed and Curved). Some has recess (insets).~~

In other words, our Coal blends need to have extraordinary shrinkage, together with reasonably large size in order to have an easy push. Of Course, large size coke also means more useful metallurgical Coke available to blast furnace.

Nowaday, more & more steel mill operators emphasize Coke Strength After Reaction (high temperature strength, CSR), due to the PCI or gas injection. CSR seems to be even more important than Coke Stability (room temperature strength). Western Canadian Coals provide all the above.

Actually, ACME Steel was the first U.S. Steel Mill to introduce both petroleum coke and Western Canadian Coal into the U.S. cokemaking society.

II. Pushing Problem

The No. 1 important goal for a cokemaker is not to damage the oven (to prolong the life of oven). Hard push or sticker is the most frequent way leads to oven deterioration. In order to provide an easy push, the best coke shape should be rectangular and forms two columns inside the oven after coking (Fig. 1). If there is some coalescing force between adjacent coke blocks, it will even be a plus. That means, before pushing out of the oven, cokes seldom separate. This way, oven wall get minimal pressure. The worst scenario is one whole oven loaded of small spherical balls. During pushing, spherical balls slip toward the side and pressure the oven wall, and get an instant sticker. Oxidized Coals and mineral matter usually produce ill-perfect spots inside semi-coke. These spots provide an initial points of cracking upon stresses during solidification. Therefore, they provide odd shape coke and/or small size coke. At the present time, ACME has no problem to push coke with roughly 52% plus 2" size. When coke size dropped to roughly 45% or less plus 2", pushing became a problem.

Coke size & shrinkage is a function of coking time. Longer oven time (slower heating rate) allows more time for gas to escape and longer time for coke to shrink during final solidification phase. And, it also provides more time for plastic layer to agglomerate the inert ingredients to form larger size coke.

~~Therefore, longer oven time tends~~ to ~~generate more shrinkage & larger size coke (Figure 3).~~ ??? The best laboratory scale method to estimate coal shrinkage during cokemaking is thru Sole-Heated Oven Test. ACME Steel found out, We need 8—10% minimum SHO-Test results in order to get a easy push (Table I). However, the blend SHO-result is not additive. Brysch and Ball[1] reviewed data from the Bureau of Mines Sole-Heated Oven and noted that the relationship of the expansion pressure and the percentage of a given coal in a binary blend was not a straight line, and the infection point occurred at different percentage for various blend. ~~Empirical Formula Can be derived,~~

~~with 20% low-volatiles:~~

~~$E_B = 0.728\, E_{HV} + 6.4$~~

With

30% low-volatiles:

$$E_B = 0.576 E_{HV} + 7.1$$

where E = percentage expansion at wet bulk density of 55.5 lb/cuft, and subscripts B and HV refer to blend and high-volatile respectively.

ACME also found that the shrinkage of U.S. high-volatile fluid coal in a blend is the most unreliable source.

The shrinkage of Western Canadian Coals in a blend is much more reliable than that of U.S. Coals. Blend's SHO-results is always less than its added SHO-results from individual coals. Moreover, high fluidity tends to increase the Pushing Amps[2] (Fig.4), and create small-size coke. M.F.O. diagram[3] also discourage blend fluidity more than 1000 dd.p.m.. ACME successfully blends petroleum coke and Western Canadian Coals into the mix. This is a profitable way and a very successful way to make coke, because U.S. Coals contain less ash, less oxygen, high fluidity, and cheaper in price. However, the amount of petroleum coke in the blend ~~is~~, usually, could not exceed ~~less than~~ 10%.[4]

Examples of SHO-results of coal blends are listed in Table II → Table V.

Theoretical SHO-result is the added result assuming ~~they are~~ it is additive by their individual coal weights.

Theoretical fluidity is the logarithm additive of individual coal's fluidity by its weight. Table II tells us that the actual SHO-results, not only much less than the theoretical SHO-results, but also unpredictable. ~~Table III shows us that blend with Western Canadian Coal improved the overall shrinkage somewhat, but still quite unpredictable. Table IV indicates that the SHO-results became much more predictable and always could get reasonable shrinkage.~~ Table IV illustrates the reliable high percentage shrinkage from blend to blend if they contained both pet-coke & Western Canadian Coals.

Keep

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Sometimes, Western Canadian Coals were blamed for too high ash content. People say that ash in coal is a "necessary evil". So, ash in Western Canadian Coal is a "friendly necessary evil". Why there is difference in ash content between Western Canadian Coals and U.S. Coals? It is due to the mineral matter distribution in the coal. Western Canadian Coals usually have fine mineral matters which could not easily be washed out (Fig. 5 & Fig. 6). In addition, low in these elements, such as Fe, K, Na, Mg, Ca, also mean high ash fusion temperature. This is another way to prolong your oven life.

III. Ash

CSR & CRI properties of the Western Canadian Coals are excellent. Usually, CSR & CRI properties should be considered as additive, if coking conditions are fixed. One of the reasons is attributed to their low in elements such as Fe, Na, K, Mg, and Ca in ash. The ash compositions of these Western Canadian Coals experienced by ACME are listed in Table VI. These elements are known to act as Catalysts of CO_2 gasfication; others, such as Al_2O_3, SiO_2 .... tends to be negative Catalysts.

Goscinski & Patalsky[5] also found out

that ash ingredient is the second most important role in CSR or CRI determination, only next to the rank.

Alkali Index,

$$\frac{Fe_2O_3 + CaO + MgO + K_2O + Na_2O}{SiO_2 + Al_2O_3}$$

eliminate!

is the general formula to check the influence of ash content on CSR.

Inland's Catalytic Index[6], which includes sulfur content, is also emphasizing the important of ash content.

Catalytic Index = 9.64 Alkali Index + 14.04 Sulfur

Inland's CSR = 28.91 + 0.63 Plastic Range − Catalystic Index

IV. Apparent Specific Gravity of Coke

A survey of Table VII, it is not hard to find out that Western Canadian Coals always have lower V.M. if Comparing U.S. Coals with similar MMR. Lower V.M. blend during cokemaking always produces coke with lower porosity. Brown et al[7] reported that apparent specific gravity (ASG) were determined by Volatile matter (VM) and can be described by an empirical formula.

$$ASG = 1.327 - 0.013 VM \text{ (Air Dried)}$$

with a standard error of ± 0.076.

In order to have a strong coke either at room temperature or at high temperature, a necessary condition (not a satisfactory condition) is to have a high apparent specific gravity. It is ~~impossible~~ difficult ??? to propose a coal blend (with U.S. Coals only) and obtain a comparable apparent specific gravity coke, because its blend's mean Maximum Reflectance will be too high. It will generate enormorous pressure & not enough shrinkage.

For example, it is very hard to make coke with ASTM Stability of **64** or above with U.S. Coals only at max production. However, it is not hard with the help of Western Canadian Coals.

V. Oxygen Content.

Table VII also tells us that Western Canadian coals always contain more oxygen than comparable U.S. Coals.

Any organic material during coalification (or exposing to prolong heat in absense of air), deoxygenation occurs, and resulted in decreased volatile matter and increase Carbon Content + hydrogen contents (less dramatically, since it was lost — along with the oxygen — as water, whereas Carbon was evolved as Carbon dioxide). It also accompanies with a molecular re-organization or a kind of metamorphism.

~~All~~ Most the coals in this world usually can be fitted inside a general trend. However, some Japanese or Taiwanese coals do not plot on regressions that depict the progressive metamorphic change. Maybe, the local mineral matter had some kinds of abnormal catalytical effects or the initial starting material had extraordinary high hydrogen content. Western Canadian Coals, the author think, is another exception, which is out of normal world-wide coalification progressive metamorphic change. Keep & condense The only difference between Western Canadian Coals & Japanese Coals is that Western

~~Canadian Coals Contain~~ too much ~~oxygen instead of hydrogen.~~ Oxygen produce linkage during heating. That's why the fluidity of Western Canadian coals is abnormally low, if you compare them against the U.S. Coals with similar V.M.

These extra oxygen content reduces the by-product yield (a loss to Cokemaker). However, it makes high productivity possible. Lower blend fluidity reduces the oven pressure.[2]

→ On one hand, the extra oxygen content in Western Canadian Coals means more heteroatoms & functional groups. These

INTRODUCTION

Acme Steel Company's Coke Plant is located on the southeast side of Chicago. It has two 50-oven double-divided Wilputte underjet batteries. These batteries were constructed in 1956-57 and were through-wall repaired in 1978-79, replacing all 102 heating walls. The maximum coking rate is 123 ovens per day (19 hour coking time), with 18.4 tons of coal blend being charged to each oven. The plant operates at the maximum rate.

added sentence

One of Acme's operating criteria is to use coal blends that pose no risk to the ovens. Coals that can generate high wall pressures are avoided, and blends must possess good shrinkage to ensure easy pushing. The quality of the coke must be high as measured by chemistry, stability, coke strength after reaction and size distribution. The use of blends that contain Western Canadian coals, Eastern U.S. coals and petroleum coke helps Acme achieve its cokemaking goals.

PROPERTIES OF COAL BLENDS AND COKE

Cokemaking is the science of blending a number of materials that individually have unacceptable properties, but when combined in correct proportions meet the cokemaker's requirements. Chemical, rheological and petrographic characteristics must all be taken into account. Table 1 shows these properties for some typical Eastern U.S. coals, Western Canadian coals and petroleum cokes. Tables 2 and 3 list properties generally attributed to desirable coal blends and coke. When the goal is to maximize coke production, the demands on the coal blend are at their greatest.

In recent years Acme has mixed Western Canadian high vol., mid vol. and low vol. coals with U.S. high vol., mid vol. and low vol. coals in a number of blends which for the most part contained petroleum coke. When used in combination, Eastern U.S. coals, Western Canadian coals and petroleum coke provide a cokemaker with a flexibility that is lacking with more limited material sourcing and properties. This added flexibility can benefit both the cokemaking operation and the quality of the product. Information on several of these blends and the coke produced is shown in Table 4.

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Coals continued -

In its evaluation of coals to utilize for blending Acme is always concerned with a particular blends impact on oven walls thru internal pressures generated during the coking cycle as well "amps" required to "push" out each oven. Ash components, oxygen content, sulfur, apparent specific gravity of coke produced, carbon texture, and the binding and interaction properties of coals during cokemaking are also given careful consideration. These are of course in addition to the standard proximate and ultimate analysis.

II ~~Wall pressures~~ ~~Oven~~ oven Pushing Concerns.

A primary ~~[illegible]~~ goal as a coke producer is to prolong the life of our batteries. One of the most ~~frequent~~ detrimental conditions to encounter is an oven which requires an extremely abnormal amount of force to "push out" of the coking chamber

In order to ensure that a minimal amount of force will be required. Several criteria must be considered.

The best coke shape should be rectangular and form two colums inside the oven after coking (FIG 1). ~~If there~~ Coalescing force between adjacent coke blocks will aid in coke mass integrity as it leaves the oven chamber thereby exposing the walls to minimal pressure.

Coke size & shrinkage is a function of coking time - Longer oven time (slower ~~coke~~ heating rate) allows more time for gas to escape and longer time for coke to shrink during the final solidification phase. This additional time also provides more time for the plastic layer to agglomerate the inert ingredients and form larger size coke —

One of the best laboratory scale methods to estimate coal shrinkage during cokemaking is thru the sole-heated oven test (SHO) ~~Acme fo~~ We at Acme Steel believe that a target of 8-10% minimum SHO test results will provide an easy push coke. However one must be reminded that the blend SHO result is not additive. Brysch and Ball[1] reviewed data from the Bureau of Mines Sole-Heated oven and noted that the relationship of the expansion pressure and the percentage of a given coal in a binary blend was not a straight line and the infection point occured at different percentages for various blends –

Acme has also noted that the most unreliable component coals in predicting ~~Shrink~~ Shrinkage are US- ~~Hig~~ Volatile ~~fluid~~ coals.

The Shirkage of Western Canadian Coals in a blend is much more reliable the that of U.S. Coals. A Blend containing Western Canadian coal SHO- results are always less than its added SHO. results from individual coals.

Moreover, high fluidity tends to increase the pushing amps (Fig 4) and create small size coke. M.F.O. diagram[3] also discourages blend fluidity more than 1000 ddpm. Acme successfully blends Petroleum coke and Western Canadian Coals into the mix along with U.S. Coals – This is a successful way to make high quality coke because U.S. Coals contains less ash, less oxygen, and are cheaper in price, all inspite of the high fluidity.

However, the amount of petroleum. coke in the blend should not exceed 10% – to maximize coke quality. –

Examples of SHO results ~~of~~ of coal blends are listed in Table II for 100% US coal blends and TABLE III for coal blends containing Western Canadian Coal, U.S. Coal and Petroleum Coke –

Theoretical SHO result is the added result assuming it is additive by their individual coal weights. Theoretical Fluidity is the logarithm additive of individual coal's fluidity by its weight. Table II ~~it~~ tells us that the actual SHO results are not only much less than the theoretical SHO results, but also highly unpredictable.

Table III illustrates the high degree of reliability between theoretical and Actual SHO. from blend to blend if they contain both Pet Coke and Western Canadian Coals.

III Ash

~~At times, water~~ At first glance it is possible to discount or eliminate Western Canadian coal due to it's seemingly high ash content. There is however a difference in mineral matter distribution between ~~US~~ Western ~~and Western Canadian coals~~ Canadian and US coals as demonstrated by FIG 5 and FIG 6 –

Western Canadian coals generally contains fine mineral matter which cannot be easily washed out. In addition it is low in elemental Fe, K, Na, Mg and Ca which translates into higher ash fusion temperatures. ~~Basically although Western Canadian coal contains the "necessary tool" component Ash but~~ So as the Ash content of Western Canadian coal is generally higher and more finely dispersed it is of a more "friendly" nature to coke makers —

CSR and CRI properties of Western Canadian coals are excellent. Usually CSR and CRI properties should be considered as additive, if coking conditions are fixed. One of the reasons is attributed to their low elemental composition. Ash compositions of these Western Canadian coals experienced to date are listed in TABLE (VI?) These elements are known to act as catalysts of CO_2 gasification, others ~~as~~ such as Al_2O_3 and SiO_2 tend to be negative catalysts.

Goscinski and Patalsky (5) also found out that ash ingredient has the second most important role in CSR or CRI determination next to coal rank. ~~This~~ can also be demonstrated by the Alkali Index formula as well as Inland's Catalytic Index.

IV Apparent Specific Gravity of Coke

A Review of TABLE(VII)?; clearly shows that Western Canadian Coals always have lower V.M. when comparing U.S. Coals with a similar M.M.R. A Lower V.M. blend always produces coke with lower porosity. Brown et al[7] reported that apparent specific gravity (ASG) ~~was~~ is determined by Volatile matter (VM and can be described by an empirical formula —

$$ASC = 1.327 - 0.013\,VM \text{ (Air dried)}$$

with a standard error of ± 0.076 —

In order to have a strong coke, either at room temperature or higher, a necessary condition is to have a high apparent specific gravity. It is very difficult to propose a coal blend using only U.S. coals, which will obtain a comparable specific gravity coke specifically because of the high ~~mean~~ & mean maximum reflectance. Blends with high mean maximum reflectance will generate ~~enormous~~ enormous pressure and very little shrinkage in the coking chamber.

As an example, through our experience it is very difficult to make coke with ASTM Stabilities above 62 at full production, using solely U.S. coals —