A Corrected CO/CO₂ Ratio for Blast Furnaces

by Sid T. Killian

The utilization of the reducing power of blast-furnace gas can be estimated by applying two rectifying calculations to the gas analysis. A resulting corrected CO/CO₂ ratio varies inversely with furnace production. Directions for calculating the corrected CO/CO₂ ratio are given, and a corrected CO/CO₂ ratio is compared with actual furnace production.

The inadequacy of the normally accepted CO/CO₂ ratio as a measure of blast-furnace performance and furnace efficiency was discussed following the presentation of the paper by H. F. Dobscha.* In this outstanding example of careful observation on large scale blast-furnace operation, the changes occurring with beneficiated ores were: 1—A net gain in tonnage of 21.2 pct. 2—A decrease in net coke of 15.3 pct. 3—A decrease of 1.9 pct in the CO/CO₂ ratio. In this great change in furnace performance, the CO/CO₂ ratio proved itself worthless.

The discussion of the inadequacy of expressing furnace performance and efficiency by the CO/CO₂ ratio led indirectly to the calculations forming the basis of this paper. At that time Dr. T. L. Joseph said: “We must consider difference in CO₂ from the stone in the two cases when we talk about the ratios of CO/CO₂.” This statement is used for the second of the two CO/CO₂ ratio corrections forming the basis of this paper.

The research work in attempting to find out why the furnaces could operate so differently with practically the same CO/CO₂ ratio lead not to the answer sought but, after a shift to the gaseous phase in the research work, the proof that the normal CO/CO₂ ratio was outmoded and a new corrected ratio should replace it. To be of any value, any new corrected ratio should express approximate furnace efficiency and give an idea of practical furnace performance to be expected. This the normal CO/CO₂ ratio has failed to do. However, in the absence of anything better, some credence has been attached to the normal CO/CO₂ ratio. As far as the writer can ascertain, the present paper is the first attempt to change or improve the normally accepted index of

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furnace efficiency. A corrected CO/CO₂ ratio is proposed as the future criterion of the blast furnace.

**Corrections Necessary**

The calculations involved in figuring the corrected CO/CO₂ ratio are performed in two main steps. The first calculation involves placing the gas analysis on a hydrogen-free basis. The second calculation consists of deducting the amount of CO₂ evolved by the flux from the gas analysis.

The first correction is almost mandatory, if the CO/CO₂ ratio is to be continued as a measure of furnace efficiency, inasmuch as it can be figured so easily. The second step however should be adapted to furnace records and must be used carefully to render true service.

When the gas analysis is placed on a hydrogen-free basis, the CO/CO₂ ratio expresses the ratio of the total unused reducing power to the used reducing power with the flux CO₂ included as used reducing power. The normal CO/CO₂ ratio attempted to give a ratio of unused to used reducing power, but the resulting ratio could vary considerably due to the exclusion of the hydrogen content of the gas and the inclusion of the flux CO₂ in the ratio. However when both corrections are made, a close expression of the ratio of unused reducing power to used reducing power in the gaseous phase is obtained. Neither correction should be omitted if any resulting corrected CO/CO₂ ratio is to be used as a representation of furnace efficiency or furnace performance.

**Chemical Principles of the First Correction**

Gas Analysis on a Hydrogen-Free Basis: The gas-analysis correction of placing the gas analysis on a hydrogen-free basis in no way involves furnace reactions, but merely corrects the gas analysis for a variable which can change the actual gas analysis and the ratio calculated from it.

The equation:

\[
\text{CO}_2 + \text{H}_2 \rightarrow \text{CO} + \text{H}_2\text{O}
\]

1 vol + 1 vol \( \rightarrow \) 1 vol + 1 vol

shows how the interaction of the \( \text{CO}_2 \) and the \( \text{H}_2 \) with the CO and the H₂O can change the ratio. As the \( \text{H}_2 \) increases, the \( \text{CO}_2 \) is increased at the expense of and in the same amount as the \( \text{CO} \) is decreased. Similarly, as the \( \text{H}_2 \) decreases, the \( \text{CO}_2 \) is decreased in the same amount as the \( \text{CO} \) is increased. The variable of the hydrogen content of the gas is eliminated by changing the gas analysis so that the reaction goes to completion in the direction that eliminates the hydrogen. The two components of the \( \text{CO}/\text{CO}_2 \) ratio are then left for the calculation. Thus the correction merely involves the subtraction of the percentage of hydrogen in the gas from the percentage of carbon dioxide in the gas and the simultaneous addition of the percentage of hydrogen in the gas to the percentage of carbon monoxide in the gas. In other words, every 1 pct of \( \text{H}_2 \) in the gas analysis will drop the \( \text{CO}_2 \) percentage exactly 1 pct and simultaneously raise the \( \text{CO} \) percentage exactly 1 pct when the correction is made.

In order to show clearly how the hydrogen content of the gas changes the normal CO/CO₂ ratio, Table I has been calculated. In it all volumes are changed entirely by the reaction:

\[
\text{CO}_2 + \text{H}_2 \rightarrow \text{CO} + \text{H}_2\text{O}
\]

in steps of 0.50 volumes of each of the reacting gases. All the analyses and CO₂ ratios in Table I are identical when placed on the hydrogen-free basis. All given an identical corrected ratio of 2.683.

**Second Correction**

Gas Analysis with Flux CO, Deducted: While the CO₂ evolved from the stone is an important factor in furnace performance and furnace efficiency, from an overall viewpoint, the calcining of the stone consists of the addition of CO₂ (completely oxidized carbon) to the gaseous phase. The inclusion of this CO₂ tends to give an illusion that a greater oxidation of carbon is taking place than really occurs. In other words, the inclusion of this CO₂ tends to hide the real efficiency.

The second correction of taking the gas analysis on a hydrogen-free basis and deducting the CO₂ evolved from the flux is best accomplished by equating the total carbon input with the total carbon output. The easiest means of computing this carbon balance should be to use 24 hr as the basis with no calculations involving the wind blown. The blowing media used vary widely in efficiency and quite often the wind ordered differs markedly from the actual wind delivered. Thus complex stoichiometric calculations are avoided and practically all calculations can be made from furnace records.

**Carbon Balance:** The carbon input normally includes: 1—net coke carbon to furnace excluding fractions not charged, 2—carbon in stone, and 3—carbon in scrap. The carbon output normally includes: 1—CO in gas, 2—CO₂ in gas, 3—carbon in total amount of pig iron produced, 4—carbon in flue dust and sludge, 5—cokes, 6—rolls and slips, 7—carbon in the gas as coke particles and as stone particles, and 8—hydrocarbons in the gas.

All the items should be observed and calculated before assuming them to be negligible. For a complete carbon balance, every item should be checked.

**Illustration of Calculation:** The corrected CO/CO₂ ratio is illustrated in the calculation of a furnace using 1.00 fuel (80 pet net carbon) with 300 lb of...