ADAPTATION OF THE BOILER AS CALORIMETER METHOD TO TWO-STAGE MUNICIPAL WASTE COMBUSTORS

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The author is to be commended for publishing his efforts to make sense out of a complex collection of data, frustratingly incomplete, in an effort to use Boiler as Calorimeter procedures to obtain reasonably good estimates of the variations in the HHV the waste supplied, while taking into account factors contributing to boiler efficiency. His efforts show what an engineer can or must do to carry out his responsibilities in protecting the interests of his client while being fair to the contractor who has signed a contract to operate the facility. If the contractual quantity of waste does not generate the contractual quantity of steam, the discrepancy may be the result of the HHV of the waste, or failure to operate and maintain the facility properly. Without a basis for measuring the HHV, both sides can be hurt and confidence lost.

The Harford County RRF is typical of the two-chamber modular starved-air technology which was widely applied 10 to 20 years ago in order to meet the need for WTE facilities buring 300 TPD or less which could compete with the low landfill fees of the time. These facilities had capital costs half that of their sophisticated waterwall competitors, yet were able to meed the then applicable PM emission limits. While they provided excellent combustion of the pyrolysis off-gases of the primary chamber, as reflected by the low CO emissions, the primary chamber pyrolysis process left high levels of unburned carbon in the ash residues. With cheap landfill, this was then not a serious problem.

Use of the BOC procedure for ongoing evaluation of the performance of WTE facilities has become commonplace, as reflected in the paper published by myself and by Ogden Projects in this journal several years ago. It is possible to calibrate WTE facilities during acceptance tests, and then use this calibration to evaluate performance thereafter.

Lacking the extensive data obtained during BOC performance tests, and having to piece it together from sporadic and incomplete acceptance tests and compliance tests, the author has accomplished the seemingly impossible task of estimating the HHV with accpetable accuracy, without having to analyze the waste input.

My personal experience in testing municipal and medical waste combustors parallels that described by the author. Calculating the radiation losses using heat transfer areas and basic principles; measuring stack gas flow, composition and temperatures and boiler inlet and outlet gas temperatures; and weighing the ash and testing its moisture and carbon content, together with obtaining a reasonably good water balance allows one to obtain a model of performance which can be used to relate the measured steam flow to the quantity of waste fed.

Analysis of ash residue quality versus steam generation rate show a clear correlation with loading, especially overloading, as the author found. I found it necessary to perform a heat balance around the boiler to determine the gas flow through the furnaces in order to determine the efficiency of the boiler itself, since obviously the stack gases contained considerably more excess air than could possibly have passed through the boiler. This was necessary, although always useful, because no oxygen readings were available at the outlets of the individual boiler units.

I would like to ask the author whether he found a correlation between steaming rate and ash quality, especially unburned carbon, and whether he used this in his analysis? Also, whether he included boiler outlet temperatures to evaluate the cleanliness of the economizer and other boiler surfaces?

AUTHORS' REPLY

Regarding ash quality, there were at least two determinations which formed an integral part of the BAC analysis. First, there was the moisture content which was needed for establishing the overall water mass balance. The results of this balance are reflected in sensible heat losses from the ash quench system, i.e. items IVf and IVg in Tables 4a and 4b. Their effects are relatively minor.

Second, there was the unburnt carbon loss, or item IVd in the above tables. In the body of the paper, it was pointed out that this loss played a major role, which is an unavoidable characteristic of the two-stage combustor technology.

Testing for the unburnt carbon loss was problematic throughout the program. As on many other occasions, compromises became necessary. To begin with, there were difficulties with the collection and processing of samples which were truly representative of the BAC test periods. Often the type of lab test performed was actually a loss-on-ignition (LOI) test. It was then assumed that the vast majority of the mass lost was exclusively due to the combustion of elemental carbon. Item IVd was then calculated by using the HHV for elemental carbon. Still, "unburnt carbon" serves merely as a surrogate for what is called more appropriately "losses due to incomplete combustion in output solids" in Section 4.10.1.2 of ASME PTC-33.

In order to check, during one BAC test period, aliquots of the same samples were actually subjected to both bomb calorimetry and LOI testing. The results indicated fairly close agreement. Theory suggests that improving burn-out would increase steam production and vice versa. In response, Figure 6 was prepared, which plots the specific steaming rate against the amount of unburnt carbon found in residue. Although only four points were available (for burning MSW only), there appears to be a promising functional relationship. A reduction of about 60% in unburnt carbon corresponds to about a 25% rise in the specific steaming rate (SSR). (Note: All are on wet basis.) The message appears to be clear: Either obtain fuel which is more readily combustible or do a better job in burning out the available fuel. As mentioned in the paper, overloading is obviously not the answer to make up for a shortfall in steam production.

The discussor's last question is a formidable challenge. The boiler outlet temperatures, or more correctly, the economizer gas outlet temperatures, were already included in the computation of items IVa and IVb. Their potential correlation to the cleanliness of the heat transfer surfaces in the steam generation systems goes beyond the original BAC topic. After some initial research, it appears that complex multi-variable relationships may be involved. Although a full-length discussion should be reserved for a separate paper, a few preliminary comments follows.

Unlike some other WTE facilties, in the HCRRF the three steam generation systems (consisting of one interconnected boiler and economizer each) are manifolded together on both the gas inlet and outlet side. All three systems — if available to do so — will run simultaneously. Since nameplate steaming capacity is 3 x 55,000 = 165,000 lb/h but the facility generates only between 65,000 and 75,000 lb/h on average, the systems are usually less than half loaded.

Coming from the inlet manifold, the fluegas stream is not apportioned to the three systems by intent. Instead, it seeks the path of least resistance, i.e,. the one which causes the lowest pressure drop receives more of the flow. Disregarding certain extraneous factors such as deviations from design geometry in the physical layout, cleanliness comes into full play. Clean surfaces simply mean that a larger cross-section is open to the flow of fluegas.

Compressed air-driven soot blowers are installed in both the boilers and the economizers. They come on for brief periods of time, roughly once every six hours. In spite of this fact, much additional cleaning must be performed by hand with high pressure water hoses. The operating plan calls for each boiler to be cleaned every six weeks and each economizer every three weeks. Typically, such cleanings take 12 to 24 hours. On a facility-wide basis, there may be 80 such unit cleanings in a given year. Because of the existing excess in steam generation capacity, this does not impose any serious operational hardship. Two systems can readily carry the entire facility load alone.

The cleaning schedule as described above appears to be mostly the result of operating experience. Apparently, measurements of pressure and/or temperature are not taken (even though they are available from the plant computer) in order to initiate any particular cleaning procedures. To the best of the author's knowledge, the height of the flyash deposits on the heat exchange surfaces is not measured and recorded. Reportedly, the soot blowers were shut off during the BAC test periods. Likewise, manual cleanings were temporarily suspended.

Against this background, what can be said about potential correlations? In order to find out, more research was done beyond the scope of the original paper. Maintenance records were carefully scrutinized as part of calculating net operating time for each steam generating system since its last cleaning prior to BAC testing. Since boiler cleanings did not always coincide with economizer cleanings, it became necessary to develop a method by which the time for a given boiler could be reconciled with that of a given economizer. This was accomplished by using the amount of heat recovered in one versus the other as a weighting factor. It was then assumed that weighted net operating time (WNOT) could serve as a key variable in any correlation model.

The economizer gas outlet temperatures (EGOT's) were extracted from the PSR's and averaged for each steam generation system and BAC period. The lowest average was 259°F compared to the highest of 486°F for all BAC test periods. For a particular test period, a difference of 108°F was encountered between the highest and the lowest system average.

On a parallel track, the average rate of steam generation was calculated for each system. This rate was then related to the facility's installed nameplate capacity by expressing it as a percentage thereof (NPSP). It varied between 9 and 20% during the worst BAC test period.

By dealing with individual systems when firing MSW only, 12 separate data sets evolved. These were then subjected to multiple linear regression analysis (MLR). For estimating purposes, the following multiple regression equation was computed:

$$\widehat{NPSP}\ [\%] = 9.433 + 0.241 \times 10^{-2}\ (EGOT)\ [°F] - 0.810 \times 10^{-2}\ (WNOT)\ [h]$$

The positive sign in front of EGOT indicates that system steam generation and gas outlet temperature tend to rise together. On the other hand, the negative sign in front of WNOT signals that lengthening the intervals between cleanings is detrimental to steam production and load distribution. The accompanying correlation coefficient of about 81% is fair, but it also suggests that there is room for improvement, i.e., more and better data should be used. Furthermore, other variable which were excluded from the above analysis may need to be included after all.

Tables 4a and 4b demonstrate that fluegas heat losses are by far the greatest of any losses, with about 25% out of the total HHV. (See items IVa and IVb). Since the EGOT is the driving force behind these losses, it becomes desirable to keep the EGOT's low and uniform. Possibly, this could be accomplished by cleaning the boilers as often as the economizers. Since outside contractors are relied upon for this service, additional costs would materialize, which may not necessarily be justifiable.

In conclusion, lower unburnt carbon in ash, more frequent boiler cleanings, and reduced gas outlet temperatures can all help to cut losses and increase thermal efficiency. However, before making any firm recommendations, the impact of incremental energy revenues and incremental operating costs would have to be studied.

FIG. 5 RELATIONSHIP BETWEEN SSR AND UNBURNT CARBON DURING BAC TESTING