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Discussions

Thermal Performance Evaluation of MSW-Fired Steam Generators – A New Approach[1]

G. Stabenow.[2] The authors are to be complimented for presenting an interesting new approach to the always tedious procedure of testing large incinerators with waterwall furnaces and boilers for energy recovery.

The greatest "unknown" in determining an incinerator performance is always the heating value of the everchanging heterogeneous composition of the MSW (municipal solid waste). It is therefore almost useless to attempt to collect a representative sample of the MSW for calorimetric analysis, especially for large incinerators such as indicated under reference [2] in this paper, which is based on a daily throughput of 600 t/day or 25 t/hr or 50,000 lb/hr.

To obtain a representative performance picture, the selected test period for such a unit should be at least 8 hr, during which 200 t of representative MSW is to be burned.

Even when collecting typical samples at 15-min intervals during an 8-hr test run, assuming that a 2.5-kg calorimeter instead of the usual 10-g sample were available, only 80 kg or 176 lb out of 400,000 lb, which equals 0.044 percent, would be analyzed.

To avoid the refuse sampling altogether, European engineers have adopted a method to utilize the boiler as a full-scale colorimeter. This procedure, however, requires a very careful analysis of the moisture as heat loss in the stack gases, which do not consist of H_2O due to hydrogen burning and initial free moisture in the MSW, but also the residue quench vapors and air moisture. Chart No. 8 shown in reference [2] indicates clearly that quench vapor and air moisture contributes considerably to the stack losses:

	lb/lb fuel	Percent	lb/lb fuel	Percent
Moisture in refuse	0.2240	34.34	0.2240	40.61
Moisture from burning H_2	0.3276	50.07	0.3276	59.39
Moisture from quench	0.0279	4.26	0. –	
Moisture in air	0.0748	11.43	0. –	
Total	0.6543	100.00	0.5516	100.00

For the sake of comparison with a coal-fired boiler of identical output, the moisture losses in the stack gases would look as follows:

	lb/lb fuel	Percent	lb/lb fuel	Percent
Moisture in coal	0.0240	4.10	0.0240	5.26
Moisture from burning H_2	0.4320	73.72	0.4320	94.74
Moisture from quench	0. –	0. –	0. –	0. –
Moisture in air	0.1300	22.18	0. –	0. –
Total	0.5860	100.00	0.456	100.00

Quantitatively, the MSW or coal consumption to generate the equivalent heat input shows that the moisture discharge varies considerably.

		MSW firing		Coal firing	
Fuel heat input	KB/hr	225,000		225,000	
HHV	Btu/lb	4500		13,400	
Fuel consumption	lb/hr	50,000		16,791	
Total stack gas moisture	lb/hr	32,715	0.6543 lb/lb	9790	0.5831 lb/lb
Stack gas moisture less air and quench moisture	lb/hr	27,580	0.5516 lb/lb	7656	0.456 lb/lb
Dry products of combustion	lb/hr	289,900	5.978 lb/lb	227,686	13.56 lb/lb

When reviewing the difference in percent moisture for MSW with or without air and quench moisture, the variation is considerable.

Total stack gas moisture	10.14 percent	32,715 lb/hr
Dry stack gas	89.86 percent	289,900 lb/hr
Total	100.00 percent	
Stack gas moisture less quench and air moisture	8.69 percent	27,580 lb/hr
Dry stack gas	91.31 percent	289,900 lb/hr
Total	100.00 percent	

In conclusion, it can be said that any disregard of the

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quench and air moisture has a considerable influence on the performance evaluation of a MSW incineration system, which can be compared as follows:

	Moisture percent		Dry gas percent	
Total stack moisture	10.14	(100.00%)	89.86	(100.00%)
Stack gas moisture less quench and air moisture	8.69	(85.70%)	91.31	(101.61%)
Difference		14.30%		1.61%

From the foregoing figures, it is obvious that for an accurate evaluation of a MSW incinerator performance evaluation, and subsequent HHV evaluation, it will be necessary to determine the stack gas moisture content very carefully by means of closely spaced stack traverse readings. To determine the MSW throughput, O_2 content and temperature of the flue gases, as well as combustible content in residue and fly ash alone could lead to very erroneous conclusions.

E. R. Kaiser.[3] The authors propose a simpler test than the "ASME Test Code for Large Incinerators" to avoid the complexity and higher cost of the latter. Unfortunately, the inaccuracy and doubt that would result from the simpler test would probably leave all parties dissatisfied.

Because the partial oxidation of the metals in the solid waste contributes 3 to 5 percent of the heat released, and the residue contains unburned elements other than carbon, a more detailed analysis of refuse, residue and flue gas is required. Effort should be directed to developing data from which complete heat and mass balances can be calculated. An elemental balance is also necessary to account for the oxidation of metals.

Sampling of MSW can be followed by hand sorting, followed by moisture determinations and preparation of laboratory samples. The composite analysis of the waste and the composite Btu determination can then be calculated. Thus, the waste would not be represented by a single gram sample.

The flue gas analysis will show a slightly lower oxygen content than for hydrocarbon fuels because of the oxygen absorbed by the metals oxidized. Approximately 10,000 Btu are released per pound of oxygen thus consumed.

Of course, by agreement of the parties, an abbreviated or simplified test can be conducted and the findings used as the basis of decisions on the adequacy of the incinerator-boiler combination.

H. G. Rigo.[4] The authors have presented an interesting approach to monitoring incinerator performance that should be of considerable value to people who are trying to enforce waste-to-energy plant contract provisions.

In many operating contracts, the operator has to guarantee to maintain certain plant performance standards such as steam raising rate, plant throughput and ash generation rate. The operator may be excused from meeting these guarantees if the failure can be attributed to a change in waste composition. Unfortunately, after it is burned, the waste cannot be sorted to determine if its composition has changed.

The authors have presented a way to realistically assign fault for poor plant performance to either the operator or the waste. The authors observed that if the furnace is operating at the correct excess air level, the ash has less than a stipulated combustible content and the gas temperature leaving the last heat trap is below a specified level, then the incinerator is performing as well as it can.

In order to determine if poor plant performance is attributable to a change in waste composition, a little more plant information than the authors addressed is needed. The total amount of steam being raised provides an indication of whether or not the unit is being operated at capacity. A failure to maintain tonnage throughout while raising the design steam flow means that the heat content of the waste has increased. Similarly, if the feeders are wide open, the furnace parameters are in line and too little steam is being generated, the heating value of the waste is less than design. Since most plants have more than one boiler, an additional test for assigning blame to the waste or the operator is that all the units in the plant must be misbehaving in the same way in order for the fault to lie with fuel. If only one unit has its key indicator parameters out of line, I would suspect a maintenance problem when a guarantee is not met. If all units are "misbehaving" in the same way, then I would suspect the waste.

I do not believe that the author's work is finished, nor do I believe that my simple discussion is sufficient to turn this approach into a generally accepted standard procedure for long-term monitoring of plant performance. I do believe, however, that the new approach to thermal performance monitoring has considerable merit and should be pursued as a practical means of enforcing change of waste contract provisions.

S. E. Martinez.[5] The paper proposes a long overdue necessity in the solid waste industry. The traditional ASME performance test simply does not apply to a solid waste plant due to the continuous variation on the fuel being used. There is simply no way that the efficiency of the steam generator can be calculated since the basic information for the input is not available.

In any case, what the buyer wants is assurance that the steam generator performs as it is supposed to do. In other words, that it can burn the required amount of material and that it produces the required output, of course, without any excessive losses.

The idea presented is excellent and should be followed up. Possibly some modification will be required in the procedure for determining unburned combustible loss. It will probably also be a good idea to add under the items to be considered for fulfillment of performance guarantee, the actual output in pounds per hour.

J. H. Fernandes.[6] I certainly am not against a new approach to municipal solid waste steam generator testing and I am pleased to hear that responsible people are considering new approaches to the complicated business of performance testing of MSW firing systems and steam generating equipment. I would caution that we cannot afford to completely sacrifice a reasonable degree of accuracy.

I did have a few problems with this paper. Its depth of reporting on the calculations in support of the conclusions was weak. There is merit to the approach but it needs qualifiers in its use and an indication of the accuracy attainable. I am afraid the industry would not want a multimillion dollar contract handled in this loose a manner.

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[6] ASME V.P. Perf. Test Codes; Combustion Engineering, Inc., Windsor, Conn. 06095

I think the code writer would have to offer the client more guidance with respect to accuracy attainable. However, this approach may well have considerable value in day-to-day unit operation. Then, building on this experience, a code might be justified.

I have a serious doubt that performance testing of a multimillion dollar installation can be justified if not conducted in a painstaking manner with reasonable accuracy assured. Inaccurate results can cause one to draw expensive faulty conclusions. I would remind the authors that we are discussing large, very expensive installations. Certainly one could justify one percent of the installation cost to properly determine the performance (see "A Procedure for Determining the 'Optimum' Accuracy on a Cost/Effectiveness Basis of an Acceptance Test" by K. C. Cotton, et al., presented at the 40th Annual Meeting of the American Power Conference in Chicago on April 24–26, 1978), and I would not expect testing costs to approach one percent of the cost of a large incinerator/boiler installation. The fact that the present test procedures are cumbersome and difficult to perform is not a reason to compromise or abandon them.

I feel it is important at this point to review some of the reasons for which one conducts performance tests. There are many, but the principal ones are the following:

1 verify that the system performance meets guarantees;
2 evaluate system performance when incrementally loaded;
3 establish benchmarks for future performance evaluations;
4 analyze system performance with a view to improving it;
5 develop optimum operating conditions;
6 indicate need for scheduled maintenance;
7 proper testing and maintenance assures improved reliability;
8 obtain needed design data;
9 evaluate the development of tighter design specifications;
10 establish more reliable guarantees of performance.

These are not necessarily in an order of priority and I would point out that these are the reasons PTC 4.1 on large steam generators and especially PTC 33 on the performance of large incinerators was written. It should be noted that PTC 33 was undertaken at the request of the Solid Waste Processing Division.

Further, because of the complexity of PTC 33, an appendix to PTC 33 was developed – PTC 33A. Possibly a combination of PTC 4.1 and PTC 33 should be developed, but at the present time it can be accommodated by "items of agreement" between knowledgeable engineering professionals. They could leave out what is considered unimportant and accept the increased potential for error to a level acceptable to the objects of the test.

The authors mention improved sampling techniques. We would all agree that this would be extremely valuable, especially if they would be more accurate and less expensive. The large calorimeter being pursued at the National Bureau of Standards at the request of the ASME Research Committee reflects the need for improved calorific determination of municipal solid waste. I feel that efforts in this direction would be more fruitful than trying to establish an easily determinable performance factor.

In addition to the authors' performance parameters, I suggest that they should consider including steam quantity produced and its thermal conditions. In other words, inlet water and product steam, pressure, temperature and pounds per hour. These are normally measured as part of almost any performance guarantee for an incinerator/steam generating unit.

I would remind the authors that efficiency is a dimensionless parameter that combines the effect of all pertinent parameters, especially those chosen by their approach. In determining efficiency, many parameters are evaluated and when this is strengthened by a capacity determination we have a meaningful and reproducible measure of how the unit is performing within reasonable engineering accuracy.

The statement that the flue gas temperature and O_2 level is a measure of the heat exchange effectiveness causes me to ask "Why?". I must also ask why the CO content of the flue gas is not measured. There are CO measuring devices available that have reasonable accuracy and once these quantities are properly analyzed, a short form, similar to PTC 33A, is really what we are talking about and your knowledge of the unit's performance is of much greater value.

I wonder if the authors and those participating in this discussion should not review PTC 33A and consider items of agreement, etc., and accomplish in a little more formalized manner the results that the authors are attempting to accomplish. Once the necessary information is obtained, they could also apply it to their monograph and if, after we had some experience with the monograph and it is properly reported in a session similar to this one, we may well see a way of improving and simplifying our ability to evaluate a steam generating incinerator's performance.

In closing, I want to compliment the authors for their ingenuity in developing this approach and in bringing it before this body. I hope I have offered some constructive thoughts and that as a society we will be able to improve performance testing at a reduced cost.

Authors' Closure

The comments made by the five discussers, all distinguished in the field of energy-from-refuse, are very much appreciated. It is gratifying to have provoked so much discussion.

While a number of the discussers speculate that the proposed approach is not sufficiently accurate, no data is presented to support this speculation. That is, no data is presented to show that the suggested performance guarantees are not sufficient to demonstrate that a MSW-fired steam generator has performed as specified and/or guaranteed.

Mr. Martinez and others suggest a guarantee of pounds of steam per pound of refuse. If the guarantees listed in the paper do establish that an MSW-fired steam generator performs thermally as intended, then the rate of steam generation is just an indication of the quality of the refuse at that moment. The more available energy in the refuse, the larger the quantity of steam generated. The new approach eliminates the need for establishing the heating value of refuse burned.

(To illustrate the problems associated with a measured or calculated heating value, an example is offered from a recent Request for Proposals for a full service systems supplier. Guarantees of steam and electric generation are requested based upon a higher heating value of the solid waste ranging between 3800 and 5000 Btu/lb. Guarantees for pounds of steam per ton and kilowatt hours per ton are required. Suppliers of equipment with equivalent performance could make significantly different guarantees. One supplier may feel the guarantee must be based on the assumption that the worst refuse (3800 Btu/lb) will be available at the time of the test while another supplier may elect to take the chance that the refuse will be somewhere near the mean of the range. For a given weight of refuse, assuming that most of the change in heating value is due to change of moisture in the refuse, the steam generated by 5000 Btu/lb refuse could exceed 140 percent of the steam generated by 3800 Btu/lb refuse. Clearly, the evaluation procedure could easily become muddled.)

The intent of the new approach is not to save cost or to sacrifice accuracy. Rather, it is to focus on those parameters than can be accurately measured and to determine that the accurate measurements can be used to establish performance.

The new approach is not proposed to substitute for research. The reasons for conducting performance tests itemized by Dr. Fernandes are all valid. The purpose of the new approach is to satisfy only the first reason, i.e., "Verify that the system performance meets guarantees." Research funds, when available, can be put to good use in detailed testing and measurement. We, for two, would welcome the opportunity to participate in this kind of research.

Dr. Fernandes asks why CO content of flue gas is not measured. Carbon monoxide in flue gas from combustion of refuse is normally measured in the low hundreds of parts per million. The actual loss due to incomplete combustion of carbon to carbon monoxide should be less than one-tenth of one percent. (This is not to suggest that carbon monoxide measurements are not important when made in conjunction with stack emission tests.)

Mr. Stabenow goes to some length to show that moisture in air and moisture from the ash quench area represent a significant percentage of the moisture in the stack gases. We do not disagree with that. We do suggest that the effect of moisture in air on the performance of the steam generator system is minimal if not negligible. The effect of air moisture on the thermal performance will be essentially the same regardless of the hardware. With regard to the evaporated quench water, this is a quantity that must be determined empirically as it is impossible to measure directly. However, the water evaporated will not vary too much from one system to another and thus quench water evaporation should not have an impact on the evaluation of one system relative to another. (Quantification of these moistures is important if one is trying to calculate the heat input in fuel; but it is not important if the heat input calculation is not required.) With regard to test duration, 6 hr was suggested as this was about the longest test duration that could be conveniently scheduled within one operating shift.

Professor Kaiser makes some interesting observations regarding the contribution of metal oxidation to heat release. We share his interest in the origins of the heat available in refuse, and would be delighted to participate in a research project on this subject. However, we do not believe that metal oxidation is an important parameter in determining if a refuse fired boiler is performing thermally as expected. His suggestion for hand sorting of samples and separate heating value determination of the various components would result in testing of perhaps 10 to 20 g of sample rather than 1 g; but when one considers that 454 g make a pound, one must realize that a very small test sample would be used to represent the whole.

We look forward to further discussions and specific findings from operating MSW-fired steam generators so that the validity and applicability of the new approach can be evaluated. We agree with Dr. Rigo: our work is not finished.