

THE CHARACTERISTICS OF TWO-STAGE MUNICIPAL COMBUSTOR ASH (EXAMPLE: HARFORD COUNTY RESOURCE RECOVERY FACILITY IN MARYLAND)

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Discussion by:

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The author has provided a paper which correlates the specific ash rate (SAR) with the specific steam rate and the time of the year. In developing the data, the author has, as shown in Fig. 1, mixed and quartered the ash from the 1/2 in. x 1/2 in. under stream in accordance with *ASTM-D346-78*. This may be the reason for the similar results between E.L.I. and B.E.I. for the same quarter. I would suggest that this mixing and quartering procedure be used earlier in the field processing procedure, starting when the wheel loader bucket dumps ash on the floor.

The plant performance has been quite consistent in all respects, as shown in Table 3, Annual Performance Factors. With this high level of consistently good annual performance, I wondered why there was such a concern with the month-to-month SAR.

The concern with seasonal variations in ash production focused on the supplemental fuel (tires) as the cause for change in SAR. Although the hypothesis follows the relationship described, there is no mention of any analysis of the fuel stream done on either a seasonal or monthly basis. I would suggest that the waste stream be sampled to identify what is in the waste and what changes occur in the waste on a seasonal basis before attributing all SAR changes to tires.

It is difficult for me to be concerned with SAR variations when the plant has performed so well since 1988. Typically, plant guarantees focus on steaming rate, throughput, availability, and capacity factor. I agree with the author's proposed remedy, renegotiate the ash guarantee upwards.

In his final paragraph, the author states that future emission controls on acid gases and the addition of chemical scrubbers to the flue gas stream will result in an increase in

the SAR. This, in turn, will result in the plant improving its technology, changing its guarantee, or obtaining a modification to its operating permit. I suspect that all three factors will come into play.

AUTHOR'S REPLY

Several of the concerns expressed in this discussion are addressed in reply to the other discussion by Mr. Winka (for example, the reasons for building up a composite pile of all the unders and then quartering this pile down as compared to the overs, which were lab tested in their entirety).

In the absence of seasonal waste classification tests, it was hoped that the monthly SAR might provide some clues which could be related to other factors, such as heavy precipitation, yard clean-ups, plant water-treatment problems (Note: excess water and solids are dumped onto the ash pile.), and the like. On the near-term basis, these attempts were not overly successful, because the logistics were such that the ash hall was not always empty at the beginning and the end of a given month. However, on the long-term basis, both Figs. 8 and 9 suggests that seasonal factors are at work.

Mr. Eppich states quite correctly that not all of these can necessarily be ascribed to the cofiring of tires. Concurrent analysis of the fuel stream on a frequent basis as recommended would definitely help to better define any causal relationships. Concerning the tire impact, an additional study was performed whose results were not included in the paper. It involved the relationship of the SAR, the SSR, and the rate of tire cofiring. Based on multi-year averages, reasonably good correlations were found which show that such cofiring pushes up both the SAR and the SSR.

During the oral discussion following presentation of the paper, Mr. Hollander raised another interesting point. He questioned whether tire burning (save for the beads) would produce any ash at all. In order to find out, the Modesto

Energy Limited Partnership was contacted with the following questions:

(a) On an annual average basis, how much dry flyash is recovered from the boilers per ton of "as-received" tires fired?

(b) On an annual average basis, how much dry flyash is recovered from the baghouse per ton of "as-received" tires fired?

(c) On an annual average basis, how much dry bottom ash and slag is recovered from the boilers per ton of "as-received" tires fired?

(d) What percentage of (c) consists of tire beads and belting material?

(e) On an annual average basis, how much wet bottom ash and slag is recovered from the boilers per ton of "as-received" tires fired?

(f) Have you observed anything unusual about the moisture-holding capacity of tire waste derived ash?

Unfortunately, no reply was received, but literature sources indicate that this facility burns whole tires on grates under which quench tanks are mounted. In addition, flyash is recovered from the boilers and the baghouses. (Note: In the HCRRF all of this was added to the bottom ash.) Thus, there seems to be little doubt that whole tire burning does make ash. In addition, Ms. Stellan referenced her work on a confidential project which involves the burning of shredded tires. Reportedly, submerged ash conveyors are required for the transport of ash in substantial quantities.

We tend to believe in the following hypothesis: The ash from tire burning is high in carbon and it behaves similar to activated carbon. The filtration industry has reported for years that activated carbon can increase its weight (not volume) due to moisture adsorption. This hypothesis can be put to the test by burning a tire whose weight is known. All the ash is collected, dried, and weighed (over a desiccant). The ash is then submerged in water and checked for a constant temperature because adsorption would cause a temperature rise. After equilibrium is achieved, the ash is strained and reweighed. Any weight increase could be attributed to free water and adsorbed water. We suggest that a small research program be funded in order to come to terms with the tire ash problem.

Discussion by:

Roger S. Hecklinger
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From the title, one expects the paper to address the inherent fact that continuously-fired, two-stage combustors produce a heavy loading of fixed carbon in the furnace

residue and a high unburned combustible loss. In the paper itself, one finds scant mention of this fact.

Rather, the paper draws a number of conclusions from a small amount of test data. In addition, some of the data appears to have been incorrectly interpreted. For example, Table 2 presents data on components of ash as "Overs", "Unders" and "Unified" on a wet basis; and then presents data on a dry basis in the same categories. The adjustment from wet to dry assumes that the percentages of dry material in the overs and unders has the same relationship as for the wet data, whereas the amounts of dry overs and unders are essentially equal. The following revised Table 2 is offered as the proper adjustment from wet to dry.

AUTHOR'S REPLY

The unburnt combustibles are included in the paper under the headings "Volatiles" and "LOI". As such, test values may be found in various places, such as Table 2 and again in Figs. 3 and 4.

In addition, on page 133 differences in the LOI test values of undersized ash are discussed. Although ELI mixed the contents of its sample container, only a few grams which had been "spooned" from the container by the lab technician were actually processed. In contrast, BEI lab processed an aggregate of nearly 7000 grams of undersized ash, i.e., the entire contents of its sample container. Undoubtedly, ELI had better control over the volatilization procedure in its lab furnace compared to BEI with its roaster. However, "spooning" allows for much operator bias as to what is readily "spoonable" and what is not. Therefore, it is believed that the BEI result is more representative.

The LOI for the oversized ash is discussed on page 134. It was visibly lower, which can be explained by the fact that most of the magnetic metal, glass, and clinkers had remained amongst the overs.

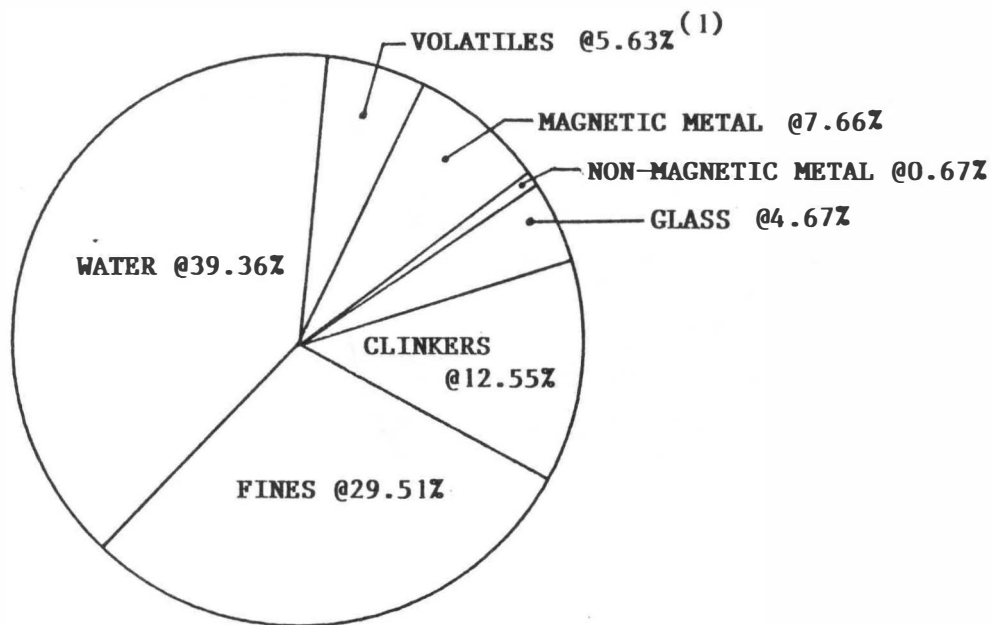
On page 135, the results for volatile determinations are briefly compared with those of the prior Ash Test I. In addition, other ash tests had been performed by another lab (Gascoyne Laboratories) on other occasions. For one such series in 1991, the average LOI was 29.9% by dry weight and the average elemental carbon content was 20.8% by dry weight. If one assumes an average moisture content of 45% in the raw ash, then the wet based values were 16.4% and 11.4%, respectively. It is agreed that these are not good values when compared to the performance of waterwall combustors. In fact, this is a distinct disadvantage of the two-stage combustors which must be balanced off against their lower capital investment costs. Concerning composition of the unified ash sample, Fig. 3 was checked again and found to be correct. However, the related tabular presentation in Table 2 was only partially correct. Therefore, the discussor's

efforts to recalculate the dry based portion are appreciated. Since Fig. 4 is derived from Table 2, its dry based portion, i.e. Fig. 4(b), was revised accordingly.

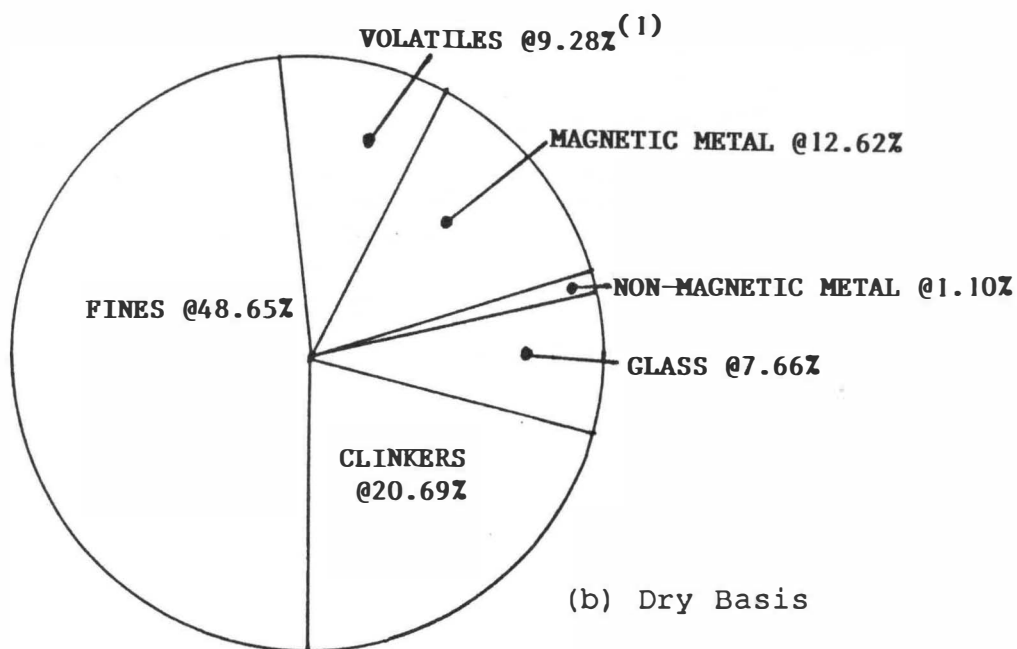
The changes in Table 2 do also affect development of the MSW compositional model. It follows that the sum of inerts on page 136 increases slightly from 0.2450 to 0.2469 dLb of ash per 1 wLb of MSW. Consequently, the compositional model for MSW which was projected in Fig. 5 was revised.

**TABLE 2
COMPOSITION OF UNIFIED ASH SAMPLE**

Component	W e t B a s i s			D r y B a s i s		
	Overs (0.3961)	Unders (0.6039)	Unified (1.0000)	Overs (0.30281)	Unders (0.30369)	Unified (0.60650)
Moisture	9.326	30.026	39.352	-	-	-
Magnetic Metal	7.445	0.210	7.655	12.27	0.35	12.62
Non-magnetic Metal	0.657	0.011	0.668	1.08	0.02	1.10
Glass	3.572	1.074	4.646	5.89	1.77	7.66
Clinkers	11.799	0.749	12.548	19.46	1.23	20.69
Fines	5.048	24.457	29.505	8.32	40.33	48.65
Charcoal	0.193	0.069	0.262	0.32	0.11	0.43
Volatiles	1.567	3.799	5.366	2.59	6.26	8.85
Totals	39.607	60.395	100.002	49.93	50.07	100.00

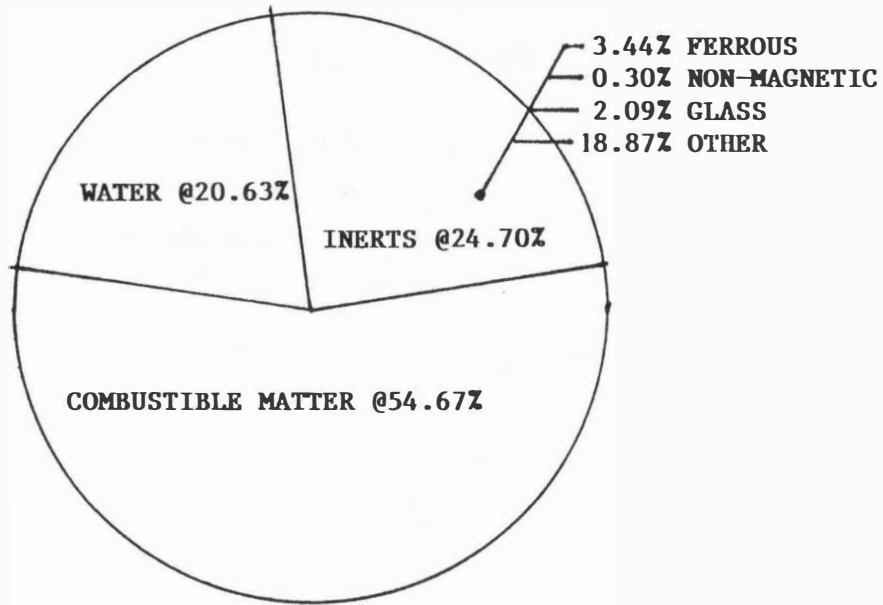


(a) Wet Basis

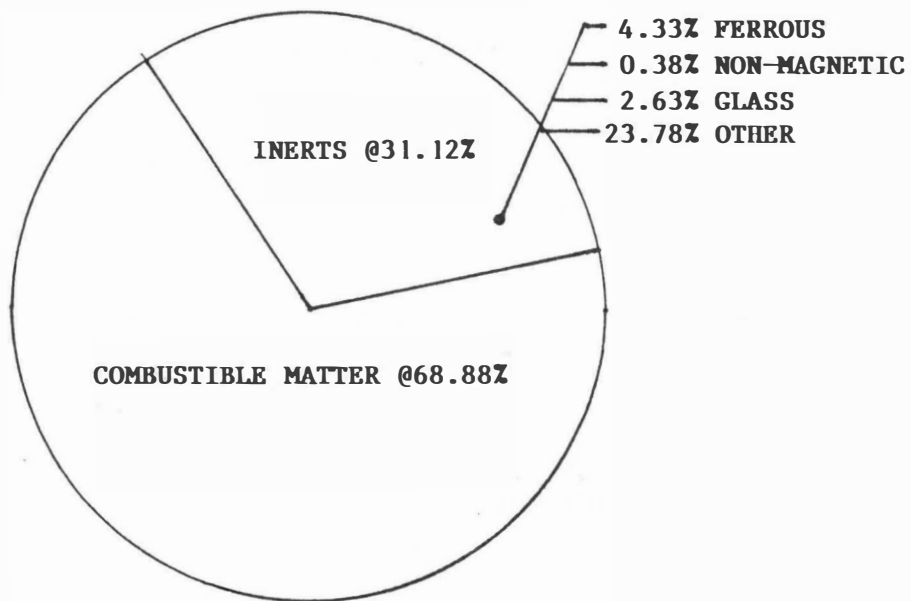


(b) Dry Basis

FIG. 4 COMPOSITION ANALYSIS FOR ASH
 (Note: (1) Includes Charcoal)



(a) Wet Basis



(b) Dry Basis

FIG. 4 COMPOSITION ANALYSIS FOR MSW

Discussion by:

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I am not as familiar with sampling and analysis of residual ash for performance guarantees (such as total putrescible matter — TPM) as I am with sampling and analysis of the heavy metals content of the various residual ash streams. Therefore, I have limited my comments to those areas where concerns and knowledge cross. While the study was thorough, overall I noted the following on which I will expand in some detail:

- Mass balancing of the facility — ash monitoring and emissions testing.
- Ash sampling — average properties.
- Correlation of operational data to lab data — total heat release;
- Ash model/solid waste model calibration/validation.
- Improvement/Test I Data.

(a) The decision to perform ash sampling with the emission testing is sound and should be a standard operating practice. It allows for mass balancing of the MSWIs operation during that test period. It is critical to amassing good scientific understanding of the environmental impacts of MSWIs that complete data be generated. Ash sampling during emission testing allows for the generation of complete data.

(b) Solid waste into an MSWI is highly variable, as noted by Fig. 8. Data from New Jersey facilities support this statement. New Jersey requires four-season, two weeks per season weighing/composition (w/c) studies by solid waste districts in the planning phase of any new facility. These w/c studies include total weight and composition of 27 different components (e.g., paper, plastic, glass, etc.) of the district's solid waste. The district's w/c studies also include ultimate, proximate, HHV, nutrient value, and heavy metals for each of the 27 different components and the total composite.

From the proximate analysis for two New Jersey counties (each county in New Jersey is considered by statute to be a solid waste district) over a year (four-season, 2 weeks/season) sampling the following range is available (as received):

Moisture Content	22.0–32.5
Volatile Matter	44.8–54.6
Fixed Carbon	4.2–5.8
Ash	6.2–17.5

As can be seen from the above, the range can be somewhat significant. Even during an operational day, this swing can occur. The sampling program should account for this

variation if the "average" properties of the waste are to be described.

The EPA draft protocol for sampling ash calls for 1-hr grabs over an 8-hr shift, repeated for two shifts during the day. New Jersey's ash sampling protocol calls for 1-hr grabs for 24 hr/day, composited over the week or month. (Sampling in New Jersey facilities is mostly automated.)

The larger the sample size, the greater the ability to sample the average property. It is unclear from the discussion of the Lab Phase how much the 4000 lb per unit sample represented in terms of total ash generated per day. In order to more fully describe the average properties of the residual ash, the taking of a smaller sample size composited over a larger period of time will more accurately describe the average property of the waste. EPA's sampling guidance in *SW-846 Test Methods for Solid Waste* requires meeting two criteria: accuracy and precision. The accuracy criterion pertains to the method of evaluating the average property of a waste during any one sampling event. This is accomplished using simple statistical methods. The second criterion addresses the method of evaluating the average property of the waste over time.

In order to calibrate this data, additional aliquots from the sample should have been analyzed in order to describe the average property of the ash. In order to more fully validate and verify the conclusion of this paper, the sampling event should run over additional seasons to analyze the trend. The conclusion that the residue generation guarantee has been met on an annual basis is tied to a one-time sampling event.

(c) Given the above, a methodology which correlates MSWI operational parameters, such as SAR and SSR, with lab data for solid waste, such as the proximate analysis, is a valuable asset. The data in the paper appear to be a method by which the performance guarantees can be tracked on a routine basis and the trend evaluated. However, as stated in (b) above, that correlation should be calibrated and verified through data sampling and analytical events over the year.

The author makes the statement that "For the better part, the SSR is proportional to the HHV". This, of course, is a correct statement and points to another method of correlating operational parameters to lab results, through the use of the steam production, annual efficiency of the boiler, and the enthalpy of the system to the annual HHV. In this manner the total heat release in the system can be monitored. As the waste's HHV is decreased, more waste could be processed by the facility. As the waste's HHV increases, less waste would be processed — all within the total heat release envelope as approved. The permit condition to set a limit on daily throughput and total heat release should be evaluated. This should be unitized only if the upper and lower limits are reviewed and approved by the MDE. This could address one of the potential remedy issues as noted in the paper.

(d) In order to prove the ash model, a mass balance of the

proximate analysis of the input solid waste into the facility should be performed. This proximate analysis of the incoming solid waste can be used to evaluate the results of the waste model developed for the ash model. This mass balance could calibrate the results and validate the model.

(e) A number of statements were made in the paper about improvements in ash quality over that from Test I. In fact, one of the questions in the introduction and background was "Has recycling improved performance?" However, no test data other than TPM in Table 1 were included in the paper. The conclusion that ash from Test II showed definite improvements over Test I cannot be made without supplying the data analysis.

AUTHOR'S REPLY

During Ash Test II, the total amount of ash generated was not determined by actual weighing. (Note: During the preceding Ash Test I, close agreement was observed between the daily and the monthly SAR.) However, estimates suggest that about 311,200 lb were involved. As indicated in the paper, the total amount that was moved into the segregation area for sampling and analysis was estimated at about 32,000 lb, which represents about 10% of the daily ash total.

Where and how to sample two-stage combustor ash is a controversial subject which would require a separate paper. In the quench tank itself there are all kinds of ash particles, some of which remain permanently suspended while others tend to settle. Typically, the ash ejectors under the combustors operate for only about 4 min following a waiting period of about 43 min. Consequently, some sort of a flow plug makes its way up the inclined drag conveyor which contains both solids and water. While much of the free water runs back down the conveyor, some small solids are also returned to the quench tank. Moreover, the conveyor does not pull the material at a constant rate (i.e., it goes from nothing to crest to trickle and back to nothing). Thus, sampling in the quench tank or off the conveyor does not seem to be a good idea.

The conveyors dump their ash through discharge towers onto the floor below. Cone-shaped piles form which permit bulky, heavy, and round objects to roll off the sides. Thus, sampling off the piles is subject to severe bias towards smaller particles, a problem which was encountered during Ash Test I in the year before.

Therefore, for Ash Test II, a different sampling philosophy was instituted. A wheel loader with a large enough bucket was positioned directly below the discharge tower for a long enough period of time to catch the entire amount of ash generated during a complete ejector and conveyor cycle. Thus, the entire discharge was delivered into the sampling area, including "balls and clumps." In this context, it should be remembered that unlike their waterwall cousins,

the two-stage combustors do not have mechanically articulated grates for churning and mixing fuel and ash. The procedure was applied to each combustor twice — once in the morning and once in the afternoon.

After each bucket was dumped on the floor in the segregation area, a conscientious effort was made to include the balls and clumps as material was picked for transfer into a 5-gal pail. Approximately ten shovel picks were needed to fill one pail. Of course, the diameter of the bucket was the limiting factor as far as the bulky items were concerned. Thus, several bulky items had to be disregarded during the course of the test day (e.g., one lawn mower, one bicycle, one 4-ft piping section, and one concrete block). How much of an error did this introduce? Probably less than 1% of the total ash weight collected, which appears to be well within other tolerances of the test.

Figure 3 is only a generalized and simplified presentation of the ash sampling and processing methodology. The field screen was a convenient method for separating overs and unders from each 5-gal bucket. It should be emphasized that only the unders were put into the composite pile which was quartered later on. On the other hand, all of the overs were collected and brought back to the BEI lab for processing in toto.

How would the 1-hr grab samples mentioned by the discussor work out in relation to the two-stage combustor specifics described above? If random times are used within each hour, and if the sampling location is the conveyor and the sampling tool is a shovel, then the results may vary widely. One shovel may be empty, another may be full of water with only small solids, and yet another may be fully occupied by a single brick. Only a few may contain some sort of a representative mix. In the end, how representative will the composite be?

Another problem concerns the requirement for reasonable concurrence between ash testing and emission testing. Emission testing is generally confined to the day shift only in 1/2 hr segments, and repeated over the course of three consecutive days. Therefore, including a complete second shift would not add very much. However, staggering the ash test would help to make the results more representative because of the long retention time (better than 3 hr) in two-stage combustors. This means that ash testing should be started at least 2 hr later than emission testing on any given day.

The discussor's suggestion about processing a larger sample taken over a longer period of time is appropriate. Repetition on a four-season basis is also a good idea, as are the inclusion of HHV testing, ultimate analyses, and waste sorts. But all of this would require a substantially larger budget than what was available for Ash Test II. As a first step, a repetition of the ash test should be considered, as discussed in the paper, three times, i.e., once for each emission

test day. Since only one annual emission test is required by law in Maryland, and since such tests are relatively expensive, extension rather than replication of the ash test is probably all that can be hoped for.

The discussor has made many other constructive comments which deserve careful consideration. However, given the limitations of time and space it is not possible to deal with all of them at this time. The results of the previous Ash Test I alone would become the subject of a separate paper.

Regarding the potential effects of recycling, a waste classification test was performed several months ago. Included was component testing for proximate analysis, ultimate analysis, and HHV. Later this year, an attempt will be made to correlate these new test results with those from the ash and BAC test programs. Should there be a positive outcome, another paper may be presented to the next ASME conference.

AUTHOR'S CLOSURE

A problem inherent to the production of ASME papers is the pressure to keep them short. The original report for Ash

Test II encompassed about 110 pages. When condensing this wealth of information into some 14 pages, one faces conflicting goals. How can one present a complete and credible picture while at the same time retaining clarity and brevity? Invariably, cuts had to be made which are a disadvantage to the interested reader later on.

Another matter concerns the fact that the HCRRF is privately owned and operated. There was no local regulatory requirement to perform sophisticated ash testing like the one practiced in New Jersey. Instead, Ash Test II was a voluntary undertaking with a very limited budget, and it was not possible to do a perfect job. Its ulterior motive was to provide input to the BAC program which proceeded on a parallel path. For practical reasons, numerous short cuts had to be taken. Therefore, the results should be viewed only against these rather limited objectives.

It was satisfying to receive several discussion papers which suggests a high level of interest in the nature of two-stage combustor ash. With an eye towards the future, we will consider planning a better Ash Test III. For this purpose, the lessons from Ash Tests I and II will be merged with the comments received from the discussors. Further investigation of the tire ash phenomenon should be part of such efforts.