COMPLETION OF THE DUESSELDORF REFUSE POWER PLANT

K. S. FEINDLER
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Wheatley Heights, N.Y.

and

K. H. THOEMEN
Duesseldorf Refuse Power Plant
Duesseldorf, West Germany

Discussion by

John C. Ellis
Bureau of Sanitation
Solid Waste Disposal Division
Northwest Waste to Energy Facility
Chicago, Illinois

I am pleased to be one of the chosen discussers of this excellent paper. I personally subscribe to the concept of a number of smaller units in a facility with their attendant flexibility as opposed to fewer but larger units. It appears to me that the high operating percentage attained is due in part to the ability to rotate equipment out of service for scheduled maintenance without affecting the overall capacity to any great degree. My comment is based on an operator’s point of view with regards to maintenance and operation scheduling, not first cost economics.

If it is found that you still have to go to landfill even with six units, have you considered the economics and practicality of recovering recently deposited landfill refuse during times when garbage collection is light – or – would this light garbage period better afford you the time for scheduled major maintenance?

Has it been determined that the increased ash generation rate, related to the new scrubber, is equal to the stoichiometric amount of Calcium Hydroxide forming with an acid? As an example, Calcium Hydroxide and Sulfuric Acid reacts as Calcium Sulfate and water. If it is found that the precipitate of the reaction exceeds the stoichiometric balance, can it be assumed that part of the increased ash generation rate is due to a higher, overall collection efficiency?

The 73 percent actual to theoretical operating percentage is quite good. However, is this at full capacity? What is the percentage of availability of the first five units over the past 10 years?

Are the new combustion controls for Unit No. 6 controlled from furnace temperature? If so, have you experienced burning back in the feed area due to the drive being shut off? Are you also using a multi-element feed water control to more closely control the level in the boiler?

It would appear that your decision to not generate your own electricity may be based on economics. The energy in 1,000 lb (453.6 kg) of steam is worth more for sale than conversion, in-house, to electricity using your own turbo-alternators, especially when you are supplying the steam to a utility type facility that will generate electricity more efficiently.

Do you expect the equipment utilization factor to return to the mid-to-high 70 percent range over the present mid 60 percent range now that the sixth unit is operational? If so, at what point and by what parameter will you opt to expand your operation further?

Is your processed ash the sum of fly ash, precipitator and bottom ash? Is there commercial value besides use as roadway material?
Does the tipping fee and heat value of the bulky commercial and industrial waste justify the nuisance and hazard of shredding and subsequent increase in fireside corrosion? If the tipping fee is high enough, perhaps shredding only for landfill would be preferable, or perhaps another form of volume reduction such as high density compaction.

I was interested in reading that positive displacement feed rams were now in use on the new unit in place of feed tables. What is the area of the opening and the aspect ratio? Does jamming cause a problem? How are jams handled?

The buildup of slag on the “Carbo-fax” refractory can help protect the lower areas from erosion. However, if allowed to “grow” too much at a higher elevation, the possibility of a shearing action must be guarded against or you may experience a loss of protective refractory.

The use of air jets to cool the refractory is fine, provided you can control for wet and dry garbage. The turbulence is a benefit in combustion. It would be interesting to plot the effect the new scrubber has on the fly ash resistivity by removing the acidity. Is the flue gas temperature affected?

Overall, I am quite impressed with the described operating history and most recent expansion of the Duesseldorf Refuse Power Plant. It is because of the excellent engineering and fine operation that the “State of the Art” of mass burn technology allows for such flexibility as described in this paper. Messers Feindler and Thoemen are to be congratulated for a fine and informative paper.

Discussion by

R. S. Rochford
Babcock and Wilcox Co.
North Canton, Ohio

The information presented in this paper showing costs and operating trends of a major refuse processing plant over a 15 year period is invaluable to anyone involved in the planning of a new refuse to energy facility. It is easy to see how unforeseen added costs imposed by government regulations, in this case value added taxes and coal subsidy assessments, could drastically affect the tipping fee at some later date. Today’s planner should try to provide for these possible contingencies.

As the authors point out, the steam conditions at the plant are quite severe; however, they have taken many steps in the design of the latest unit to keep down time from corrosion to a minimum. It would be interesting to know the authors’ appraisal of how their utilization factor would improve if their steam conditions were set at a more customary 700 psig, 750 F at the superheater outlet instead of 1305 psig, 932 F. Further, in Fig. 2 of the paper, we note their O&M expenses amounted to 46.7 percent of their expenses. With the high steam conditions, the maintenance cost must have been significant. It would be interesting to know approximately how much of this percentage was the maintenance cost.

The writer was impressed with the success achieved at this facility in disposing of their residues. The fact that of the 4,418,000 ST of refuse processed during the life of the plant, they were able to sell 148,900 ST of ferrous scrap and 950,800 ST of ash or 25 percent of the incoming weight is quite a feat, not to mention the reduction in residue landfill needs.

In conclusion, the writer feels the authors are to be commended for sharing the wealth of information amassed in this paper.

Discussion by

Richard B. Engdahl
Consultant
Columbus, Ohio

This excellent paper continues and culminates the very helpful accounts of the Duesseldorf experiences which have constituted a major contribution to the development of waste-to-energy technology over the years since 1961 when the first roller grate was invented there. Much has been tried out at this plant, and the details of the newest and larger boiler given here show the incorporation of the results of many of the lessons learned.

Some of the modifications which improve line no.6 over the older lines at this plant were first applied by others elsewhere, but this in no way detracts from the major and steadfast contributions which Mr. Thoemen and his associates have made to the art by taking pioneering steps and then publishing the results, the bad with the good, so that all might benefit from the lessons thus learned.

Other European plants have also encountered severe limitations on boiler-furnace input as the heat value of their refuse has continued to rise. Basically, this has been a problem of furnace outlet temperature that temperature can become high enough to accelerate corrosion by chloride deposits.
on the tubes in the downstream passes unless refuse input is cut back as the heat value of the refuse rises. No other account has depicted this situation so clearly as in Table 2, although it is summarized a bit too briefly on the first page, "...it became necessary to reduce the rate of waste processing in order to avoid overloading". More specifically I would suggest that last word be "overheating".

The retention of the furnace guide vane which first forces the flames to flow downward parallel to the fuel bed before they turn upward to enter the first pass is a bold and unique design which has been evolved at this plant. Together with ample high-velocity secondary air jets, this should provide excellent mixing and complete burnout of the gases. The impacts of temperature, scouring and erosion are probably very severe at the lip of the guide vane, but the staff at this plant has vast experience in designing to combat such impacts.

Air-cooled Carbofrax wall blocks protecting the wall tubes is an expensive but justifiable alternative to the use of castube refractory on studded tubes. Experience has shown that when the steam pressure exceeds corresponding to a saturation temperature of about 600°F (315°C), the furnace wall tubes must be protected by refractory up to the level where visibly active burning terminates.

Use of a completely open first pass without superheater loops filling the top of the pass is an important way of minimizing chloride corrosion of superheaters that has been demonstrated at many other plants. This is particularly important here with 923°F (500°C) steam temperature, which courts chloride attack if the gases entering the superheater exceed approximately 1,700°F (925°C).

Use of parallel-flow vertical steam tubes in the entire first superheater section (second pass) is a conservative and costly but wise choice to minimize tube erosion and corrosion by the still hot, ash-laden gases. Are these tubes cleaned by any in-place deposit-removal system?

When the Battelle team toured this plant in 1977 the capital cost figure stated for the first four lines was $15,000/ton-day and for line 5, $16,400 (both in 1977 dollars). With no new building required and lacking the need for a new turbogenerator, I assume the comparable cost of line 6 was about $45,000/ton-day (in 1980 dollars), or $35,000/ton-day (in 1977 dollars). Is this guess near to being right?

It is interesting to see the switch to a ram-type feeder and a piston-type residue remover, both of which have become widely used because of the advantages cited by the authors.

We look forward to learning later of the extended performance results with the experimental quasi-dry scrubber for the control of acid gases. There is an obvious wet-deposition and corrosion hazard to the precipitator if some plant upset causes incomplete evaporation of the hydroxide slurry. Eventually, also, it will be helpful to know the cost of the scrubber. In special publication No. 13 of Mull and Abfall in 1978, H. Grimm quoted the cost of wet scrubbing at Kiel as one-quarter to one-third of the total operating expense of the plant.

The curious definition of lower heat value in Note 2 under Table 2 needs explanation, despite its being labeled frankly as an approximation. Consider a dry (water-free) waste such as heavy petroleum which is high in hydrogen content. Its HHV is normally determined in a bomb calorimeter. If it is really free of water, the approximation shown would have LHV equal HHV. Actually, its high hydrogen content would cause its LHV to be considerably less than its HHV.

The writer, in thanking the authors for this outstanding contribution to the art, wishes, once more, to thank them and the representatives of Vereinigte Kesselwerke for their past cordial kindness and cooperation toward me and my colleagues on many occasions.

Discussion by

Sergio E. Martinez
Resources Recovery
Dade County, Inc.
Miami, Florida

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 of 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.

Discussion by

John H. Fernandes
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Combustion Engineering, Inc.
Windsor, Connecticut

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 multi-million dollar contract handled in this loose a manner.

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 multi-million dollar installation can be justified if not conducted in a pains-taking 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 would not expect testing costs to approach one percent of the cost of a large incinerator/boiler installation. I don't feel the fact that the present test procedures are cumbersome and difficult to perform is a reason to compromise or abandon them.

I feel it important at this point to review some of the reasons one conducts performance tests. There are many, but principal among them are as follows:

1. Verify that the system performance meets guarantees.
2. Evaluate system performance when incrementally loaded.
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 O2 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 shouldn’t 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 monogram and if, after we had some experience with the monogram 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’ REPLY**

To J. C. Ellis

The inference that even with six processing lines, raw refuse needs to be bypassed to landfill, is no longer valid for the new conditions which now prevail at Duesseldorf (see also the Author’s Epilog below). The paper stated quite correctly that during 1980 substantial bypassing did occur, but this was only during the first 9 months. In October of the same year when the new and larger number six processing line came into full play, this practice stopped.

The idea of retrieving refuse previously landfilled in order to even out refuse supply logistics cannot be treated in a general way. Nevertheless, the authors believed that economic rather than technical factors would make the difference. It appears rather unlikely that earnings from the sale of high quality energy can compensate for the many additional costs associated with such refuse retrieval. In terms of Duesseldorf, the distance between the RPP and the landfill is too great. In addition, the landfill involved is a large operation which does not distinguish between combustibles and noncombustibles. Huge deposits of construction and demolition wastes are especially troublesome.

The authors much more readily accept the suggestion of using temporary plant excess capacity for scheduled major maintenance.

With regard to the ash generation rate, neither Table 1 nor Table 2 indicate anything thus far. During 1980, ash generation was about average both in absolute and specific terms. As of this date, a detailed analysis has not been performed in order to assess any potential future increase due to the large-scale use of scrubber chemicals. In any event, the new scrubbers are intended to operate with an excess of lime corresponding to an amount of two to three times the stoichiometric ratio. Consequently, the specifics of the chemical reactions involved are not expected to affect the outcome appreciably.

The question of whether the average equipment utilization factor of 0.725 relates to full load can easily be answered for the boilers by referring to the specific steaming rate, or SSR. Figure 1 shows the relationship of the actual SSR to the design SSR over the operating life of the plant. Except for the “OPEC Dip” during the 1973 to 1975 period, the actual SSR equaled or exceeded the design SSR, thus indicating full load performance. During the “OPEC Dip” the heating value of Duesseldorf refuse dropped temporarily, making steam generation less productive.

Unlike many conventional powerplants, the tendency in Refuse Power Plants is to run mainly at full load as far as the supply of refuse and discrepancies in the heating value permit.

Equipment availability and equipment utilization are closely related to each other. The difference is the amount of time during which equipment, while technically available, is not being run for certain practical reasons, such as intermittent refuse shortages, test work, training exercises, etc. The authors have conducted supplemental research into the plant’s operating log and found this difference
to be in the order of 2 to 3 percent. Thus, by adding the median of this difference to equipment utilization, an average availability of 0.750 can be estimated.

The combustion control system for the number six boiler responds to a number of control parameters, of both a primary and secondary nature. Furnace temperature, steam pressure, steam flow and fuel bed depth above the grate make up the primary parameters. The quantities of primary and secondary flow serve as secondary parameters. So far, not a single instance of bum-back has been observed resulting from a control system induced shut-down of the ram feeder. It is correct to state that the boilers are equipped with 3-element feed water controls in order to hold water level fluctuations within close limits in the drums.

The decision not to generate electricity for implant use was largely based on the disadvantage which small turbines have in competing against the larger and more sophisticated turbines in conventional power plants.

The authors do expect the equipment utilization factor to return to the upper 70 percent range. Indeed, as the epilog shows, an increase has already occurred during 1981. The previous drop-off was mostly due to corrosion damage and modifications of the number five boiler unit.

A new construction program, i.e., Phase IV, has been in the planning stage for some time. This concerns the original four processing lines which now approach a service life of 20 years. Originally designed for a substantially lower heating value, these lines are now restricted to a full load feedrate of 8.8 stph instead of 11.0 stph — a consequence of the increased heating value of Duesseldorf refuse.

This limitation of throughput capacity will be redressed by installing four new boilers of a design similar to the number six unit. A precise date for the beginning of construction has not been set, but this will also depend on how stable the refuse supply remains in terms of quantity and composition in the future.

The ash which goes into the processing building is actually a mixture of four components: normal bottom ash from the end of the grate, riddlings from underneath the grate, fly ash from the boiler bottoms and fly ash from the electrostatic precipitators. Besides being used for road construction, the processed ash is also used for parking lots and sports arenas. While this ash generally has little economic value, its sale does reduce O & M costs because transportation costs to the landfill, and tipping fees at the landfill are eliminated. In addition, the life of the existing landfill is further extended.

The comments concerning the shredding of bulky wastes are based on wrong assumptions. The tipping fee and the heating value were not responsible for the installation of a shredding capability at Duesseldorf. Instead, size reduction of bulky wastes was deemed necessary because of three other reasons: First, because of their relatively small size, the feedchutes cannot accept very large bulky objects without clogging. Second, because of the unwieldiness of such objects, effective fire control is further diminished. Third, because of a limited retention time in the fire zone, oversized particles may not burn out completely. Truck tires are a good example. One important exception to this reasoning may be seen in the Ivry RPP in Paris. In this facility bulky wastes are fired even without prior size reduction, but then again the reader should be reminded that the Ivry furnaces are at least four times as wide as the Duesseldorf furnaces. Thus, if one wishes to make a case for smaller unit sizes, then logic would dictate a provision for a size reduction capability as a reasonable compromise. This is especially true in Duesseldorf where a shortage of landfill space does not permit the landfilling of combustible bulky wastes such as packaging materials.

It is also worthy to note that the technology for the size reduction of bulky waste reduction has advanced. Systems for the detection and suppression of explosions and/or fire have been developed for shredders. At the same time new alternatives are now available such as the "Roto Shear" built by Undemann which is performing well in Kiel and elsewhere.

Positive displacement feed rams are far more effective in equalizing feed rates than the older feed tables. Over the years, the density of Duesseldorf refuse decreased almost steadily, which caused a reduction of friction between the particles and the tables. As a result, the uniformity of fire control was disturbed with increasing frequency. The new number six furnace has a grate width of 11.5 ft (3.5 m) and the furnace entrance is 4.4 ft (1.35 m) by 11.0 ft (3.35 m). The ratio of the face area of the ram to the entrance area of the furnace is 1 to 3.4. Thus far, the entrance has not clogged up inasmuch as the thrust developed by the piston has always been adequate to overcome such conditions.

The purpose of the silicon carbide type of refractory (Carbofrax M) is primarily to avoid the
baking on of slag. However, the refractory also protects the boiler tube walls against erosion and corrosion. It is mostly because of the excellent slag repellent characteristics of this refractory that the conditions anticipated by the discusser did not materialize.

The air flow rate through the secondary jets is adjustable indeed.

The resistivity of the fly ash collected after start-up of the scrubber was not tested, because this is a rather costly undertaking. More important, perhaps, is the observation that the particulate removal efficiency of the affiliated precipitator was not negatively affected.

To R. S. Rochford

The reduction of superheater steam outlet conditions typically to 700 psig (4.82 x 10^6 Pa) and 750 F (385 C) by itself does not constitute a guarantee against corrosion. Instead, special consideration must be given to certain structural details during the design of the furnace and the boiler in order to maximize the benefits resulting from the choice of lower steam conditions. The nearby Bielefeld Refuse Power Plant can serve as an illustrative example. In spite of more modest steam conditions, i.e., 600 psig and 750 F, the Bielefeld superheaters had barely reached 3,000 operating hours when severe corrosion practically made them inoperable. As a result, major and costly modifications were required.

Undoubtedly, high pressure boilers are more costly to maintain in the long run. When considering the O & M Expense item in Fig. 2, it is important to note that this item includes not only maintenance of the boilers themselves, but also much in the way of ancillary equipment, especially electrostatic precipitators, refuse feeders, ash extractors and the like. On the average, about 28.5 percent of the O & M total is allotted to maintenance of the boilers and their ancillaries.

To R. B. Engdahl

Corrosion in refuse fired boilers has been a major trouble source which received much attention over the years. The mechanism of corrosion is a complex physical-chemical issue which cannot be attributed solely to excessive temperatures. It is generally accepted to associate rising furnace outlet temperatures with the heating value of refuse. This is especially true at Duesseldorf where the heating value is still rising from year to year. (See Column 2 in Table 2.)

However, much more significant is the fact that due to the continued rise in the heating value, the design limitations of the boilers were reached. In some cases, these limitations were even exceeded. This can best be explained by referring to the specific steaming rate, or SSR. Figure 1 clearly illustrates how the actual SSR reached or exceeded the design SSR. Steaming rates are predominantly related to the product of refuse feed rate, refuse heating value and boiler thermal efficiency. This product can also be considered as the "thermal flux" and any given boiler design can only accommodate a finite thermal flux.

In view of this discussion, the term "overloading" must be accepted as appropriate. This contention is further strengthened by mentioning that the older boilers, i.e., numbers 1 through 4, (which had been designed for a lower thermal flux) started to actuate their relief values with increased frequency during the seventies. In order to avoid the needless venting of excess steam, the refuse feed rate was cut back.

With regard to the furnace guide vanes, the authors assume that Mr. Engdahl’s discussion is directed towards the new number 6 boiler. In this boiler, the complete guide vane is clad with massed silicon carbide refractory to guard against the impacts of temperature and erosion. The same holds true for the collector inside the furnace chamber and the end of the guide vane, both of which are protected by silicon carbide blocks.

Steam tubes in the first superheater section (second pass) are not being cleaned at all any more. However, as a preventive measure, three retractable sootblowers were installed during the most recent construction. Throughout the first months of boiler operation, these blowers were used, but thereafter it was decided to discontinue their use on a trial basis. It was then observed that light ash deposits build up to a layer of approximately 0.8 to 1.2 in. (20 to 30 mm) in thickness. This layer eventually becomes fairly stable and does not adversely affect the boiler exit temperature on the steam side.

The cost figures for the sixth processing line as presented in the discussion are too high. Using an exchange rate of about $0.395 equal to DM 1.00, the cost of the furnace, ash extractor and boiler inclusive of installation can be put at $5.33 million. To this, approximately $0.4 million for an electrostatic precipitator and $0.59 million for mechanical work (piping) and electrical work (instrumentation and controls) must be added. Thus the total incremental cost for Phase III construction amounts to
about $6.32 million, or about $19,000/STPD of installed capacity.

In terms of Phase II construction, i.e., the fifth processing line, the authors wish to point out that the costs given not only include a scope of supply very similar to the one above, but also certain extraneous equipment and appurtenances, such as a shredder.

Test results with the experimental quasi-dry scrubber have proven to be quite satisfactory. After 1½ years of testing, the required removal efficiencies for HCl, HF and SO₂ were attained. Consequently, the regulatory agency has approved the permit to equip the entire facility with four scrubbing towers of this type. Construction should be complete by the middle of 1984.

Although not firm, investment capital costs have been estimated at $4.75 million, which will include a large new electrostatic precipitator to replace two old and smaller ones of 1965 vintage. Operating costs are assumed to range from $2.90/ST to $3.60/ST of refuse. These costs may increase somewhat further if fly ash from the precipitators is declared a hazardous substance. In the latter case the costs for transportation to and disposed at a special landfill set up for hazardous waste disposal must be added.

The commentary offered with regard to the relationship between the lower and higher value is well taken. When calculating the thermodynamic efficiency of boilers, one must subtract the latent heat of vaporization for any water which originates from the fuel. This is because the resultant water vapor leaves the stack with the rest of the flue gases at temperatures in excess of 212 F (100 C), i.e., well above the boiling point of water. Consequently, this heat of vaporization cannot be recovered in the boilers for steam generation. In the case of refuse as a fuel, there are at least two sources of such water. One is free water contained in refuse as it is received into the storage pit. The other is chemically formed water which is the result of the combination of hydrogen with oxygen during the combustion process.

In Europe, boiler designers generally prefer to use the lower heating value, because it represents the net amount of thermal energy available for steam generation. In the U.S., the higher heating value is more prevalent, because it can be related more readily to experimental procedures used during the determination of heating values. One of these is the oxygen bomb calorimeter, in which refuse samples are combusted under controlled conditions. During such calorimetry, the latent heat of vaporization is recovered and, as a result, the higher heating value, or gross heating value, is determined.

Presently, an intense exchange of information is being carried out between Europe and the U.S. in the field of mass-fired boiler systems. In this context, the authors would like to recommend that the appropriate ASME standards committee undertake the task of setting up a common format for facilitating comparisons between European and U.S. practices. This way a better method can be found for making quick conversions, thus obviating the need for approximations of the kind used in the paper.

**EPILOG**

In the body of the paper, the authors promised to supply the new operating statistics for the year 1981 as soon as they became available. This new data holds particular significance in that it represents the first full operating year of the completed Diesseldorf RPP.

After the May conference, these statistics were received and they can now be presented by completing Table 2 as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1980</th>
<th>1981</th>
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<tr>
<td>Lower Heating Value:</td>
<td>3,408 Btu/lb</td>
<td>3,408 Btu/lb</td>
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<tr>
<td>Boiler Thermal Efficiency:</td>
<td>0.750</td>
<td>0.750</td>
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<tr>
<td>Specific Steaming Rate:</td>
<td>2.19 ST/ST</td>
<td>2.19 ST/ST</td>
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<td>Steam Conformance Factor:</td>
<td>0.950</td>
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<td>Specific Ash Rate:</td>
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<td>0.320</td>
</tr>
<tr>
<td>Specific Electrical Power Consump.</td>
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<td>53.8 kWh/ST</td>
</tr>
<tr>
<td>Specific Oil Consumption:</td>
<td>0.010 gal/ST</td>
<td>0.010 gal/ST</td>
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<tr>
<td>Specific Water Consumption:</td>
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<td>Equipment Utilization Factor:</td>
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<td>Capacity Factor Grates:</td>
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<td>Capacity Factor Boilers:</td>
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</tr>
</tbody>
</table>

With the exception of the heating value and electrical power consumption, all other performance parameters in 1981 bettered the values for 1980. Most significant are the upward leaps in refuse processing (up by 20 percent) and steam generation (up by 25 percent) which are largely the result of a superb performance by the new number six line.

This positive statement can be further embellished by referring to Fig. 7 which is similar to Fig. 1 in the original paper. However, the new data points for 1981 have been entered and lines which fit best have been drawn for each of the four major parameters displayed. With an eye towards forecasting future trends, these lines have been extended out to the year 1986 when the Diesseldorf
RPP will conclude 20 years of continuous operations. The prognosis is for refuse processing to approach the 400,000 STPY mark and for steam generation to exceed the 800,000 STPY mark. This of course depends on stable population levels and undiminished per-capita waste generation rates.