DISCUSSION by Robert E. Sommerlad, Foster Wheeler Energy Corporation, Livingston, New Jersey

Mr. Bozeka's paper is "fortunately" a very "dull" paper — "dull" because the paper presents the results of a performance test of a refuse-fired steam generator in a forthright manner, stating design conditions followed by a series of six tests which consistently show results meeting design conditions and "fortunately" because this paper is a verification that refuse is a fuel that can be applied for steam generation. The results also indicate that refuse emits low levels of gaseous emissions and that the particulate emissions are fairly consistent considering the heterogeneity of the fuel.

The paper will undoubtedly be a valuable reference as are the results of Chicago Northwest. The chemical analyses and results will aid the work of the PTC-33 Committee.

DISCUSSION by John H. Fernandes

As the Chairman of ASME's PTC #33 — the Test Code for Large Incinerators, I am very pleased to see such an important test performed and the valuable results published. The complete test results of an incinerator-boiler and its operating characteristics are very valuable to the engineering profession. There have not been enough of these tests performed by competent test crews that were made public. I want to commend the author and those involved with this test program for their foresight in making this information available.

I have a comment on the length of tests — the paper indicates that the tests were from 2 hours 20 minutes to about 3 hours 30 minutes long. This is fine for dust sampling as part of a larger test program which insures stable conditions and would have more than one dust sampling performed during the major test of the unit, but this did not appear to be the case. The 6 tests were run on 4 different days. I consider this to be a very short testing period for an unprepared heterogeneous fuel, like refuse. Most boiler tests to be considered accurate and meaningful on a fuel such as coal take a minimum of 8 hours. It may be reduced to 6 or even 4 on a very homogenous, easily controlled fuel such as gas, but certainly this should not be the case with refuse. I would also ask how the 4 hour refuse sampling program related to the gas and ash sampling procedures. Measuring and sampling procedures are very critical to any test program, but they must be especially precise for a fuel such as refuse.

How much is a partial bucket full? What procedures were followed to insure a representative sample of the charging stream in the partial bucket? How were the noncombustibles separated? These and other questions immediately come to my mind, and I am sure the author took the necessary precautions, but I wish he had shared them with us, because incinerator sampling is very difficult.

A comment was made that the steam pressure and temperature was not quite to design. This in itself is not a calamity, but it would have been informative to know how steady the steam pressure and temperature were. These variations can be a problem and information on these characteristics would have been most helpful.
No mention was made of oil firing. Was there any oil stabilizing used during the tests?

I noted only two refuse samples reported during the 6 tests. I wonder why only two, and when were they taken and what was their relationship with respect to the 6 tests reported? In the paragraph, "Refuse and Refuse Properties" the noncombustible quantities were given as 11.4 and 20 percent, respectively. I cannot correlate this with the figures in Table 2. Was Table 2 just a presentation of the combustible fraction in the refuse or was it a total representation, as one would assume from the title, "Refuse Analysis"? In the flue gas, was there a check made of the incomplete combustion with respect to hydrogen and hydrocarbons and was any allowance made for their presence? The members of PTC #33 believe that unburned hydrogen and hydrocarbons constitute a significant incinerator loss that is at least equal to the heat loss due to the burning of carbon to carbon monoxide.

When computing the boiler efficiency, was the residue combustible loss determined by bomb calorimeter? If the combustible was assumed carbon, it might be low since our Committee investigations indicate that there can be hydrocarbons present that would increase the loss beyond that due to carbon alone.

The author is quite correct in pointing out the difficulty in sampling and analyzing an incinerator-boiler. I would like to have seen an error analysis of the various means used to determine the fuel rate, ash rate, the representativeness of the fuel samples and data analysis. It would have been most valuable because these, as the author indicates, have problems not normally found in conventional fossil fuel fired units, and about which we need to determine more precise information.

There is considerable valuable data in this paper, and from my position as Chairman of PTC #33, I want to thank the author for sharing it with us. If I sound critical, it is because I share the author's appreciation for the difficulty of the task and a desire on my part to obtain all the data I can for inclusion in PTC #33's deliberations. A draft of this Code is about to issue, and we would encourage future incinerator testers to consider its use and share with the Committee their evaluations so improvements can be factored into the final draft. If this procedure is followed, the Committee will be able to come up with a test procedure about which we would anticipate an absolute minimum of questions.

DISCUSSION by Robert J. Schoenberger

This paper presents an excellent review of solid waste burning in a water wall, steam generating incinerator. The performance tests were aimed mostly at air pollution control and particulate emissions, although some attention was given to the properties of ash and refuse as-fired.

In determining the noncombustible fraction of the refuse an error is introduced by hand separation. When refuse is massed burned, it is normally expected that some ferrous oxidation will occur as was determined by Kaiser in previous studies. While hand separation of the noncombustible fraction does facilitate the ultimate analysis, the error which is introduced must be factored into the overall results when characterizing the fuel input.

In determining the bottom ash characteristics as given in Table 7 of the paper the results are rather encouraging for this unit. The results of tests five and six, do however, indicate a marked decrease in efficiency in destruction of the volatile matter. Various researchers have spoken on the inaccuracy of the putrescible test and Bowen in another paper stated that he had little faith in the results of that test. The volatile matter fraction and the carbon analysis are excellent measures of the burning efficiency of the unit. An 80 or 81 percent burning efficiency is rather poor, even under the best of conditions one would question the ability of this unit to handle refuse efficiently.

In the analysis of particulate matter and ash the determination of chloride, sodium and calcium should be further explained. No chloride results are given for the particulate matter, although it has been recognized from other tests that this is a major constituent of flyash, slag, and particulate emissions from the burning of refuse. The sodium values in the ash are not necessarily accurate and in all probability, can be sodium or potassium values. One of the dangers of analyzing ash is the interference and general redundancy attributed to certain ions within given classes.

In general this paper is a valuable contribution on predicting some of the operating parameters of a mass burning solid waste incinerator. Good and accurate tests on operation of an incinerator are difficult, expensive and time consuming. A good deal of information is derived from well run tests, and the acquisition of this data helps us to further understand how refuse incinerators perform.
DISCUSSION by Elmer R. Kaiser, P. E., Scarsdale, N. Y.

Papers of this nature are of interest at this time because a test code for large incinerators is being prepared by the ASME Performance Code Committee No. 33. Unfortunately, the paper does not give enough specific data for a complete mass and heat balance. Hopefully, the author can supply more details in this closing remarks.

The input refuse may have been sampled satisfactorily, but a serious error was introduced by neglecting the moisture and combustibles left on the so-called “noncombustible” fraction. Paint, labels, fats, etc. associated with metallic and ceramic (glass) wastes have heating values equal to about 300 Btu per pound of the raw refuse. The partial oxidation of the metals during combustion in the boiler furnace add about 3 percent to the total heat from the burning of the organics in the total refuse.

If the 4900 Btu per pound of as-fired refuse given by the author is multiplied by the given feed rate of 30,208 lb/hr, the heat available is 148,019,200 Btu per hour. The heat to the feedwater is (1293 – 201) 107,000 lb/hr equals 116,844,000 Btu/hr. The boiler efficiency indicated by these figures from the paper is 78.9 percent. However Table 3 reports 71.9 percent efficiency. Why the discrepancy?

For a water-wall furnace and boiler it is possible to determine boiler efficiency and the losses given in Table 3 without analyzing the fuel or determining its Btu value by bomb calorimeter. Perhaps Table 3 was constructed in that manner.

We are glad to have the values given for NO\textsubscript{x}, SO\textsubscript{2}, CO and chloride, which appear to be in the expected range. Regrettably, the particulate emissions were above current requirements.

DISCUSSION by Richard B. Engdahl, Senior Researcher, Battelle Columbus Laboratories, Columbus, Ohio

The title of this paper refers to tests and the paper confines itself faithfully to these tests. Unfortunately it leaves out very important performance details (a word which is also in the title) which are essential to a full professional evaluation of this unique plant.

The tests were run between February 10 and 17, 1975. However, the wall waters had already begun to fail in January. The paper makes no reference to that problem which has since been solved by the same means — silicon carbide covering — already proven necessary over many years in most water-walled refuse burners in Europe. Neville and McDermott have subsequently reported (Actual Specifying Engineer, February, 1976, pp 50-53) that:

... “In January, 1975, there were some failures in water-wall portions of the incinerator boiler tubing in the furnace area. In April both boilers tubes were ultrasonically tested to determine wall thickness. Following the testing, it was determined that they be replaced. At that time, the first and second boilers had logged 3,608 hours and 2,491 hours, respectively.

The boiler manufacturer initiated an exhaustive study to determine the probable causes of the tube wastage. Surveillance test coupons were placed in the lower and upper furnace, superheater and in the first and second boiler banks when the boiler was installed. Chordal thermocouple tubes and the tube shields in the superheater section were also installed as part of the original testing program. The manufacturer pointed out the following combination of conditions as the probable causes of the tube damage:

- Insufficient air for thorough combustion in certain areas of the incinerator/boiler
- The absence of any protective coating on the outside of the tubing.
- Excess scale accumulation on the inside of the tubing due to poor chemical treatment of the boiler water.

Thermal subsequently revised its program of water treatment and initiated the following repairs and modifications to the two incinerator/boilers:

- Acid cleaning of scale from the inside of all boiler surfaces.
- Replacement of all boiler tubes located in the lower combustion area.
- Modification of the combustion-air system.
- Modification of the “underfire” combustion-air system.
- Installation of a protective coating of silicon
carbide to the outside of the lower boiler tubes.

Modifications to and repairs on the second unit were completed, and it has been in operation since October 23, 1975. Repairs on the first unit were scheduled to be completed by mid-January, 1976.

In addition to the tube failures in the furnace area, there have been several failures in the superheater tubes. The manufacturer submitted the following report on October 21, 1975:

To minimize superheater and furnace wastage, the unit should be operated at design steam flow and design excess air should be continuously monitored and maintained. Flames should be minimized in the upper furnace by not using the auxiliary burner fan for steam flow control and by adjusting undergrate airflow for furnace conditions rather than steam flow'.

The recommendations were reviewed, and as a result, Thermal replaced all superheater tubes in each incinerator/boiler with heavier gage steel tubes”... The Neville and McDermott paper also indicates that the early scrubber emissions 0.41 gr/dry scf (corrected to 0.093 gm/Nm³, 12 percent CO₂) and later (no date given) was reduced to 0.17 grain/std ft³, but that was about double the allowable emission of 0.08. If the boiler emissions measured in February, 1975, stayed constant, the final stack emission of 0.17 would indicate a collector efficiency of 96 percent at the highest rate and 85 percent at the lowest. These efficiencies, if valid, would have to be upgraded to about 98 and 92 percent, respectively, to meet the allowable limit of 0.08. This is obviously an extremely demanding requirement in view of the substantial amount of submicron material measured — 20 percent entering the collector. Hopefully the current installation of electrostatic precipitators will meet that requirement when completed.

The Nashville plant is a pioneering effort. No other installation in the world heats and cools such a large group of office buildings from refuse as the primary energy source. From the long experience of many European cities with steam and power generation from refuse there is ample indication that when the initial difficulties have been overcome the Nashville plant will be a successful energy-conserving plant.

**SELECTION FACTORS IN EVALUATING LARGE SOLID WASTE SHREDDERS**

PETER FRANCONERI, P.E.
Combustion Equipment Associates, Inc.
New York City

**DISCUSSION** by Kenneth L. Woodruff, President, Resource Recovery Services, Inc., Woodbridge, New Jersey

This paper is valuable in that it provides the municipal public works manager type with an overview of municipal solid waste shredders. In addition, it should be of value to the consulting engineer working with a municipal agency regarding the procurement of shredding equipment. The paper does a good job at giving a general description of the chief components, their function and key features to be examined when considering the purchase and installation of a shredder. In addition, the bid evaluation form is of benefit in selecting the piece of equipment to be purchased. However, it should be noted that the specification to be issued should address all the items to be sure manufacturers respond with all the pertinent information.

As mentioned, this discussor feels that the paper should be useful to those involved in the decision-making regarding shredder selection. However, the author does not include any criteria for selecting the necessary material handling equipment which is key to the successful operation of any shredding facility. No matter how good the shredder, if material can not be fed to, or discharged from, the shredder adequately, the processing facility will not perform as desired. Because of the inter-relation of the material handling equipment performance and shredder performance, this discussor feels the author should have included this type of information in the paper. It is important to treat shredding as a process and not just as a unit operation. From an operational standpoint, the overall system must be considered.

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In addition to shredder operation, the cost figures indicated in the paper should include the cost of material handling equipment in and out of the shredder. As mentioned, the shredder can not operate without this equipment and thus an idea of its cost would be helpful to those considering shredding facilities.

In general, this discussor was favorably impressed with the paper as it should serve as a useful aid to those somewhat unfamiliar with municipal solid waste shredders, their operation and integral parts. The evaluation form provided is important for anyone trying to compare one vendor's proposed unit with another, and as such is a useful tool.

**DISCUSSION** by F. M. Fregerio

I would like to take this opportunity to thank the ASME and in particular, Mr. Franconeri and Mr. Hecklinger for the honor of discussing a very fine paper on large shredder evaluation. One must comment first on Mr. Franconeri's courage. As the market for large tonnage municipal shredders is relatively new and most information on the technology lies with the manufacturer it is most commendable that Mr. Franconeri has been able to glean a portion of that information from the manufacturers, massage it into a professional document, and then open himself to criticism from manufacturers such as myself, from whom he originally obtained data.

I feel my place here today is not so much one of criticizing or discussing but rather one of expanding on the paper based on our Company's experience in this industry.

In the Abstract and Introductory sections of the paper, reference is made several times to the limited operating experience in shredders of 60 or 70 TPH capacity. This is certainly true; the number of shredders with documented records showing this capacity for extended time periods i.e. -60 tons per hour, 480 tons per 8 hour day, 5 days per week can almost be counted on one hand. This leads one to question the validity of the evaluation of a shredder based on technical data (such as mass hammer weight, etc.) when little or no objective data as to the past track record and performance of a particular machine is available. If a machine has never performed to a certain level, how can one specify its design criteria?

Municipalities, because of the nature of their operations, maintain different types of performance and operating cost records on equipment; and private operators, probably because of competitiveness, are reluctant to divulge cost information. Without data as to performance and cost effectiveness of a shredder, how can one feel confident in specifying a unit with such given design parameters. I feel the solution lies in a performance specification; but more on that later.

A common misconception regarding product density is evident in the Introduction. Shredding does not immediately reduce the bulk or volume of municipal refuse. A shredder decreases the "as-received" density of 350-400 pounds per cubic yard to as little as 125-150 pounds per cubic yard, depending on the final particle size. A volume decrease of as much as 50% is only achieved after compaction, typically in the landfill.

The information contained in Mr. Franconeri's paper tends to indicate much of his information has been obtained from only a few of the many manufacturers in the industry. I know there are some of us who object to the statements that "a shredder must have 8 hours of maintenance for 16 hours of run time" and that "a shredder's-on-stream time is only 75% of that scheduled." Madison, Wisconsin shows less than 5% unanticipated downtime. The statement that "occasional jamming and other problems will reduce the shredder's availability to only 75% sounds not only like a basic shredder design problem, but really more like a feed system problem. Mr. Franconeri's comment on the need for 20% surge capacity is also relative to proper feed conveyor design. I find that a "shredder system" capacity, which is really what the design engineer is concerned about, is as much dependent on ancillary equipment as on the basic shredder itself. A properly written performance specification will assure the final customer of the needed capacity. Again, more on that later.

Recent surveys by the E.P.A., N.C.R.R., Waste Age Magazine, and other periodicals show that a large percentage of shredders processing municipal solid waste are of vertical shaft design. My own company has installed more than 43 vertical shaft shredders in the U.S.A. and Canada. A few paragraphs in a 12 page article is not adequate discussion of a design responsible for this much of the market. Just because more manufacturers offer horizontal shaft units, a paper such as this one should not gloss over important design features so that a potential customer can overlook and not understand the difference in design and operating characteristics between the vertical and horizontal shredder.
Mr. Franconeri, on several occasions in his paper, refers to two specific problem areas in regard to purchasing shredders. The first is lack of operating experience on the part of most manufacturers and their inability to evaluate a shredder's capacity isolated from the remainder of the “system”. The second problem is directly related to the first one; namely that it is difficult to evaluate each shredder “apples-to-apples” when writing a technical specification because of non-availability of comparable “systems” capacity information from all manufacturers.

Mr. Franconeri’s Evaluation Form appears to be an attempt to purchase based primarily on a technical specification, which I think will result in the identical problems he himself has referred to.

I contend that the final customer, that owner of the large multimillion dollar processing and/or recycling facility really doesn’t give a damn whether shredder A has 150 pound hammers rather than 110 pound ones—or whether the infeed chute is 84” X 115” X ½” HRS. plate. What he wants is assurance that the “system” will in fact process the tonnages and particle size to be met and the method of testing.

Then it's not a question of whether the feed system is inadequate or the shredder is too small or the motor doesn’t have enough horsepower. The fact is that if the “system” doesn’t meet performance specifications the supplier is totally and individually responsible, and he must face the consequences of the bid guarantee.

This type of spec and guarantee means that a reliable manufacturer is going to supply a system with a maximum safety factor, thereby assuring the customer that the hammers will be large enough, WR² will be high enough, controls will function properly, etc. It also means that some less reliable manufacturers or “opportunists” with limited financial resources will not bid for fear of warranty repercussions and the financial effect on thier firms.

Finally, and I can not over emphasize this in light of the limited experience available with large shredders, prior to purchase, visit the existing shredding facilities of the various bidders. Talk to the owners and operators. Find out what is the actual average capacity of the plant. Never mind what the surge capacity or the design capacity is, what is the “real” operating capacity. What are the limiting factors in the plant in regard to the system. Is it the feed conveyors, the shredder, the discharge system or whatever. Of course, this is where you should learn what the operators’ actual experience has been in the way of machine and system maintenance schedules and costs, system reliability, and on-stream time, etc. If necessary, park yourself in the plant for a week and keep your own records. With shredding systems approaching a million dollars or more, a week’s living expense is minimum.

Thank you for your time and attention, and my apologies if I may have wandered somewhat from the context in my discussion of this paper.

DISCUSSION by Leonard F. O’Reilly, P. E.

I would like to take this opportunity to discuss some of the pros and cons of this paper, to point out some of its’ uses and cast a warning of the potential misuse as a handy “How to-do-it” manuel for buying large shredders.

Over the past five years, shredders have come into their own as the “fast,” safe answer when all else is too expensive, complex, or risky. As the technology in this field emerges from waste destruction to resource recovery, almost all advanced
technologies require some sort of size reduction as a first step. Even the established mass burning adherants are considering the advantages of uniform bed depth and fuel particle size as well as turning a jealous eye on the secondary ferrous market.

All this means is that front end preparation (here read large shredders) is here to stay for at least the next five to ten years. We’d all better know a little about them. Thank you, Peter.

The very first thing to realize is that big shredders cost big money. They can cost nearly $500,000 to purchase, another $500,000 to install and energize, and maybe an additional $250,000 to convert municipal solid waste instead of automobiles. If you doubt it, ask the guy who has one.

What, then, does the poor project manager/ municipal official/ owner-operator do?

Three obvious choices present themselves.

First, he can hire a “Consulting” engineer. But chances are “he who consults” may have little or no more experience with large MSW shredders than “he who needs consultation.” He may have designed a bulky waste shredder as part of his last incinerator. Then, it may have been operated for thirty minutes a day for the first six months and now lies gathering dust in the sub-basement. Experience in this field is meager and in some parts of the country nonexistant.

Secondly, he can go to the shredder manufacturer and come home with a performance specification and guarantees. He can tuck it under his pillow and sleep soundly until the plant is constructed when he may awake to the following dialogue: “It’s the feed conveyor; it’s the discharge conveyor; it’s the interface between the conveyor and the chute; it’s the operating personnel; it’s the electrical interlocks; its the type of material; it’s . . . . . . ,” etc., and so on. If he’s really clever, he might get a system guarantee but in view of the record of the recent past history of Fortune 500 companies slinking away from guarantees, leaving behind besmirched reputations and unhappy customers, this is hardly satisfactory.

The third, and maybe worst option, is to take Mr. Franconeri’s paper as Holy Writ to quick shredder selection and proceed to blow $1,000,000, with no recourse to anyone.

The only real choice is to hire a knowledgeable consultant or educate yourself, using Mr. Franconeri’s experience as a guide through some of the pitfalls.

This paper is a good first step in sorting out some of the verbal mystique surrounding shredders; power vs. angular momentum; WR²; vertical vs. horizontal arrangement; rated capacity vs. actual through-put; weight; starting torque and instantaneous surges; unbalanced forces; etc.

At this point, after consuming whatever supplemental material may be available, you are ready to start talking with the manufacturer’s representative. And, by all means, plan to visit operating installations. Stay awhile. Talk with the operator. He’s usually glad to chat about his problems with someone who knows what he’s talking about. The payroll and out-of-pocket investment is only a small fraction of the cost for errors made in installing costly equipment like shredders.

For most engineers, Mr. Franconeri’s discussion on reversible hammers, one, two and four sided hammers, liner and breaker plate design, bearings, etc. should be left to the specialists. But in any case, let him give you the benefit of his hard won experience. Permit him a chance to refute any of Mr. Franconeri’s comments. Does he really have sufficient experience to back up the sales talk or is he guessing?

But, most important, don’t try to push him in the corner so hard that he can’t comfortably guarantee the machine.

Once the shredder has been selected, the job is not over, but just beginning.

The epilogue to this paper should be written to include the proper selection and interfacing of the feed and discharge conveying systems. Poor layout and selection at this point can choke or starve the best shredder in the world.

Once the mechanical work is satisfactory, electrical power and controls are the next critical point. This is not a simple machine and requires good, isolated instrumentation and controls.

For a machine of such size and power, proper, vibration free, custom designed foundations are necessary. Again, this is no place for handbook engineering. If you don’t know how, get good, first class, proven help.

With the annual mortality of shredders due to explosives in the garbage, last but not least, good dust control and explosion suppression systems are a must. Shredders are by nature inherent dust and noise makers and require proper enclosures, ventilation and must meet OSHA standards.

All in all, this paper is a good first effort at putting shredder technology on a scientific footing and leaves plenty of room for additional contributions as experience grows with this type of equipment.