GUIDE TO SUCCESSFUL EVALUATION OF A RESOURCE RECOVERY FACILITY PRODUCING REFUSE-DERIVED FUEL

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Discussion by

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This paper seems to cover the subject completely, so completely that some of the more esoteric performance criteria (Recovery of Al, Zn, Pb, Mn, Sieve Analyses, etc.) may be a long time coming in view of the struggle with most Resource Recovery Plants to operate continuously or meet the most fundamental requirement of RDF quality, production and raw infeed restrictions [1].

SCOPE OF EVALUATION PROGRAM

Under this heading, item 6 should be emphasized and should include a thorough examination of the bid specifications to compare the specified raw material input with what the system can actually accept, i.e., if oversize and difficult materials were included in the raw infeed specification, can the system handle it [1]?

Is unexpected presorting required on the tipping floor or during collection?

This should also apply to simpler shred only systems most of which do not pass such scrutiny.

The limits to infeed should be made clear for every installation. To date, there has been very little accountability for such commonly overlooked and unexpected limitations [1].

SCOPE OF EVALUATION PROGRAM

In this section, the author’s statement: “Evaluation of the health and safety features of these facilities is beyond the scope of this discussion” is disappointing considering that these factors have finally become a major concern as evidenced by the post facto maze of blast mats and vent ducts which sprouted in most plants etc.

In this connection, there seems to be a Pied Piper-Like Trend in remedial measures for shredder explosions, — a fixation for venting concepts which do not seem to be entirely rational along with a nearly total disregard for ignition phenomena, rotor windage/vapor and dust distribution and MSW dust flammabilities [2].

The author’s suggestion that: “Untrained operators will make mistakes that may cause breakdowns . . .” is kind of a buck-passing bum rap and begs the question of poor system and inferior equipment design [3].

EVALUATION PLANNING

Under this sub-heading, the author has recognized a very important shortcoming in current system design practice: “The work of the planners (evaluation team) becomes easier if during the plant facility design, the necessary requirements . . . for sampling and data gathering are provided . . .” [1].

In this regard, ASTM (American Society for Testing and Materials) is currently in the difficult
process of developing equipment sub-system performance evaluation methods/criteria.

Controversial compromises are under debate due to systems design shortcomings, accessibility and dependence on unreliable downstream (or upstream) flow continuity which can preclude any meaningful testing.

SAMPLE CASE STUDY

In discussing raw refuse characterization [4] under this heading, identification of OBW (over-size bulky waste) is highly desirable along with long stringy textiles/plastics, hard plastics wire, rope, rubber etc. which contributes to the troublesome shredded top-size fraction (downstream fouling and clumping, etc.). It is astonishing how these vagrant pieces frequently survive all of the grinding, screening, blowing, etc. and remain to contaminate the product [5].

Likewise, the primary shredded material particle size distribution analysis should focus on more thorough evaluation of topsize fractions and avoid the usual preoccupation with characteristic particle size ($x_o$) [5-7].

DISCUSSORS CONCLUSION

It is obvious that the author speaks from experience and that his paper is a worthy contribution to the effort to improve the integrity of resource recovery system design.

REFERENCES


Discussion by

Fred H. Sanneman
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The information contained in this paper should prove to be a valuable check list on the myriad of data that must be gathered to properly evaluate a RDF facility. As more and more of this type of processing plants are constructed and if the effects of inflation continue to radically affect operating costs, engineers will see a larger involvement in evaluating the cost effectiveness of resource recovery plant design. The author made a good point in emphasizing the importance of planning during the design phase of a project for the ability to conveniently gather the samples and data needed to analyze system performance properly. This is often an after thought when the time of plant testing and acceptance nears.

The author states that many of the planned resource recovery facilities will be financed through state and federal cost sharing programs. This is very true and results in a demand to account for the performance of the completed facility to justify the program. Our firm currently is retained as the consultant to the governmental body and bond holders that are financing a large resource recovery installation. We must provide the type of evaluation that the author outlines to prove plant performance prior to acceptance. This plant is being designed and constructed by a full service contract or who will operate the facility for 20 years after completion. Not only will evaluation be required upon completion, but annually during the 20 life of the bonds.

A valid statement is made concerning the objectives that have been set out for an RDF facility. A proper evaluation cannot be made without understanding the objectives. A public body that must be served by an RDF plant may be seeking a reduction in the cost of refuse disposal, rather than making a profit, as its main objective. On the other hand, a private organization may need to generate a profit to justify financing a RDF installation.
Discussion by

Floyd Hasselriis
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The author has provided a detailed check list to be used in performing technical, environmental and economic evaluations of a resource recovery facility, presumably to be used after the facility has been built and is operational. This is the test the designer and builder will have to pass after working a few years preparing for it. He would like to know, when he faces this test, whether his examiner is a student who wishes to study what he has created, a critic who is hoping to mark him down for points where he failed, or someone who would like to see the project succeed.

The technical evaluation Chatterjee describes, including the descriptions of the process, material and energy balances and process efficiencies, was presumably made by the designers of the plant.

The process flowsheet and the measurements needed to determine flowrates and stream compositions, may look like one for a chemical processing plant, but such a single-point mass-balance is highly misleading, due to the constant variability of the MSW feed and the resultant streams.

The detailed testing of the plant described in this paper would be impossible to carry out in any plant not specifically designed for testing. In general plants are built to produce a given set of end results, without providing the means of measuring the internal conditions which produce this result: few weigh-scales are provided, and few points from which samples can be taken, especially between pieces of equipment, and when the plant is running. If we stop the plant, we can obtain a set of samples which describe the material in transit through the process, or so it seems until we realize that while the samples are approximately what we measure them to be, we still do not know what would have happened to them if they had been allowed to proceed through the process. Whenever we take a sample out of a stream, all we really know is that that particular sample will not be processed further.

Great difficulties result from the high variability of flow rate and composition of the refuse as it enters the plant and is processed. The best we can do is to take so many samples that their average will not be far from the truth. We can probably be 90 percent confident that the samples will be no closer than +/- 25 percent to the mean.

Methods of collecting samples, and deciding on the size of samples, number of samples, and timing of sample collection, have been the subject of much discussion over the past five years within several subcommittees of ASTM E-38 on Resource Recovery, but to this date no standards exist for most of the streams we would be concerned with. This research need is now beginning to get some attention and preliminary funding.

Evaluations of the type detailed by Chatterjee have been at least partially carried out at St. Louis, Ames and several other facilities. They have given us quite a large number of measurements of the amounts of material removed from the discharge points of the plant, sometimes the total weight of the feed material, and sometimes reasonably accurate weights of the fuel produced. In addition, they have given us the detailed composition of the material as it flows through the plant, as to paper, plastics, metals, moisture, combustibles, ash and ash chemistry, but generally without the flow rates needed to evaluate equipment performance and the “splits” of the components. On the other hand, we have extensive pilot plant data which tells us about the splits and flow rates, but not for a total stream of real MSW. Most important, when we look closely at the data, we find that the moisture is getting lost during the process, and nobody noticed, so we cannot “close the loop” of the mass balance except perhaps to say that the moisture loss accounts for the error. Having been through several attempts to close the mass-balance, I should say that to be within 10 percent might require considerable luck.

Any evaluation must start with a clear definition of objectives. For instance, an overall mass-balance comes first: it is possible to weigh all the material entering the plant and all the leaving streams except the moisture lost. Even the moisture can be estimated by psychrometry, and flow measurements of all of the air exhausts from the plant. It is possible to take samples of the exit streams to estimate average moisture, and use this information to estimate the moisture in the incoming refuse. But to measure the moisture of the incoming refuse is a monumental job, requiring a large number of samples to give a statistically valid estimate. Sampling the various species in the MSW, finding their weight percent and their moisture content permits an estimate, perhaps within +/- 10 percent of the MSW, at the time the samples were taken. To use this information for closing the plant mass
balance requires that the plant samples be taken over the same period during which the MSW samples were taken. It is doubtful that the information about the MSW is as accurate as the information obtained by weighing and analysing the output materials. It does not add anything to our information, since moisture loss is still unknown.

A practical evaluation would be directed toward necessary information related to contractual obligations, such as:

1. Can the plant receive and process the specified daily or weekly tonnage reliably?

2. Does the fuel moisture and ash content meet specifications?

3. Does the refuse entering the plant have a moisture and noncombustible content equivalent to that specified in the contract? (If not, what then?)

4. Is the amount of rejected material close to that anticipated? (this depends upon the nature of the MSW received).

5. Do the mechanical components perform as the vendors promised?

6. Did the equipment specifications relate to actual operating conditions?

When a resource recovery plant comes on stream, it will have to handle the materials it receives, a constantly changing feedstock. The ferrous metals may be far more or less than anticipated. The aluminum has been reduced to a small fraction of a percent: how could we possibly find it and measure it in the MSW?

What really matters is, how can the product of the plant be improved, and who pays for making the changes, and who gets the resulting benefits? The money which would be spent to make an elaborate study of how the plant is operating at the moment it is being tested would be better spent on determining how to make improvements which would increase revenues, and on actually implementing these improvements.

Process evaluations should be made by the people who have an interest in making these improvements, and who will have to balance cost/benefit, not people who have an academic interest in what happens to the streams, and who would place several dozen people around the plant to take measurements, the results of which might not be made available to the plant people for weeks or months. To begin with, improvements are made by taking a large number of adjusting steps and evaluating the results, not by making a single, comprehensive test and stopping there.

The environmental aspects of the plant must, of course, be tested, insofar as they represent emissions and conditions affecting the plant workers. If working conditions involve excessive dust, suitable masks would have to be provided for those who work in the areas, or filtered air provided for a loader operator.

Economic evaluations are, of course, necessary: hopefully they were made prior to construction of the plant, and are confirmed once in operation. Unfortunately, in a new industry, much important information is lacking in the concept and design phases, so adjustments have to be made as the facts become apparent. Future plants can be planned with more realistic information: existing facilities will have to do the best they can to adjust to reality as it presents itself.

It is hoped that readers of the “Guide to Successful Evaluation” will recognize and overcome the many difficulties in making such evaluations, so that the result will be a sequel entitled “A Guide to Successful Operation of a Resource Recovery Facility.”

Discussion by

Emil Nigro
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This very thoughtful guide should go far in establishing productive evaluation methodology in producing a fluff type refuse derived fuel (RDF). It should encourage the author and/or others to do likewise for facilities producing the various configurations of densified fuel (dRDF) such as brick bricketts, cubes and pellets and also powdered fuel (Eco II) so that the full range of RDF facilities are considered. This will be an added benefit for management in preliminary discussions relative to entering into RDF operations by a community.

Capacity, perhaps more than any other word, tends to be a most ambiguous word in discussing resource recovery plants. This word also antagonizes owner management the most when used in reports produced by the uninitiated. Mr. Chatterjee is to be commended for noting the distinction between various capacities in Item 6 of Scope of Evaluating Program. However, it is not noted whether the reference is to input or output capaci-
ties of the overall process train, nor is this provision made to note the effect of the total environment on these capacities.

It could well be the case that on the input side, the actual operating capacity could equal the design or expected capacity and therefore give the appearance of a successful operation while in fact the facility could be considered by management as a disaster from the output side. I here refer to the actual versus design split of the processed stream, i.e., percentage RDF derived from unit input quantity of solid waste. While it is true that the economics of an RDF facility could depend somewhat on throughput tonnage if a tipping fee is involved, it is likewise true that the greater revenue producer is the RDF generated for a customer.

I do not suggest that every RDF facility will or should have the same ratio of RDF to MSW. Several factors in addition to facility operating effectiveness, such as geographical, socio-economic and source of waste may be casual factors influencing the potential ratio split. These factors notwithstanding, of importance to management is the actual versus the predicted split since the economics of a plant are based on the predicted or projected split. This projection was in large measure the financial justification for plant construction. Therefore, management judges as successful those facilities operating RDF ratios within close approximation of predicted values. In like manner, the quality of the RDF produced impinges upon plant economics and thus management's judgement of success or failure.

Although this paper notes that evaluation of the health and safety features of RDF facilities is beyond the scope of the discussion, this discussor suggests that to ignore these factors leads to a significant reduction in the value of the overall analysis. To my knowledge, not one operating RDF facility has escaped fires, explosions, etc. that impinge upon the health and safety of operating personnel not to mention the cost of damaged facilities and loss of production time. I would suggest that at least all health and safety features designed into a plant be documented for the guidance of others.

Since solid waste managers think in terms of systems costs in addition to unit facilities costs, it may be well to include transfer station costs and transportation costs in the economic evaluation section. If it is realized that approximately 75 percent of the cost of a solid waste system is in the collection sub-system, then it will be recognized that even the most cost effective disposal facility or sub-system cannot be justified if its siting, operations, etc. add costs to the collection sub-system. This consideration of the possible impact of disposal plants upon the collection function is real and as energy costs continue to escalate, this consideration could significantly influence management's evaluation of RDF benefits. Therefore, any cost increase in collection influenced or brought about by an RDF plant should be charged against the subject plant.

Under the economic evaluation section, I would suggest that in addition to the factors mentioned and which I agree are necessary, it be noted whether lowest dollar costs of operation were the primary concern of the management. Under some sets of social/political factors, lowest cost may be secondary to the communities desire for the most environmentally acceptable disposal method. Therefore, I believe a determination should be made of the priorities that lead to the facility selection. Lowest cost may not be the best solution in particular situations, but unless the community priorities are noted, this emotional bias will not be properly reflected in the economic analysis.

I would agree wholeheartedly with the evaluation planning paragraph of this paper. The data collection points are theoretically well located and as the author notes, the work of the planners would be easier if during the plant facility design, the necessary requirements of the evaluation program are considered and the data gathering and sampling stations are provided in the plant layout and equipment system design. From a practical and economic viewpoint, this ideal may not be possible to implement for several reasons. First must be considered the benefits possibly accruing to the community for the additional costs involved. To fit some of the sampling stations into the plant layout could involve additional costs that must be justified.

On the basis of producing data for national consideration, the costs may be warranted to be covered by grants from one or more Federal agencies such as DOE or EPA, but it is doubtful that the full cost of an elaborate sampling program is worth the financial burden to a local agency or community.

In summary, the Guide discussed here is well designed with few exceptions. The exceptions are managerial rather than technical and they can be meaningfully included in the guide by an alert management.
Discussion by

Howard F. Christensen
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and

D. H. Graham and J. E. Mackey, Jr.
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This paper discusses an evaluation procedure for solid waste resource recovery facilities. However, the evaluation goals expressed in the paper do not coincide entirely with actual operating practices and industry goals, in existing operating facilities. Referring to subheadings in the paper:

**SCOPE AND EVALUATION PROGRAM**

The author excludes facilities that produce energy (from RDF) from this paper yet repeatedly mentions an energy balance for the overall process train, subsystems, etc. This does not appear appropriate for the types of plants this paper covers. Energy consumption should be monitored, and applied to the economic (plant operating costs) analysis.

The author also excludes adequate consideration of health and safety features of today’s facilities which are essential to sound engineering practices. In fact, a good portion of any analysis these days attempts to confirm present design efficiency and forecasts possible deficiencies. Recent studies in shredder explosion suppression, shredder venting, advanced fire detection and protection systems, industrial hygiene studies, dust explosibility studies, etc., indicated the interest and prominence these activities now have in the resource recovery industry, in addition to current OSHA requirements.

Initial system deficiencies and operator training should be addressed and accounted for with adequate contingency funding. The paper makes no reference to landfill needs and alternate disposal plans.

**DATA AND SAMPLING**

The author stresses the importance of efficient data collection and indicates computer assistance should be provided for. Many facilities are moving in this direction. The Monroe County’s New York Resource Recovery Facility, is implementing a Management Information System (MIS) which collects and analyzes data on preventive equipment maintenance, employee salaries, spare parts inventory and parts replacement. Data is input daily and analyses are made on a weekly, monthly and year to-date basis. To properly support such a system, accurate and timely information must be routinely prepared and inputted. There is no mention of developing or adopting sampling and testing procedures for quality control.

**SAMPLE CASE STUDY**

The author mentions pertinent field characterizations and lists refuse characteristics as one area. The ability to statistically represent the refuse characteristics of one day’s incoming waste, at 2,000 ton/day (or similar) facility, is questionable and open to criticism. The analysis predicted for this report (Table 2, Physical Composition of Incoming MSW) would require several days of laboratory effort to support, which is compounded by multiple samples taken by poorly defined techniques to create a representative analysis. Practical methodology is computing incoming wastes from and ultimate analysis of process output fractions.

The author also proposes to perform an ultimate analysis of incoming waste, with the same timeliness which the previously discussed analysis would generate. This type testing might best be taken at the incineration point and perhaps taken at the exhaust gases in comparison to normal coal/oil firing.

Environmental data collection, as discussed by the author in this section, might also consider biological surveys, in relation to particulate emissions, dust analysis and waste-to-landfill samples. Noise abatement surveys are to be conducted with the proposed OSHA personnel exposure regulation compliance (85dBA per 8 hr work exposure), not merely routine reference noise samples and defense against the public sector.

The determination of waste water analysis parameters may be dictated either by a local or other regulatory water pollution control agency. Costs associated with effluent treatment may also dictate some of the technology decisions.

**ANALYSIS AND EVALUATION**

The author summarizes his paper with the
As explained in the text, technical evaluations include material and energy balances, thermal, mechanical and conversion or process efficiency. Clearly, of these, only the material balances and process efficiency studies will be productive and supportive to the system evaluation/analysis effort. Energy balances and thermal/mechanical efficiencies are theoretical aims that are unnecessary for a plant which only produces RDF, but has no steam, heat or electrical power production capabilities.

Economic analysis should also reflect a pre- and postconstruction marketing analysis, as this is the base stone to a resource recovery program's political and economic success. Proposed modifications or improvements in an existing plant are all gauged by the impact of the product market. Feedback from the marketing program will definitely impact the facility operations and productivity.

**CONCLUSION**

The evaluation effort of any resource recovery facility has for its primary purpose the improvement of operating costs and product quality. Any analysis plan chosen to accomplish this goal must be based upon the following fundamentals: (1) Can the required samples be obtained as specified without undue expense or effort on facility operations? (2) Are the samples required meaningful and reasonably representative? (3) Are the needs of future requirements (OSHA controls, hazards and personnel protection, biological controls, etc.) being met with the present evaluation? (4) Can the data gathered be coherently and logically organized, understood and reduced to functional system designs? This paper serves as a general outline for such a program. Specific needs of each facility will modify and/or dictate the individual analysis paths. Operating requirements, markets to be served and data handling capabilities will also dictate, in the long run, what the substance of this evaluation should be.

**AUTHOR'S REPLY**

To W. D. Robinson

"..... thorough examination of bid spec..." In almost all cases such documents will not be available to the evaluator. Don't forget evaluation of a resource recovery facility by an outsider is not always welcomed. Evaluation is generally based on the equipment that is operating on-site. As most of the plant equipment are specified by the consulting engineering firm and the selection is based on the basis of specification, the evaluator has very little to say.

"..... Health and Safety..." Normally technical evaluation of a resource recovery project is funded by EPA/DOE or Local County. As health and safety of the plant facility fall under NIOSH and OSHA responsibilities, and as the plant was designed by a competent consultant and the design received acceptances from appropriate regulatory agencies, EPA/DOE may not insist on elaborate evaluation of those fields. I agree, though, that some agency should look at the Health and safety aspects of such facility.

"..... Oversize bulky wastes..." Most plant operators make a sincere effort to separate these types of waste. Shredder manufacturers should incorporate some safety features to protect their equipment from accidental damage caused by the bulky wastes.
To Fred Sanneman

Thank you for your complimentary comment.

To Floyd Hasserlis

The evaluation program as presented in my paper is solicited not by the academic circle (as suggested by the commenter), but by the people or agency that put up public or private funds for the facility. I do not see the point of the objections of such evaluation if the design is sound and the equipment and system are properly designed. The need for this type of evaluation is to advertise the achievements and advancements of the process as well as the shortcomings and failures of the design. The public needs to be advised on the merits and demerits of the design. Further investment is needed for the popularity and growth of this industry. The evaluator is a professional man. He is there to report to his client what he saw, how the system operated, how the design goal was met and why the system did not meet the desired and designed performance. Even with the variability of MSW, there are many valid and acceptable methods that could be utilized to reach the above conclusions.

Such an evaluation program should be welcomed by the equipment system designers. They are getting some data that will help them to design a better system in the next generation.

To Emil Nigro

Thank you for your supportive comments. Although I agree that health and safety are two very important items, these evaluations are generally done by NIOSH and OSHA.

To Howard F. Christensen, D. H. Graham and J. E. Markey, Jr.

I did exclude . . . “Facilities that produce energy from RDF . . .” just to keep my paper brief. However, the program presented in my paper could easily be used and adapted for such evaluation.

The refuse characterization technique that has been presented may be of questionable value because of variability of MSW, but this sort of analysis is quite adequate for the evaluation program. Overall mass and energy balance and even some specific mass and energy balances could be made even in a plant where no such testing provisions were made in original design. A plant designer should make every effort to incorporate such an evaluation program in the facility design. Ultimate analysis is only needed when component balances are being made . . . . Incineration is not the only use of RDF.

I appreciate all the comments made on my paper. Thank you.