START-UP AND SHAKEDOWN OF
ALBANY NEW YORK SOLID WASTE ENERGY
RECOVERY SYSTEM (ANSWERS)

ANTHONY R. NOLLET and ROBERT H. GREELEY
AENCO, Inc.
Albany, New York

ABSTRACT

This paper describes the Albany New York Solid Waste Energy Recovery System (ANSWERS), which consists of two plants — a City-owned Refuse Derived Fuel (RDF) Plant, and a State-owned Boiler Plant in which RDF is burned. This paper is chiefly concerned with the City-owned RDF Plant, and describes shakedown tests, problems encountered and solutions developed. Operational statistics and operations policies for the City-owned plant are discussed. Laboratory measurements of the heating value of RDF samples are compared with results actually achieved in the State boilers.

DESCRIPTION OF ANSWERS PROJECT

The Albany New York Solid Waste Energy Recovery System (ANSWERS) consists of two plants: a shredding plant which shreds and magnetically separates solid waste, thereby producing a refuse-derived fuel (RDF) product; and a spreader-stoker fired steam plant specifically designed to burn the RDF product. Total project design capacity is 4,200 tons (3,810 t) of RDF per week.

The shredding plant, owned by the City of Albany, was designed by Smith & Mahoney, P.C., Consulting Engineers of Albany, assisted by Gordon L. Sutin and Associates Ltd., of Hamilton Ontario, Canada. It is operated under contract by AENCO, Inc., a subsidiary of Cargill, Incorporated. Total cost of the Shredding Plant was about $11.5 million, including 36 RDF transfer trailers.

The steam plant is owned and operated by the New York State Office of General Services and was designed by that agency's Design and Construction Group. It is designed to supply the year round base load steam demand of the Governor Nelson A. Rockefeller Plaza and certain other large State office buildings in downtown Albany (winter and summer peak steam loads are carried by an existing gas/oil fired steam plant). Capacity of the steam plant's two RDF fired boilers is 100,000 lb/hr (45,400 kg/hr) each. The steam plant will burn between 600 and 725 tons per day (540 to 680 t/day) of RDF to produce 200,000 lb/hr (90,700 kg/hr) of steam.

The boiler plant occupies less than one acre of space in the heart of downtown Albany. A mass-burning plant with similar capacity would probably occupy about four acres, and would likely cost $30 to $40 million. Moreover, a mass-burning plant in a congested area often suffers from the disadvantage of having a large number of packer trucks deliver in a concentrated daily schedule. About 125 packer trucks would be required to deliver unprocessed wastes each day to produce 200,000 lb of steam per hour (91,000 kg/hr). This compares with 34 deliveries per day of prepared fuel in Compactor Trailers each containing approximately 17 tons (15.4 t).

Before describing the successful shakedown of the shredding plant, it seems desirable to discuss a few other features of the overall ANSWERS concept:
The Albany shredding plant is located in the heavily wooded pine bush section of Albany, far from habitation, at the site of the Albany landfill, and is probably one of the more aesthetically pleasing resource recovery plants built to date. Its location also offers each access to nearby interstate highways I-87 and I-90 thus facilitating transportation of RDF to the State's steam plant.

The plant's design and siting also reflects the writers' long held belief in the idea of preparing RDF inexpensively in a remote area and delivering it to an inexpensive spreader-stoker fired boiler located close to a steam user.

The plant is laid out so as to permit access to all equipment for maintenance, cleaning, repair or if needed, replacement.

In addition to the normal compliment of shredding, magnetic separation and conveying equipment, the plant also contains three unconventional features:

1. The shredders are each powered by 1,200 hp diesel engines and coupled to the same through large hydraulic couplings to ease the transmission of starting and shock loads to the engines. The waste heat from the diesels' cooling systems is captured and stored in three used 20,000 gal (76,000 l) hot water storage tanks, for subsequent distribution to the plant heating system.

2. The solid waste receiving conveyors are variable speed vibrating pan type units which level, meter and spread out the waste onto the shredder infeed conveyors, thus facilitating uniform shredder feed and effective picking operations.

3. Vibrating pan type shredder discharge conveyors are also employed to absorb impact of items discharged at high speeds by the shredders as well as to level the material burden on the downstream conveying system.

The plant cost $11.5 million, including rolling stock and an off-site transfer station. This agreed remarkably with the consultants' 1974 engineering estimate of $11.2 million.

The plant was designed only to shred the incoming waste and to remove the ferrous metals. All of the other shredded material would be burned in the spreader-stoker fired boiler. There were no separation systems, screens or other items that have proven troublesome in other resource recovery plants.

The City of Albany, under the direction of Mayor Erastus Corning II had negotiated an excellent contract with the State of New York that provided a fair price for the RDF. The contract is complicated, but generally provides that the City will be paid about 63.3 percent of the dollar heating value of No. 6 oil that would be burned to produce the steam actually produced by burning the RDF. Thus, in effect, both the City and the State share in the benefits accrued through replacing fossil fuel with RDF.

AENCO and its parent company, Cargill, Incorporated, inspected the plant and decided that it could unquestionably be made to operate at its guaranteed rate, 600 tons per day. AENCO was selected for negotiation, and signed a contract on September 11. Six AENCO people reported to the job site on September 17, 1980.

STARTUP AND SHAKEDOWN

The City's contract with the State contained mutual penalties. If the shredder plant had been late in completion, the City would have had to pay damages to the State approximately equal to the State's operating costs of the boiler plant. If the boiler plant was late, the State would have to pay the City for the cost of operating the shredder plant and landfill. Thus in order to minimize the shakedown costs to the City, it was essential that the shredder pass its acceptance test at the earliest practicable date.

To aid in accomplishing this, AENCO decided that weekly detailed program reviews with Smith and Mahoney and City officials were essential. The first was held on 23 September, at which some 14 modifications and/or completions were agreed upon.

TEST OF PLANT

It was resolved not to do extensive testing until the shredders' explosion vent installation (a retrofit subsequent to plant completion) was completed about the end of November. On 23 October, however, some 27 tons of material were spread out on the receiving area and presorted on the concrete floor. The purpose was more to test some of the equipment under load than to obtain meaningful results. Several electrical malfunctions caused delays during this test. The final reality was that some two hours were required to shred 27 tons (24 t) of material.

On 27 October, AENCO published a 26 page Protocol for the next test. Specific duties were assigned, and specified data were to be collected using forms designed for the purpose. A relatively
A small amount of presorted material was processed in one line at the fastest possible feed rate. A clock was installed on the control circuit of the shredder infeed conveyor to record feed time.

Each shredder was guaranteed by the manufacturer to process 50 tons/hr (45 t/hr) while being fed. During the test on 28 October, we processed 6.4 tons (5.8 t) of material through Line 1 in 18 min. Feed conveyor time was 16 min, showing a processing rate of only 24 tons/hr of infeed conveyor time. The shredded material was re-run at lower burden depth in order to remove the remaining ferrous scrap. It was found that only 86.2 percent of the ferrous scrap had been removed on the first pass, vs 90 percent required by the City's specification with the State. Ferrous density was measured at 20 lb/ft^3 (320 kg/m^3). A great amount of shredded material and other light product littered the shredder room. This material had clearly been lifted by upwelling air and had escaped into the room. The diesel engine driving the shredder was observed to "lug down" frequently, when objects such as small rugs or sleeping bags were fed to the shredder. Many sympathetic vibrations were observed in various structures of the plant that resonated at the frequency of the four vibrating conveyors. Particle size was much smaller than specified. The particle size distribution shown in Table 1 is close to that observed during this test.

We were very happy with this test. We had fed at the fastest possible rate, and had identified problems. Probable solutions, were defined and installed:

Two low static-pressure fans were installed downstream from the shredder discharge by AENCO to induce positive downflow of air through the shredders.

The magnetic separators were moved closer to the burden in order to recover more ferrous scrap. Solid covers were placed on the 16 ft of the infeed conveyors adjacent to the shredders.

Fourteen of the 30 hammers were removed from one shredder. Some of the webs in two grate bars in the other shredder were torched out — these were the webs that run parallel to the direction of hammer movement. We hoped that one or both of these changes would improve throughput rate and, perhaps, increase particle size.

The sympathetic vibrations caused by the receiving conveyors were cured by decoupling and detuning the backboards behind the receiving conveyors. The sympathetic vibrations from the vibratory shredder discharge conveyors were cured by hanging two specially-spaced rubber curtains at each conveyor that effectively tuned out the vibrations. In November, another program review defined 111 additional items, mostly construction punch list type items. We decided on what things to accomplish before 18 November and scheduled a 100 ton (90 t) test for that date. Again, we followed the philosophy of feeding at maximum possible rate. This test was conducted using Line 2. Because the explosion vents were not fully completed, we presorted 108 tons (98 t) of incoming material on the receiving pad. We processed this material in 99 min of infeed conveyor time (266 min of real time). However, out of 108 tons (98 t) of incoming material, only 82.4 tons (74.7 t) of shredded product and 3.0 tons (2.7 t) of ferrous scrap were produced. We had hand-picked 2.31 (2.1 t) tons of material from the incoming wastes.

It was concluded that the scale weights of the incoming wastes were inaccurate because they were based on measured gross weight and recorded empty weight. The very heavy snow on 18 November probably biased the incoming weights upward. We concluded that 85.4 tons (77 t) had passed through the plant. Total elapsed time was 266 min.

The line was shut down for 145 min due to an oil leak and a broken wire in an improperly-protected junction box of a vibrating discharge conveyor. The line was down because of diesel slowdown for 22 min due to numerous instances of diesel "lug down."

Thus, the shredder production rate was 85.4 x 60 ÷ 99 = 51.7 tons/hr (46.9 t/hr) of infeed conveyor time. The shredder met its specification of 50 tons/hr (45 t/hr) of feed time.

Thirty-one instances of diesel "lug down" accounted for 22 min of real time. Had there not been any other problems the feed rate would have been 85.4 x 60 ÷ 266 = 19.26 tons/hr (17.5 t/hr).

In October an extensive study of diesel engine performance was begun. Manifold pressure gauges, not provided initially, were deemed essential and were tested on 26 November.

The diesel engine tests were indeed revealing. It seemed likely that if the operators were to be given knowledge of manifold pressure, they could perform so as to reduce the instances of diesel "lug down".

It also seemed desirable that the control circuitry should ultimately be automated and based on manifold pressure so as to reduce the reliance on the console operators. Line 1 was equipped with a reduced number of hammers. Line 2 had some
grate bar webs removed. In this test Line 1 processed 27.21 tons (19.24 t) in 20 min real time for a feed rate of 56 tons/hr, (50.8 t/hr) with no instances of diesel "lug down." Line 2 experienced "lug down" 20 times as it processed 28.87 tons (26.19 t) in 47 min real time for a feed rate of 38 tons/hr (34 t/hr). Neither removal of hammers nor removal of circumferential grate bar webs significantly changed particle size, which was nearly identical for the two lines, and was close to what had been observed on earlier tests.

On November 13 more items were defined as needing completion before the acceptance test scheduled for 3 December.

**ACCEPTANCE TEST**

The explosion vents were complete on Line 2, but not on Line 1. Therefore, we presorted about 350 tons (318 t) of waste on 2 December to be used in feeding Line 1, and we planned on accepting an additional 400 tons (363 t) on 3 December to be processed without presort in Line 2. A high wind was blowing into the exhaust fans that we had installed to induce a downdraft in the shredders, making them somewhat ineffective. However, the infeed conveyors were sufficiently "buttoned up" so that there was little loose waste in the shredder room. Twenty four hours were available to process the 766.66 tons (704.5 t) of waste that was eventually received. After 8 min, the infeed conveyor motor on Line 1 ceased to function due to the failure of the controller. The motor was restored to service at about 1 a.m. the next morning.

Line 2 operated for a total real time of 18 hr and 42 min. Line 1 operated for 8 min on 3 December, and for 2 hr and 9 min in the early hours of 4 December. Thus, total single line operating time was 20 hr and 51 min. During this time, the plant produced 644.32 tons (584.52 t) of RDF, which was compacted into 36 trailer loads, weighed and landfilled. The plant produced 26.28 tons (23.84 t) of ferrous scrap, of which 9.42 tons (8.55 t) were picked from the tipping floor, and 4.66 tons (4.23 t) were picked at the picking stations. Real-time processing rate was 32 tons per line-hour of real time (29 t/hr real time).

Particle size distribution greatly surpassed the specifications as shown in Table 1.

Although the plant was now shown to be able to produce 600 tons/day (540 t/day) of RDF in a period of 10 hr if both lines operated well it seemed appropriate to introduce other changes, particularly since the boiler was not ready to accept the RDF.

Accordingly, further improvements were made. Smith and Mahoney designed automatic circuitry to decouple the diesels when manifold pressure exceeded 75 in. (1900 mm) of mercury. This was in addition to existing controls which were designed to stop the infeed conveyors when the diesel slowed below 1125 rpm. Also, a new method was devised to induce positive air downflow in the shredders (see Explosion Alleviation Paper).

Three new grate bars were designed by AENCO to replace three of the existing grate bars in each shredder. These new grates produced a particle size distribution that matched the City/State specification. Trolley-mounted hoists were also designed and installed by AENCO to facilitate the replacement of grate bars.

In early January, we scheduled the plant to begin routine operations on February 17. However, we considered that it would be well to operate the plant at full-scale on at least six occasions before that date. We scheduled full-scale operations on January 26-27, on February 2-3, and February 9-10. These pairs of days were Mondays and Tuesdays — which, in each of the three successive weeks, gave five days to correct any new problems that might arise. Although such problems did arise time was available to retrofit permanent solutions. On February 17 the plant began routine operations, as scheduled.

The City of Albany had budgeted $650,000 for AENCO to shake down the plant, install changes, and bring it through its acceptance test. The City had considered that the acceptance test might be completed by December 31. Actually, $203,515 was spent through December 3, the date of the successful acceptance test, and only $302,539 through the end of December.

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**TABLE 1 PARTICLE SIZE DISTRIBUTION, 3 DECEMBER 1980 TEST**

<table>
<thead>
<tr>
<th>SCREEN SIZE</th>
<th>PERCENT PASSING</th>
</tr>
</thead>
<tbody>
<tr>
<td>(127 mm × 127 mm)</td>
<td>99 100</td>
</tr>
<tr>
<td>(102 mm × 102 mm)</td>
<td>95 99.7</td>
</tr>
<tr>
<td>(76 mm × 76 mm)</td>
<td>90 98.7</td>
</tr>
<tr>
<td>(51 mm × 51 mm)</td>
<td>85 96.5</td>
</tr>
</tbody>
</table>

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The shredders were estimated to use 21 hp-hr/ton (17.3 kW-hr/t) before the installation of the new grate bars and reduction in the number of hammers. This has now been reduced to about 11 hp-hr/ton (9 kW-hr/t) which will represent millions of dollars of savings over the lifetime of the plant.

Thus far, no test deadlines, or any productive deadlines or goals have been missed.

**PLANT OPERATIONS**

From February 17, 1981 through November 30, 1981 the plant processed 99,437 tons (90,208 t) of waste, and produced 94,511 tons (85,739 t) of RDF. The RDF production has averaged about 57 tons per feed-hour per line. Substantially all of the processable incoming solid waste has been processed through the plant since February 17, 1981. Additional incoming tonnage will be necessary for the plant to furnish 600 tons/day seven days per week to the Albany Plant beginning as soon as the City of Schenectady's wastes will be delivered to the Albany Plant, preferably in 8-hr shifts, five days/week.

The shredders were estimated to use 21 hp-hr/ton (9 kWh/t) which will represent millions of dollars of savings over the lifetime of the plant. Thus far, no test deadlines, or any productive deadlines or goals have been missed.

AENCO has several philosophies for operating RDF Plants that may be of interest.

It is desirable that these plants handle the incoming waste almost as soon as it is received — preferably in 8-hr shifts, five days/week.

A separate night maintenance crew (without operational responsibilities) is desirable. The night crew performs all required scheduled preventative maintenance, lubrication, emergency maintenance and cleaning. At the end of the maintenance shift, the entire plant is clean and ready for next-day operations.

Heavy unscheduled maintenance is usually performed on weekends — using overtime labor or outside contractors, if necessary.

Detailed written plans must be developed for all emergencies, particularly for explosions.

Accurate operational and maintenance records are essential. Figure 1 shows a typical Weekly Tally Sheet. One significant number that is recorded daily is the time that each infeed conveyor is operated.

Procedures should be reduced to writing in well-organized manuals. The following manuals were produced and updated:

1. Operations
2. Maintenance

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**TABLE: WEEKLY TALLY SHEET**

<table>
<thead>
<tr>
<th>Date</th>
<th>Line 1 (Tons)</th>
<th>Line 2 (Tons)</th>
<th>Line 3 (Tons)</th>
<th>Line 4 (Tons)</th>
<th>Line 5 (Tons)</th>
<th>Line 6 (Tons)</th>
<th>Total (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>11/30</td>
<td>114</td>
<td>13.58</td>
<td>16.62</td>
<td>572.94</td>
<td>40</td>
<td>0</td>
<td>572.94</td>
</tr>
<tr>
<td>12/1</td>
<td>105</td>
<td>11.48</td>
<td>20.99</td>
<td>521.03</td>
<td>36</td>
<td>0</td>
<td>521.03</td>
</tr>
<tr>
<td>12/2</td>
<td>103</td>
<td>-13.12</td>
<td>21.62</td>
<td>594.50</td>
<td>42</td>
<td>0</td>
<td>594.50</td>
</tr>
<tr>
<td>12/3</td>
<td>97</td>
<td>18.04</td>
<td>18.04</td>
<td>568.64</td>
<td>40</td>
<td>0</td>
<td>568.64</td>
</tr>
<tr>
<td>12/4</td>
<td>105</td>
<td>13.38</td>
<td>13.38</td>
<td>606.80</td>
<td>45</td>
<td>0</td>
<td>606.80</td>
</tr>
<tr>
<td>12/5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>524</td>
<td>69.63</td>
<td>100.96</td>
<td>2,863.91</td>
<td>203</td>
<td>0</td>
<td>2,863.91</td>
</tr>
</tbody>
</table>

**FIG. 1**

Includes 10 minute coffee break and 30 minute lunch break.
3. Safety
4. Office Systems and Procedures

HEATING VALUE OF ALBANY RDF LABORATORY RESULTS

On December 3, 1980, 644 tons of RDF were produced. It was compacted into 33 trailers from Line 2 and 4 trailers from Line 1. As each trailer pulled away from its compactor station, a plastic bag full of RDF was extracted, sealed and tagged. Each such sample weighed about 10 lb.

Trailer No. 34 was dumped on the Tipping Floor, and eight samples of RDF were extracted from various places in the dumped material.

All collected material was screened to determine particle size distribution. All of the material was air-dried on the floor of the freshly-swept garage associated with the Plant, and a moisture loss of about 19 percent was determined.

The material from Line 2 was then coned, quartered and subquartered. Two composite subquarters were forwarded to Raltech Labs, Inc. of St. Louis, Missouri, for determination of heating value, ash and moisture content.

The eight samples from Trailer 34, were similarly prepared and one subquarter again sent to Raltech for analysis.

All of the four samples from Line 1 were mixed and coned. One subquarter was sent to Raltech for analysis.

The Raltech results are summarized in Table 2.

Prior to shipment, a moisture loss of about 19 percent was measured during the air-drying of the material. Raltech measured an average of 3.5 percent moisture in the four samples that we shipped. Thus the total moisture in the RDF as produced was about 23.3 percent.

Therefore, the average Higher Heating Value (HHV) of the RDF as produced, as measured by these tests, was:

\[(5,775)(1.0 - 0.233) = 4,429 \text{ btu/lb (10,300 kJ/kg)}\]

On January 27, 1978, we obtained 21 samples of the RDF — one from each of 21 trailers full of RDF that the plant produced that day. These samples were stored in plastic bags which were sealed and marked. Total weight of the samples, as collected was 217 lb (98.4 kg). We air-dried this material on the floor of the plant’s garage, and determined that the air-dried weight was 184 lb (83.5 kg). This amounts to a moisture weight loss of 15.2 percent of the incoming material. We coned and quartered this air-dried material, and selected one quarter for subquartering. We divided each of the four sub-quarters into two approximately equal parts, and labeled the samples so obtained 1a, 1b, 2a, 2b, 3a, 3b, 4a, and 4b. We sent samples 1a and 3b to Gilbert Commonwealth for determination of heating value, percent ash and moisture content. We sent samples 1b and 3a to the National Bureau of Standards; samples 2a and 4b to Williams Laboratory; and samples 2b and 4a to Raltech. The results are shown in Table 3.

The total moisture content of the RDF produced on January 27, 1981 was approximately 19.5 percent. Therefore, the average Higher Heating Value of the RDF, as produced, was:

\[(6,268)(1.0 - 0.195) = 5,046 \text{ Btu/lb (11,740 kJ/kg)}\]

It is worthy of note that during the tests on an air-classified RDF in St. Louis during the mid-1970’s, the averaging heating value of 273 samples of the RDF was 7,085 Btu/lb (16,480 kJ/kg) (dry basis); the average dry-basis ash content was 24.9 percent; and the average moisture content was 30.1 percent. The average of the St. Louis Samples indicates a moisture-free, ash-free heating value of 9,434 Btu/lb (21,940 kJ/kg). In 1980 Hasselriis reported an average moisture-free, ash-free heating value of 9,167 Btu/lb (21,320 kJ/kg).

### Table 2: Heating Value of Dec. 3, 1980 Samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Moisture-Free Heating Value Btu/Lb</th>
<th>Moisture-Free Ash Content (percent)</th>
<th>Moisture-Free, Ash Free Heating Value Btu/Lb (kJ/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composite Subquarter 1, Line 1</td>
<td>5,750 (13,370)</td>
<td>.37.3</td>
<td></td>
</tr>
<tr>
<td>Composite Subquarter 2, Line 2</td>
<td>5,776 (13,430)</td>
<td>40.1</td>
<td></td>
</tr>
<tr>
<td>Subquarter from Trailer 34</td>
<td>6,011 (13,980)</td>
<td>34.9</td>
<td></td>
</tr>
<tr>
<td>Composite, Line 1</td>
<td>5,563 (12,940)</td>
<td>35.8</td>
<td></td>
</tr>
<tr>
<td>Averages</td>
<td>5,775 (13,430)</td>
<td>37.0</td>
<td>9,167 (21,320)</td>
</tr>
</tbody>
</table>
TABLE 3 HEATING VALUE OF JANUARY 27, 1981 SAMPLES

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Laboratory</th>
<th>Percent Moisture Received</th>
<th>Percent Moisture Heating Value (Dry Basis)</th>
<th>Percent Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td>Gilbert Commonwealth</td>
<td>4.9</td>
<td>6,181 (14,380)</td>
<td>33</td>
</tr>
<tr>
<td>1b</td>
<td>NBS (average of 2 tests)</td>
<td>3.1</td>
<td>5,739 (13,300)</td>
<td>37.8</td>
</tr>
<tr>
<td>2a</td>
<td>Williams Labs</td>
<td>4.0</td>
<td>6,181 (14,380)</td>
<td>37.3</td>
</tr>
<tr>
<td>2b</td>
<td>Raltech</td>
<td>1.5</td>
<td>5,967 (13,880)</td>
<td>31.0</td>
</tr>
<tr>
<td>3a</td>
<td>NBS (average of 2 tests)</td>
<td>3.5</td>
<td>6,258 (14,560)</td>
<td>31.2</td>
</tr>
<tr>
<td>3b</td>
<td>Gilbert Commonwealth</td>
<td>3.1</td>
<td>6,247 (14,530)</td>
<td>39.8</td>
</tr>
<tr>
<td>4a</td>
<td>Raltech</td>
<td>1.5</td>
<td>6,199 (14,420)</td>
<td>27.1</td>
</tr>
<tr>
<td>4b</td>
<td>Williams Labs</td>
<td>7.2</td>
<td>7,370 (17,140)</td>
<td>24.0</td>
</tr>
<tr>
<td>Averages</td>
<td></td>
<td></td>
<td>6,268 (14,580)</td>
<td>32.7</td>
</tr>
</tbody>
</table>

Average Btu/lb moisture-free, ash-free basis: 9,313 (21,660 kJ/kg)

value of 9,380 Btu/lb (21,820 kJ/kg) for Eco-Fuel II (TM).

The Moisture-free, ash-free heating value of the averages of four different test series are shown in Table 4.

TABLE 4 COMPARISON OF MOISTURE-FREE, ASH-FREE HEATING VALUES FROM FOUR TEST SERIES

<table>
<thead>
<tr>
<th>Test Series</th>
<th>Moisture-Free, Ash-Free Heating Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Btu/lb (kJ/kg)</td>
</tr>
<tr>
<td>1. St. Louis Tests circa 1975</td>
<td>9,434 (21,940)</td>
</tr>
<tr>
<td>(273 samples) (an air-classified RDF)</td>
<td></td>
</tr>
<tr>
<td>2. Bridgeport, Conn., 1980 Eco-Fuel II (TM)</td>
<td>9,380 (21,820)</td>
</tr>
<tr>
<td>3. Albany, 12/3/80 (4 samples) (material not air-classified)</td>
<td>9,167 (21,320)</td>
</tr>
<tr>
<td>4. Albany, 1/27/81 (8 samples) (material not air-classified)</td>
<td>9,313 (21,660)</td>
</tr>
</tbody>
</table>

The above four numbers are very close together. If one were arbitrarily to assume that the average heating value of solid waste is 9,300 Btu/lb (21,600 kJ/kg) on a moisture-free, ash-free basis, it appears that one would be close to being correct. Considering the great difficulty of selecting a representative one or two-gram samples of RDF, it appears that a good way to determine the heating value of RDF would be to dry a very large sample (say 100 lb - 45 kg), and burn it to determine the ash content. The heating value of the material on a dry basis would then perhaps be approximately:

\[
\text{HHV} = (9,300) (1 - \text{fractional ash content of dry material}) \quad \text{Btu/lb or}
\]

\[
(21,600) (1 - \text{fractional ash content of dry material}) \quad \text{kJ/kg}
\]

The above data enables us to make an educated guess as to the amount of RDF that might be required to produce 200,000 lb of steam per hour, by the following crude analysis:

Moisture-free HHV, Btu/lb,
12/3/80 samples: 5,775 (12,970 kJ/kg)

Moisture-free, HHV, Btu/lb,
1/27/81 samples: 6,268 (14,780 kJ/kg)

Average: 6,021 (say, 6000 Btu/lb) (14,000 kJ/kg)

We estimate that, on average, the RDF, as produced, will contain 23 percent water. Therefore the Higher Heating Value (HHV) of the material will average about:

\[
\text{HHV} = 6,000 (1.0 - .23) = 4,620 \quad \text{Btu/lb (10,750 kJ/kg)}
\]

Presuming that the heat added to produce each pound of steam in the boiler is 1,050 Btu/lb (2,440 kJ/kg) steam, and presuming an overall boiler efficiency of 0.65, then the number of tons (N) per hour of RDF that would be required to produce
200,000 pounds of steam per hour would be given by:

\[
\frac{(4,620)(2,000)(0.65)(N)}{(1,050)} = 200,000
\]

Whence, \(N = 35 \text{ tons RDF/Hr} \) — or 840 tons (760 t) per 24 hr day.

If the boiler efficiency were 0.75, then about 725 tons (658 t) per day of "average" RDF would be required to produce 200,000 pounds of steam per hour for 24 hr.

These boilers were designed to burn two different RDF's, which were expected to be produced by the Albany Shredding Plant, as shown in Table 5.

| RDF Characteristics of Albany Shredding Plant as Predicted Circa 1976 |
|-----------------------------|-----------------------------|
| RDF #1 | RDF #2 |
| Higher Heating Value (Btu/lb) | 5,300 | 3,800 |
| (kJ/kg) | 12,330 | 8,840 |
| Percent Ash, as-fired | 10 | 16 |
| Percent Moisture, as-fired | 23 | 40 |
| Percent Carbon, as-fired | 33.16 | 23 |
| Percent Hydrogen, as-fired | 4.44 | 2.90 |
| Percent Sulfur, as-fired | 0.13 | 0.10 |

RDF #1, as defined above, cannot be produced by the Albany Fuel Preparation Plant — unless the plant is modified to produce an air-classified material. In a non air-classified RDF, such as that produced by the Albany Plant, the percent ash on a dry basis is about 35 percent. At 23 percent moisture, the material, as fired contains about 27 percent ash — nearly three times the ash assumed for RDF #1.

On the other hand, RDF #2 has characteristics that are close to what our test data would indicate for material containing 40 percent moisture. For such material, our test data would indicate that RDF #2 would have the following characteristics:

- Higher Heating Value  
  \[
  \frac{3,600}{(8,400)} = (1,050) (1.0 - 0.4)
  \]

- Percent Ash, as-fired 21
- Percent Moisture, as-fired 40

The above values, calculated on the basis of tests of the actual material produced by the Albany Plant (adjusted to 40 percent moisture), are remarkably close to the values that were estimated five years ago for RDF #2.

**ACTUAL BOILER RESULTS**

Early tests of the State OGS Boiler Plant began in May, 1981 in one of the new spreader-stoker fired boilers. A total of 537 tons (487 t) of RDF were delivered to the OGS Plant in May, 1981, and a total of 1,515 tons (1,374 t) were delivered in June. We made no attempt to correlate steam output with input tonnage during these early tests because OGS was in the process of modifying their operational procedures, and they were also retrofitting changes to solve some of the problems that they encountered.

Toward the end of June, 1981, the OGS Steam Plant was shut down for more than two weeks to retrofit changes to eliminate slagging in the boilers. Deliveries of RDF recommenced in 13 July. Although additional changes were being installed in the OGS Steam Plant after 13 July, it appeared that operational procedures had been standardized at about that time, and it seemed possible to obtain good knowledge of the actual amount of steam produced in the OGS boilers per ton of RDF delivered.

Between 13 July and 1 October, 1981, a total of 3,740 tons (3,393 t) of RDF was delivered to the OGS Steam Plant. This material was burned at various dates through 5 October.

During the period 13 July through 5 October, the OGS Steam Plant produced a total of 1,198 tons (1,087 t) of ash. On earlier measurements, this ash contained about 15 percent moisture. Therefore, the amount of dry ash produced during this period was about 1,018 tons (924 t). Thus, the RDF as produced, yielded about 27 percent dry ash, exactly as had been predicted for RDF having a moisture content of 23 percent based on our earlier laboratory tests.

During the period 13 July through 5 October, the OGS Steam Plant produced a total of 25,064,370 lb of steam (11,369,000 kg). The heat added to the steam in about 1,050 Btu/lb (2,442 kJ/kg). Therefore, the product of boiler efficiency and Higher Heating Value (HHV) of the RDF was:

\[
\frac{(25,064,370)(1,050)}{(3,740)(2,000)} = 3,518 \text{ Btu as steam/lb RDF}
\]

\[
8,183 \text{ kJ as steam/kg RDF}
\]

This product of boiler efficiency and higher heating value of the RDF is consistent with a boiler efficiency of 0.75 and a HHV of 4,690 Btu/lb (10,910 kJ/kg).
It will be interesting to learn the actual boiler efficiency when it is measured by more concise tests.

CONCLUSIONS AND RECOMMENDATIONS

The Albany Shredding Plant performs in excess of its specifications in the matter of processing rate, particle size, fractional removal of ferrous scrap, and daily throughput capacity.

The basic idea of inexpensively preparing a relatively crude RDF at a site remote from a spreader-stoker fired boiler dedicated to burning the RDF seems to be sound.

In testing RDF Plants it seems to be good philosophy to try to operate them at the highest possible feed rate even for short-duration tests. During such tests it is essential that a detailed test protocol be established and followed. Accurate data are necessary, and must be collected by using pre-planned procedures or instrumentation.

When operational problems are discovered during tests, long-term solutions should be decided upon by all interested parties (the Consulting Engineer, the Plant Operator, and the responsible Public Sector official). These solutions should be engineered for long life, and retrofitted at the earliest possible time. If the parties are not certain that a proposed solution is workable, it should be installed using a temporary method of construction — and high-rate tests conducted to assess the merits of the solution.

Reasonable sampling procedures and good laboratory practices can result in data on heating value and ash content of RDF that are useful in predicting actual performance in a boiler.

The moisture-free, ash-free heating value of three RDF's (ferrous-free shredded refuse, air-classified shredded refuse, and Eco-Fuel II™), as measured in four test series, are all close to 9,300 Btu/lb (21,600 kJ/kg). Heating value of a large sample RDF could be approximated by drying it to measure moisture content, and then burning the dry material to measure ash content. The heating value of the large sample could then be approximated based on assuming that its moisture-free, ash-free heating value is 9,300 Btu/lb (21,600 kJ/kg).

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This paper was presented from the viewpoint of its principal author, an employee of AENCO, Inc. The authors wish to highlight the close coordination that has existed among AENCO, Smith & Mahoney and Gordon L. Sutin Associates Ltd. The City Plant was built using the “A&E” approach — as opposed to the “Turnkey” or “Full Service” approach.

The authors believe that the cross-fertilization of ideas between the A&E and the plant operator during plant start-up and shakedown contributes to a successful operation. Such cross-fertilization can occur only if both parties communicate freely and professionally. Changes will be required to any solid waste resource recovery plant to make it operational and to reduce long-term costs. It is essential that the A&E of record have an open mind regarding such changes recommended by the operator. The authors gratefully acknowledge the close cooperation that has been provided by Patrick F. Mahoney, P.E.; Gordon L. Sutin, P.E.; Russell Galgana, P.E.; Wallace I. Johnson, Daniel A. Dorlon — all of whom were engaged by Smith and Mahoney, P.C., to work with AENCO during start-up and shakedown of the Albany Plant.

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Key Words

| Boiler | Reclamation |
| Calorific Value | Refuse |
| Fuel | Refuse Derived Fuel |
| Heat | Sampling Methods |
| Operation | Spreader-Stoker |