TEST OF ROTARY DRUM AIR-CLASSIFIER AT ALBANY, NEW YORK SOLID WASTE ENERGY RECOVERY SYSTEM

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ABSTRACT

The Albany, New York Solid Waste Shredding Plant produces a Crude RDF, consisting of 93% of the incoming solid waste; 4% is removed as ferrous scrap and 3% is hand picked and landfilled before shredding. A Transportable Rotary Drum Air-Classifier (RDAC™) was used in a test program partially funded by the New York State Energy Research and Development Authority (NYSERDA). The unit produced five types of Improved RDF. Significant tonnages of each type were burned in two dedicated spreader-stoker fired boilers. The characteristics of the Crude RDF and two of these Improved RDF's are reported in this paper; the others are described only briefly, and only significant findings are reported on the other types. Each of the five types of Improved RDF produced more steam per pound of raw *incoming* refuse than was produced by the Crude RDF, despite the fact that some combustibles were removed in preparing each type of Improved RDF. It was found that the best RDF was prepared by air-classifying raw incoming waste (or coarse shear-shredded waste) at a high "split" (89–92% to the Light Fraction). The Light Fraction is then screened over a ½ in. (1.3 cm) screen. The plus ½ in. (1.3 cm) Light Fraction constitutes about 73% by weight (90% by volume) of the incoming material, and contains 12.3% ash (dry basis). At 22% moisture, this RDF has an HHV of about 6200 Btu/lb (14,656 kJ/kg).

BACKGROUND

A 20 ft (6 m) diameter × 40 ft (12 m) long rotary drum air-classifier of plywood construction was tested in 1975, and the results were reported in 1976 [1].

In 1984 a transportable unit of steel construction was built. This unit is 9 ft (2.7 m) in diameter × 20 ft (6 m) long.

ALBANY SHREDDING PLANT

The Albany New York Solid Waste Energy Recovery System (ANSWERS) consists of three plants—a Shredding Plant owned by the City of Albany, [2] a State-owned Boiler Plant equipped with two 100,000 lb/hr (45,400 kg/h) boilers designed to burn "ferrous free" shredded MSW [3], and a City-owned Ash Processing Plant that has never operated at full scale (it has been shut down for 3 years). The Albany Shredding Plant produces about 650 tons/day (590 t/d) 5 days/week, and the State Boiler Plant burns about 460 tons/day (420 t/d) 7 days/week.

Approximately 10% of the trucks entering the facility are bypassed to the adjacent landfill, because they contain too much material that cannot be shredded. About 3% of the incoming material is picked from the waste stream in the Shredding Plant, either because it cannot be shredded, or because it may cause explosions in the shredders; this picked material is landfilled. Overhead magnets remove ferrous scrap from the output of the two shredders in the plant, and about 4% of the incoming material is removed as ferrous scrap. The magnets remove 90% or more of the ferrous scrap in the shredded material. The magnets are less effective in removing very heavy ferrous objects, and a good deal of heavy ferrous material is not removed by the magnets. The Albany Shredding Plant contains no provisions for cleaning the ferrous scrap, which is marketable when cleaned. The market price, f.o.b. Northern New Jersey, is about $27/ton ($30/t). The cost of removing the material from stockpile, reshredding to densify it, air-classifying it to provide an acceptable product, and transporting it to market is about $36/ton ($40/t); the ferrous scrap is therefore landfilled.

Problems

The Albany Shredding Plant has had the following problems:

(a) Explosions. The explosion alleviation systems in the Albany Shredding Plant were described in 1982 [4]. From its start-up in February, 1981, through August 10, 1985, the Albany Shredding Plant has experienced 23 explosions, which have caused a total of about $110,000 damage, which does not include the cost of approximately $7,000 per explosion to recharge the FENWAL protection system [5].

The explosions that caused damage probably resulted from shredding containers of volatile material, which was then ignited *outside* the shredder in the downstream area.

(b) The hammers must be relatively soft to prevent their breaking when large pieces of metal are inadvertently fed to the shredders. The hammers are essentially 200 lb (90 kg) "clubs," which are inappropriate for shredding the major constitutient of MSW—namely paper. Hammers and other shredder wear parts cost about $1.20/ton ($1.34/t) processed, not including labor.

(c) Visual inspection on the Tipping Floor, and visual inspection at a Picking Station located at each of the Shredder Infeed Conveyors is ineffective in removing all material which might damage the shredders or cause explosions.

(d) Much of the incoming glass is ground into the paper fibers during shredding. The glass and grit in the incoming waste are believed to be a primary cause of high shredder wear.

Because of the relatively poor quality of the Crude RDF produced by the Albany Shredding Plant, the State Boiler Plant experiences the following problems:

(a) The glass and grit in the crude RDF causes wear on the screw feeders and the fuel chutes in the boiler plant.

(b) Large pieces of ferrous and nonferrous metals cause feeder jams, feeder breakage, and also damage the plate in the furnace onto which the RDF drops from the fuel chutes.

(c) Because the Crude RDF is not of uniform quality, it is difficult to maintain optimum combustion conditions at all times. Furnace/boiler "upsets" sometimes occur.

(d) Boiler downtime caused by relatively poor fuel increases the amount of waste that must be landfilled.

(e) High glass content results in relatively low ash fusion temperatures, which result in excessive slag in the bottom ash and sometimes in the fly ash.

(f) The relatively high chlorine and sulfur content of the Crude RDF is approximately that of raw waste. Acid gas scrubbers may ultimately be mandated.

(g) Downtime at the Albany Shredding Plant has sometimes caused temporary shortages of Crude RDF. Most of this downtime has been due to explosions.

DESCRIPTION OF TRANSPORTABLE ROTARY DRUM AIR-CLASSIFIER

Figure 1 is a simplified sketch showing how the Transportable RDAC™ operates.

A 3 ft (0.9 m) wide rubber belt conveyor (1) moves material to the hopper of a 4 ft (1.2 m) diameter Ram-Tube conveyor (2). The ram-tube conveyor, which is simply a tube containing a ram, protrudes through a large settling chamber (3) and into the upper end of a tapered rotary drum (4), which rotates at about 15 rpm. No jams have ever occurred in the Ram-Tube Conveyor. The drum is set on an angle of 7.5 deg. and is double tapered in order to provide a monotonic decrease in open cross sectional area from the lower end of the drum to the upper end. The upper end of the drum protrudes into the settling chamber (3) through an air seal. Air is forced to flow from the lower end of the drum into the settling chamber by two fans—a discharge fan located downstream from a cyclone separator (8), and recirculating fan (7) which collects air from the settling chamber and discharges

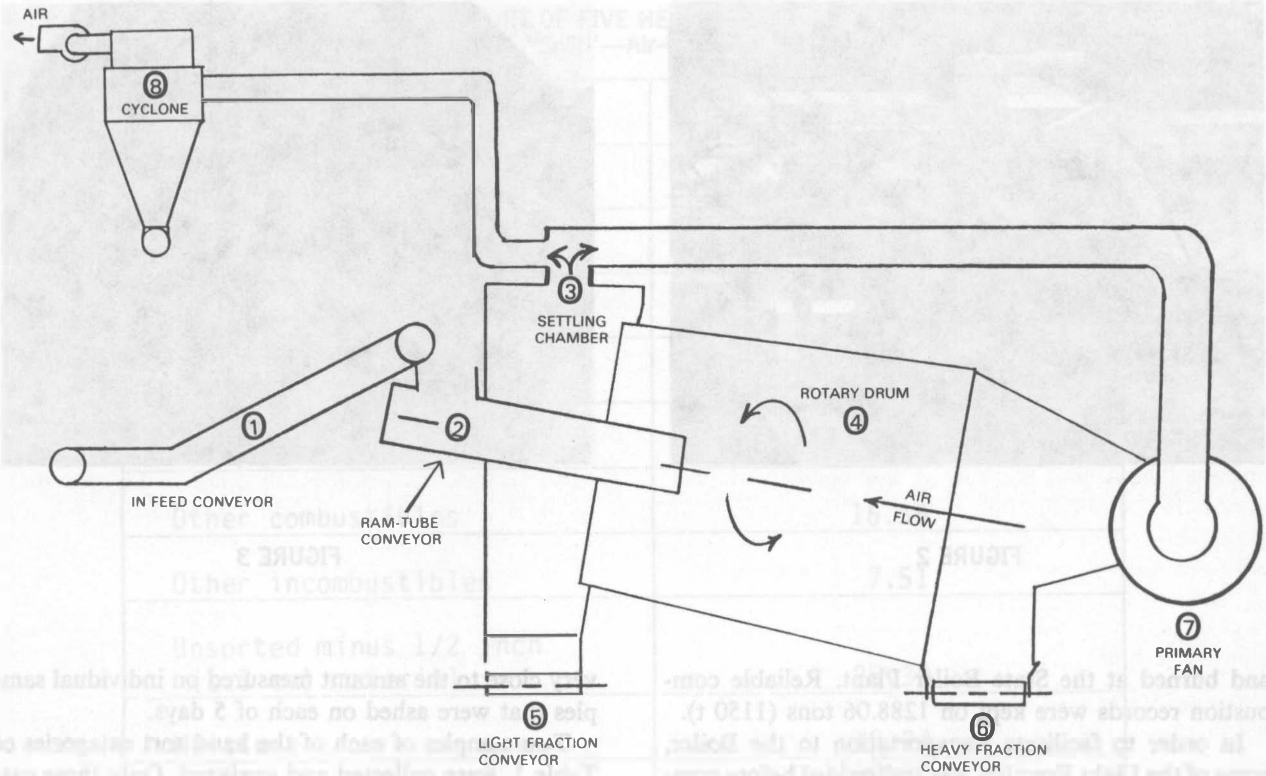

FIGURE 1

it into the lower end of the drum. The discharge fan exhausts about 31,000 cfm (880 m^3/s) and the recirculating fan moves up to 85,000 cfm (2400 m^3/s), depending on the settling of a remotely-controlled damper (not shown) which varies the cross sectional area of the recirculating duct from 5.3 ft^2 (0.5 m^2) to 40 ft^2 (3.7 m^2).

When material is fed into the drum, the material drops on lifters, on which are mounted a number of spears. The spears open the waste bags and expose the contents to air classification. The air flow moves a Light Fraction to the settling chamber, and a Heavy Fraction moves down the drum and falls on a 4 ft (1.3 m) wide Heavy Fraction discharge conveyor (6). Another 4 ft (1.3 m) wide conveyor (5) is installed in the bottom of the settling chamber, and moves Light Fraction material through a powered air lock. The Light Fraction material is then elevated by the Light Fraction Conveyor into a truck.

Figure 2 is a photograph of the Transportable Unit, as assembled in Albany.

Figure 3 is a photograph of the interior of the drum. Figure 4 is a photograph of the Control Room.

The Control Room contains all of the necessary switchgear and controls, and also contains four television sets which show the condition at four critical locations. The upper portion of the settling chamber has a cross sectional area of 280 ft^2 (26 m^2), and almost all of the Light Fraction material falls in the settling chamber. Very little material is collected in the cyclone separator.

AIR-CLASSIFIED SHREDDED MSW

The Transportable Unit was set up at the rear of the Shredding Plant, and a conveyor moved shredded material from one Crude RDF line of the Shredder to the Infeed Conveyor of the Transportable Unit. The air flow was set to produce a 95.5/4.5% "split," with 95.5% of the "ferrous free" output of the Albany Shredding Plant reporting to the Light Fraction. The unit processed the shredded material at a rate of about 40 tons hr (36 t/h). A total of 118.4 tons (104 t) of Heavy Fraction material was produced and a total of 2539 tons (2301 t) of Light Fraction was produced

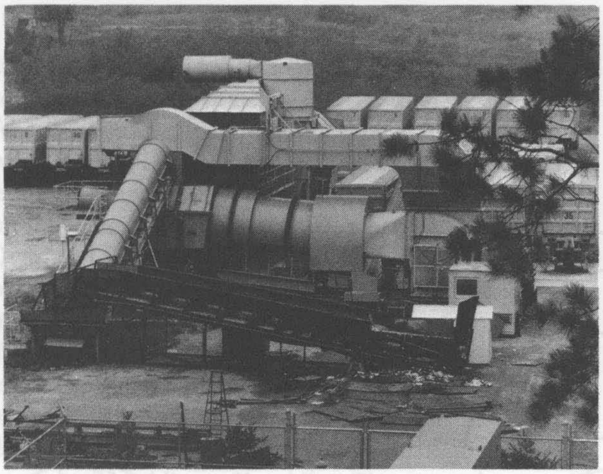

FIGURE 2

FIGURE 3

and burned at the State Boiler Plant. Reliable combustion records were kept on 1288.06 tons (1150 t).

In order to facilitate transportation to the Boiler, some of the Light Fraction was reshredded before combustion, (Type A Improved RDF), and some was delivered directly from the Air-Classifier (Type B Improved RDF). There was little difference in boiler performance, and the materials were otherwise substantially identical. In this paper, all Light Fraction produced by air-classifying the shredded output of the Albany Plant is referred to as Type A/B.

HEAVY FRACTION CHARACTERISTICS

On each of 18 days, a 42 gal (160 L) sample was collected directly from the Heavy Fraction discharge conveyor. All large pieces of metal, were removed and stored, leaving a sample that could be coned and quartered to produce a subsample weighing about 25 lb (11 kg). The subsamples were dried in an oven, and handsorted. Later, the proportionate weight of the previously removed heavy pieces of metal were added to the appropriate category ("ferrous," "aluminum" or "other nonferrous").

About 25 lb of the dried Heavy Fraction taken on each of 5 days were hand sorted. Table 1 shows the composition of the Heavy Fraction.

A synthetic 82.49 lb (37.4 kg) Heavy Fraction sample was prepared based on the hand sort data of Table 1. The sample was ashed. The material contained 67.4% ash and incombustibles (dry basis). This was very close to the amount measured on individual samples that were ashed on each of 5 days.

Two samples of each of the hand sort categories of Table 1, were collected and analyzed. Only three categories could be chemically analyzed; the others could not be milled. The more interesting analyses are shown in Table 2.

The heavy pieces of plastic and rubber would surely have burned on the grate, and not in suspension. The combustion of this chlorine-rich material could result in production of chlorinated hydrocarbons. The sodium oxide content of "other combustibles" is very high, and could be expected to reduce ash fusion temperatures and thus cause slagging.

LIGHT FRACTION CHARACTERISTICS OF AIR CLASSIFIED SHREDDED MSW

Eighteen daily samples of the Light Fraction, averaging about 10 lb (4.5 kg) were taken. They were weighed, dried and ashed at the Albany Shredding Plant site. Dried representative samples of Light Fraction, were hand-sorted and representative samples were prepared for laboratory analysis. The Light Fraction averaged 20.4% ash, and the ash fluidization temperature averaged 2216°F (1213°C). The Crude RDF produced by the Albany Shredding Plant averaged 22.9% ash and its ash fluidizing temperature averaged 2140°F (1171°C). Table 3 compares the characteristics of the Light Fraction with the non-air-classified shredded output of the Albany Shredding Plant. Table 4 compares the steam production of the Light Fraction with

TABLE 1 HANDSORT OF FIVE HEAVY FRACTION SAMPLES
(From 95.5%/04.5% "Split"—Air-Classified Shredded Material)

CATEGORY	% COMPOSITION
Aluminum	3.30
Other non-ferrous metals	3.92
Ferrous metals	23.65
All paper products	0.86
All plastics and rubber	6.57
Other combustibles	16.56
Other incombustibles	7.51
Unsorted minus 1/2 inch (1.3 cm) material	25.39
Moisture	12.24
	100.00

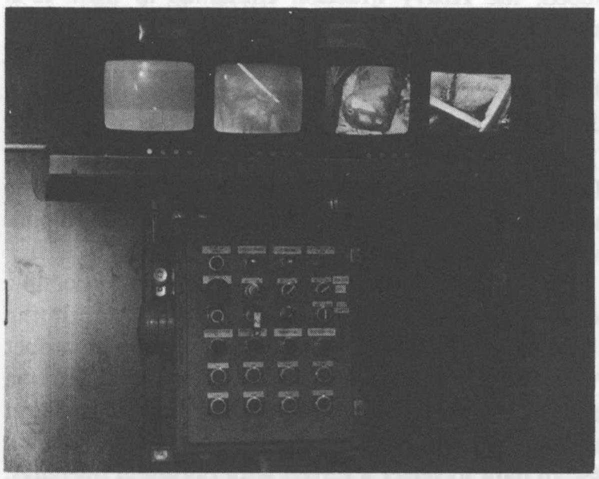

FIGURE 4

the steam production of the non-air-classified shredded output of the Albany Shredding Plant.

Table 4 shows that the Light Fraction produced by air-classifying shredded material at a 95.5/4.5% "split" (Types A/B RDF) had a 11.5% greater specific steam production than the non-air-classified shredded material. Since only 4.5% of the non-air-classified shredded material was removed by air-classification, it is clear that the act of air-classification increases steam production per incoming ton of waste material. This result is similar to the results reported by Kenny and Sommer [6], where the authors processed MSW through a different system to remove ferrous metals, grit and glass, and some aluminum cans. The remaining material produced more steam per ton of incoming material than was produced by burning the entire waste stream. Table 3 shows that the Light Fraction contained 20% less nitrogen, 11% less chlorine and 36% less sulfur than the nonair-classified shredded material, based on only five samples of each product.

AIR-CLASSIFICATION OF UNSHREDDED MSW

The transportable unit is somewhat too small to process large pieces of lightweight material, such as corrugated boxes larger than 5 ft (1.5 m), in two dimensions. Therefore, a few conveyor jams occurred when unshredded waste was processed.

TABLE 2 CHEMICAL COMPOSITION OF THREE COMPONENTS OF 95.5%/4/5% HEAVY FRACTION
(Average of 2 Samples)

COMPONENT	PAPER PRODUCTS	PLASTICS & RUBBER	OTHER COMBUSTIBLES
% Dry Nitrogen	0.7	0.29	0.61
% Dry Oxygen	33.2	11.40	41.3
% Dry Sulfur	0.21	0.66	0.12
% Dry Chlorine	0.24	4.57	0.21
Sodium Oxide (as % of ash)	5.83	4.85	12.60

70%/30% Split

The unit processed 55.64 tons of unshredded MSW, and 37.52 tons (34.6 t) of Light Fraction were produced for an actual "split" of 67.4%/32.6%. The Light Fraction contained 16% ash, which was considered excessive in light of the low yield. The 37.52 tons of Light Fraction were shredded and burned in the State Boiler as Type C Improved RDF (see Table 4). A significant amount was screened, and it was found that the plus ½ in. material would contain only 9.3% ash, but the total yield would be only 55.2% of incoming material. It was concluded that a 70%/30% air-classified "split" is too low; too many combustibles are lost.

Some 100 lb of the 70%/30% unshredded Light Fraction were screened over a 1 in. (2.54 cm) screen. 53.9% of the Light Fraction was oversize. The oversize material contained 0.28% nitrogen, 0.19% sulfur, and 0.2% chlorine. The undersize material contained 0.80% nitrogen, 0.52% sulfur, and 0.32% chlorine. This hinted that these acid-forming elements in the Light Fraction are concentrated in the smaller size particles.

Four hundred pounds (180 kg) of plus 4 in. (10 cm) unshredded Light Fraction were pulped. The pulper separated paper pulp from contraries (textiles, light-gage plastics, rope, etc.). Table 5 shows a few properties of the pulp and the contraries.

90%/10% Split

In 1984 83.99 tons of unshredded MSW were processed at an average "split" of about 90%/10%, and produced 75.59 tons of Light Fraction, which was shredded and burned in the State Boiler as Type D Improved RDF (see Table 4).

The 90%/10% Light Fraction material produced 18.8% ash, as fired (24.1% dry basis). The Heavy Fraction produced 63.0% ash (dry basis). As produced, the Heavy Fraction contained at least 13% moisture, and is a very poor fuel.

A large quantity of the Light Fraction produced at 92%/8% "split" was screened and two representative samples of the plus 2 in. (5 cm) and the minus 2 in. (5 cm) materials were sent to an outside laboratory. Table 6 shows the results, which again show that the acid-forming elements in the Light Fraction are concentrated in the smaller particle size.

The data to this point hinted that it might be possible to produce a low-ash RDF at a high yield by operating the unit at high air flow to produce a high product "split," and subsequently to screen the Light Fraction in order to remove what we thought would be a wet material rich in ash as undersize. In order to obtain design data to select a screen with optimum openings, some 10 tons (8.9 t) of unshredded MSW at a 92%/8% "split" were processed. Grab samples of the Light Fraction weighing a total of 47.83 lb were selected, and the combined sample was screened over a series of Gilson screens. Table 7 shows the screening results. After examining Table 7 and other similar data, it was decided that a ½ in. (1.3 cm) screen might be optimum in a production situation.

The tests indicated that the flow diagram shown in Fig. 5 might be realistic.

TABLE 3 COMPARISON OF CHARACTERISTICS OF FIVE SAMPLES OF IMPROVED RDF AT 95.5%/4.5% "SPLIT" WITH CRUDE RDF
(Outside Laboratory)

CONSTITUENT	RDF TYPE: AVERAGE AIR-CLASSIFIED SHREDDED MSW @ 95/05 "SPLIT" (IMPROVED RDF)	RDF TYPE: AVERAGE CRUDE RDF
Dry % Nitrogen	0.57	0.71
Dry % Oxygen	31.80	27.50
Dry % Sulfur	0.27	0.42
Dry % Chlorine	0.31	0.35
Sodium Oxide (as % of Ash)	7.27	7.59
% Dry Ash (dry basis)*	20.40	22.90
HHV (BTU/lb, dry basis)	7174.00	6143.00
HHV (moisture free, ash free)	9012.00	9265.00
% Carbon	40.92	36.58
% Hydrogen	5.72	5.05

*These laboratory ash determinations appear to be too low. About 20.0% ash, as-fired at 23% moisture, were measured locally for the Type A/B Improved RDF, and about 22.5% ash, as-fired with 23% moisture for the Crude RDF. Large samples of each product were dried and ashed locally.

TABLE 4 SPECIFIC STEAM PRODUCTION — FIVE TYPES OF RDF

RDF TYPE	TOTAL RDF BURNED (Tons)	TOTAL YIELD (% BY WEIGHT) INCOMING MSW	TOTAL STEAM PRODUCED (Lbs.)	SPECIFIC STEAM PRODUCTION (Lbs.Stm./Lbs. RDF)	SPECIFIC STEAM PRODUCTION (Lbs.Stm./Lbs. Incoming MSW)
A/B Improved	1288.06	89	9,062,000	3.52	3.13
C/D Improved *	157.84	About 85	1,113,000	3.52	About 2.99
E Improved	102.84	73	847,000	4.12	3.01
Crude RDF	12,716.73	93	79,008,000	3.13	2.91

A/B Improved. Air Classified Light Fraction produced from the shredded output of Albany Plant at 95.5/4.5% "split."

C/D Improved. 37.52 tons of 67.4/32.6% Light Fraction, mixed with 75.59 tons of 90/10% Light Fraction, mixed with 44.73 tons of Crude RDF.

E Improved. Air Classified Light Fraction produced from unshredded MSW, and then screened over 1/2" screen.

NOTE: State Boiler adds 1039 Btu/lb enthalpy per lb. steam

TABLE 5 LABORATORY MEASUREMENTS OF PAPER PULP AND PLASTIC/TEXTILE RESIDUE FROM PLUS 4 in. 70%/30% "SPLIT" LIGHT FRACTION

ITEM MEASURED	PULP	RESIDUE
Dry % Ash	5.12	8.54
Dry % Sulfur	0.15	0.14
Dry % Nitrogen	0.12	0.59
Dry % Chlorine	0.13	0.99

TABLE 6 LIGHT FRACTION FROM UNSHREDDED MSW—92%/8% "SPLIT"

	Sample			
	+2 Inch Screen		-2 Inch Screen	
Lab Measurement	1	2	1	2
Dry % Nitrogen	0.21	0.35	0.82	0.93
Dry % Sulfur	0.22	0.21	0.68	0.71
Dry % Chlorine	0.12	0.22	0.27	0.36

TABLE 7 PARTICLE SIZE AND ASH DISTRIBUTION—92% YIELD LIGHT FRACTION

				Cumulative Yield vs Ash		
Screen Size	% Passing	% Of Total Sample	% Ash (As Fired) vs. Size	% Yield Light Fraction	% Yield Ash	% Of Incoming As Fuel**
4"	62.9					
3"	50.7	72.1	8.8% without FE = 7.9%	72.1	8.8%	66.2
2"	36.9					
1"	27.9					
3/4"	25.6	2.3	24.8	74.4	9.3	68.3
1/2"	21.7	3.9	22.7	78.3	10.0	71.9
1/4"	15.3	6.4	39.3	84.7	12.2	77.8
1/8"	11.5	3.8	55.5	88.5	14.1	81.2
Pan	-	11.5	55.4	100.0	18.8	91.8
Totals			18.8	100.0	18.8	91.8

* As-fired moisture is unknown (sample air dried 6 hours before being oven-dried).

** Light gage ferrous not removed from Light Fraction.

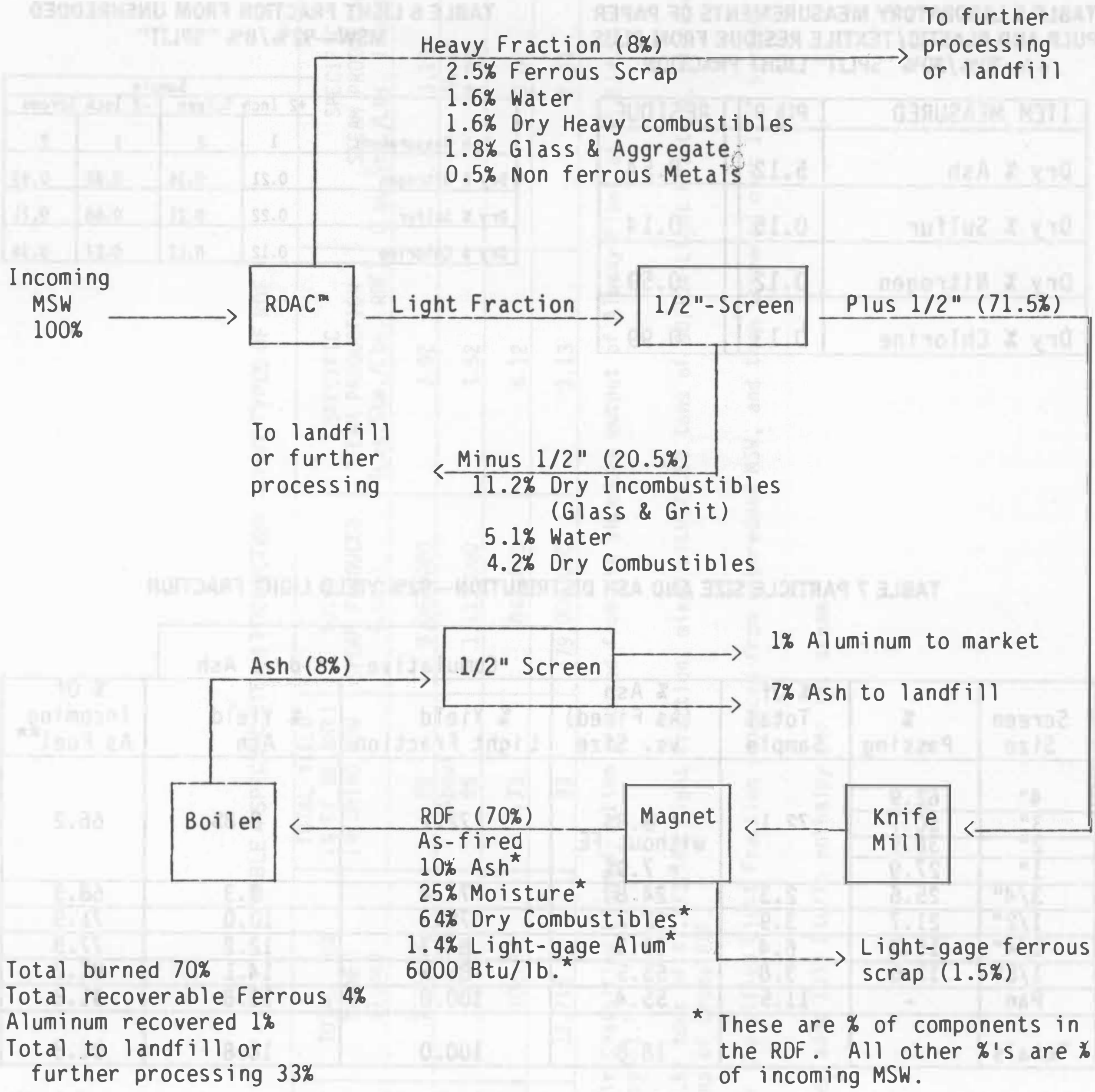

FIG. 5 NEW FLOW DIAGRAM

LARGE-SCALE LIGHT FRACTION SCREEN TESTS

Based on the experimental work described above, a 10 ft (3 m) diameter, 20 ft (6 m) long rotary screen with ⅜ in. (0.95 cm) × ⅞ in. (2.2 cm) diamond-shaped openings was installed to process the Light Fraction. This screen is referred to as a ½ in. (1.3 cm) screen. After some experimentation, the screen was set at a 5 degree angle, and it was operated at about 60% of critical centrifugal speed.

In order to measure product "split," a total of 55,700 lb (25,265 kg) were processed in four test runs of unshredded MSW, and immediately after each run, each of the three products produced was weighed. Table 8 shows the results of these tests. Table 8 also shows the "split" data from processing one trailer load of shear-shredded material produced form Chemung County Waste using an Iowa Manufacturing Shear-Shredder equipped with 4 in. (10 cm) cutter blades.

Tables 9–11 compare the predictions of Fig. 5 with the actual results obtained using an on-line ½ in. (1.3 cm) screen on the Light Fraction. It is believed that the data on moisture and ash content are reliable. Data on chemical composition is based on seven samples of plus ½ in. (1.3 cm) Light Fraction, and four samples of minus ½ in. (1.3 cm) material. The data in Table 9 show that it is possible to produce an RDF with more than 70% yield, by weight, containing only about 12.3% ash (dry basis) from mixed MSW. This plus ½ in. (1.3 cm) Light Fraction RDF appears to contain relatively small quantities of nitrogen, chlorine and sulfur. The ratio of moisture to dry, ash free combustibles is only 0.34.

Table 10 shows that the minus ½ in. (1.3 cm) Light Fraction is a particularly undesirable fuel. It contains 14% more moisture than dry ash-free combustibles, and the amount of sulfur seems to be very high. It is also rich in nitrogen. It produces 73% ash, dry basis.

Table 11 shows that the Heavy Fraction is also an undesirable fuel. The ratio of moisture to dry, ash-free combustibles is 0.69, and it produces 57% ash (dry basis). Chemical analyses of this Heavy Fraction were not obtained because of the difficulty of obtaining representative samples of this unshredded material. Certainly the heavy gage plastics and rubber have a very high chlorine content—probably in the range of 4.5% (see Table 3).

It will be noted that the percent of Heavy Fraction was somewhat larger than predicted by Fig. 5, and that the percent of minus ½ in. (1.3 cm) Light Fraction was somewhat lower than predicted by Fig. 5. However, the sum of these two percentages was almost identical with the prediction of Fig. 5. It is believed that, if the air flow in the drum had been increased in order to decrease the percent reporting to the Heavy Fraction, then the additional material reporting to the Light Fraction would have contained more of the larger pieces of glass in the minus ½ in. (1.3 cm) range, which would probably have dropped through the screen, and reported to the minus ½ in. (1.3 cm) Light Fraction. In other words, it is believed that the system used is tolerant as regards the exact setting of the air flow in the drum. Moreover, the system seems to operate consistently regardless of weather conditions or moisture in the MSW.

TABLE 8 "SPLIT" DATA

DATE	TOTAL WT.	% +1/2" LF	% -1/2" LF	% HF
7/2/85	10,920	74.73	11.72	13.55
8/2/85	9,560	73.64	7.53	15.27
8/27/85	11,360	71.48	16.90	11.62
9/20/85	23,860	75.69	12.41	12.07
Average		73.89	12.14	13.13
Standard Deviation		1.80	3.84	1.65
Shear-Shredded Matl from Chemung County 11/14/85	32,080	73.57	14.78	11.66

The air flow in the drum was not changed during the tests with the ½ in. (1.3 cm) screen installed. The tolerance of the system to changes in MSW composition and moisture is indicated by the results obtained while processing the shear-shredded material from Chemung County. Table 12 shows that the yield of plus ½ in. (1.3 cm) Light Fraction was 73.57% for the shear-shredded material, compared with 73.89% for unshredded MSW. The shear-shredded material from Chemung County was very wet; yet, without changing the air flow in the RDAC™, the yield of RDF was substantially identical in both cases.

Moreover, as shown in Table 12, the ash content of the plus ½ in. (1.3 cm) Light Fraction from unshredded MSW is substantially the same as the ash content from Chemung County's shear-shredded waste, thus indicating that shear-shredded material behaves in the RDAC™ substantially the same as unshredded material, and that the act of shear shredding does not imbed glass and grit into the paper or other light material.

TABLE 9 PRODUCTION RUNS PLUS ½ in. LIGHT FRACTION VS PREDICTION BASED ON 1984 TEST SERIES (Fig. 5)

ITEM	PREDICTION (Fig.5)	ACTUAL 1985
Lowest Yield	-	71.48%
Highest Yield	-	75.69%
Average Yield	70%	73.89%*
% Ash (as fired)	10%	9.50%
% Moisture	25%	22.96%
% Ash (dry basis)	13.33%	12.33%
% Nitrogen	Not Predicted	0.37%
% Chlorine (dry basis)	Not Predicted	0.21%
% Sulfur	Not Predicted	0.21%
HHV (Btu/lb)	6,000	6,349**
Approx. LHV (Btu/Lb)	5,275	5,728***
Uncompacted Density as produced (lbs/yd^3)	Not Predicted	128
Wt. Moisture ÷ Wt. dry ash free combustibles	0.38	0.34

* Contains estimated 1.5% light gage ferrous scrap. Would be 72.07% with ferrous removed.

** Calculated as (100 - % ash - % H_2O) (94)

*** Calculated as HHV - 7.12 (% Combustibles) - (% H_2O) (10.5)

TABLE 10 PRODUCTION RUNS MINUS ½ in. LIGHT FRACTION VS PREDICTION BASED ON 1984 TEST SERIES

ITEM	PREDICTION (Fig.5)	ACTUAL 1985
Yield	20.5%	12.14%
% Ash (as-fired)	54.63%	56.02%
% Moisture	24.87%	23.40%
% Ash (dry basis)	72.72%	73.13%
% Nitrogen (dry basis)	Not Predicted	0.80%
% Chlorine (dry basis)	Not Predicted	0.26%
% Sulfur (dry basis)	Not Predicted	0.94%
HHV (Btu/Lb)	1927	1934
Approx LHV (Btu/Lb)	1519	1542
Uncompacted Density as-produced (lbs/yd^3)	Not Predicted	697
Wt. Moisture ÷ Wt.dry ash-free combustibles	1.21	1.14

TABLE 11 PRODUCTION RUNS HEAVY FRACTION VS PREDICTION BASED ON 1984 TEST SERIES
(Fig. 5)

ITEM	PREDICTION (Fig.5)	ACTUAL 1985
Yield	8%	13.55%
% Ash (as-produced)	48%	44.11%
% Moisture	20%	22.88%
% Ash (dry basis)	60%	57.20%
HHV (Btu/Lb)	3008	3103
Approx LHV (Btu/Lb)	2570	2628
Uncompacted Density as-produced (lbs/yd^3)	Not Predicted	557
Wt. Moisture ÷ Wt.dry ash-free Combustibles	0.625	0.693

While air-classifying the shear-shredded material from Chemung County, about 100 unruptured aerosol cans were observed in the Heavy Fraction, indicating that the Chemung County Shear Shredder with 4 in. cutter blades does not open a substantial number of such aerosol containers, which are believed usually to contain volatile material that often causes explosions in shredding plants.

In 1984 Bond presented data which showed the results of air-classifying shear-shredded material using a different air classifier.

One hundred two and eighty-four one-hundredths tons of plus ½ in. (1.3 cm) Light Fraction were burned in the boiler and produced 847,000 lb of steam, for a specific steam production of 4.12 lb steam/lb of product (See Table 4—Improved RDF Type E.).

EFFECT OF PROCESSING ON POTENTIAL ACID EMISSIONS

The potential emissions of acid gases from the combustion of MSW and RDF depend primarily on the amount of nitrogen, sulfur and chlorine present in the fuel. While it is difficult to determine what fraction of these components of the fuel is actually emitted, and how much remain in the ash residue, the emissions cannot exceed the input. It is generally assumed that all of the fuel nitrogen is emitted as "fuel NO_x," all of the chloride as HCl vapor, and 50%–75% of the sulfur as SO_x. Actually, much of the sulfur and chlorine reacts with particulate matter, 99% of which is collected by particulate emission controls. When alkaline materials are added for acid gas control, a large part of the sulfur and HCl can be captured.

Reducing the acid content of the MSW or RDF will reduce their emissions to the atmosphere, or reduce the burden on the acid gas control system. The question is, to what extent can processing municipal waste reduce these acids?

The acid-forming elements in three RDF's, representing different degrees of processing, are shown in Table 13. Since emissions are commonly reported as lb/million Btu in the fuel (based on higher heating value), the data have been translated to this form. The Crude RDF (shredded and "ferrous-free") is the baseline.

It should be pointed out that the first two RDF's were produced at the same time during the summer of 1984, and might not be representative of MSW collected in other seasons.

Two analyses were made of the Light Fraction produced by air-classifying Crude RDF at a 95%/5% "split." Nitrogen was reduced by 32% and sulfur by

TABLE 12 CHARACTERISTICS OF TWO PLUS ½ in. LIGHT FRACTIONS

ITEM	PLUS 1/2 IN. LIGHT FRACTION CHEMUNG COUNTY SHEAR-SHREDDED MSW	ALBANY UNSHREDDED MSW
Yield (% by weight)	73.57%	73.89%
% Ash (dry basis)	12.23%	12.33%
% Moisture	27.38%	22.96%

43%. These analyses are comparable because the samples were taken simultaneously during the test runs. The data for 73% yield on unshredded material can not strictly be compared with the Crude RDF, as the 73% yield samples were collected during the fall of 1985.

These data should be used with some caution, because they are based on fewer than ten samples of each type of RDF. However, they confirm observations made by analyzing the larger size material in the Light Fractions produced at 70%/30%, and at 90%/10% "split" in 1984. The trend seems too clear to ignore; it appears that the additional processing definitely reduces the acid-forming elements in RDF.

The emissions in lb/million Btu can be approximately related to parts per million (ppm) concentrations in the stack gas, corrected to 12% CO_2. Nitrogen emissions of 1.16 lb/mm Btu (0.58 kg/mm kJ) corresponds to about 480 ppm. The 95% yield analysis represents a reduction to 330 ppm, and the unshredded screened RDF represents 180 ppm.

Sulfur content of 0.68 Btu (0.34 kg/mm kJ corresponds to about 200 ppm in the emissions, of which perhaps 70 ppm might be gaseous. Applying the RDAC™ to achieve 95% yield might reduce this to about 40 ppm, and unshredded to about 26 ppm. Clorides at 0.51 lb/mm Btu (0.25 kg/mm kJ) represent about 300 ppm, which would be reduced to about 230 ppm for the 95% yield material, and to about 130 ppm for the unshredded screened material.

The reduction in NO_x potentials may be valuable, since alkaline acid gas controls do not affect NO_x emissions. The reductions in sulfur and chlorine potential are substantially less than the reductions being required by many regulations and guidelines. In addition, these regulations sometimes refer to percent reductions in contaminants in the gas composition entering the acid gas control device, not the raw MSW before processing. Also, regulations call sometimes for SO_x and HCl emissions to be limited to certain outlet concentrations such as 30, 50 and 100 ppm, which are not achieved by fuel processing alone.

The degree of control required by the acid gas emission control system varies with the input concentration. For the values in Table 13, the SO_x plus HCl could be reduced to 50 ppm with about 80% removal efficiency at the 95% yield, and with about 70% in the case of the unshredded and screened RDF. These levels of control can be achieved with dry-powder injection as distinguished from spray-dry slurry injection systems. This would be highly beneficial in simplifying the acid gas control system and reducing capital and operating costs.

YIELD OF RDF VS ASH CONTENT AND ENERGY LOSS

The yield of RDF resulting from processing must be balanced against the loss of energy and the cost of landfilling the residues. The data give a clear indication of the energy losses, since the heat content and fraction of the heavy and screen rejects are documented both for processing shredded MSW with the RDAC™ only, and processing unshredded MSW with the RDAC™ followed by a ½ in. (1.3 cm) screen.

The comparison is shown in Table 14. As the yield falls, there is a substantial reduction in ash content, and an even more substantial reduction in ash per million Btu (dry basis). The weight of the RDF per million Btu is based on the dry basis HHV for consistency, although the fuel energy loss would be slightly less if it were based on LHV.

TABLE 13 ACID-FORMING ELEMENTS IN THREE RDF'S

RDF TYPE	NITROGEN lb/mm Btu	NITROGEN % Reduction	SULFUR lb/mm Btu	SULFUR % Reduction	CHLORINE lb/mm Btu	CHLORINE % Reduction
CRUDE - Hand Picked + Hammermill + Magnet only - 93% yield *	1.16	-	0.68	-	0.57	-
IMPROVED TYPE A/B - Hammermill + Magnet + RDAC™ (95/05% "split") * 89% yield	0.79	32	0.38	44	0.43	24
IMPROVED TYPE E - RDAC™ + 1/2" Screen * 73% yield	0.45	61	0.25	63	0.25	56

* Yield as % of incoming MSW

The fuel loss increases as the yield decreases, but in all cases the improved RDF's tested yielded more steam per pound of incoming material than did the Crude RDF (see Table 4).

The question is how to balance the loss in fuel yield with the benefits obtained by burning a better fuel, particularly if the fuel must be transported or stored.

OBSERVATIONS OF COMBUSTION

As the Crude RDF burned on the traveling grate, the glass particles in the RDF tended to form clinkers of slag, often associated with metal particles. Clinkers also formed on the walls, and either fell off or were knocked off by the operators. Clinkers frequently were large enough so that they could not fall off the end of the grate into the ash hopper, requiring frequent efforts on the part of the operators to break them up.

The Improved RDF, even at 95% yield, was devoid of the troublesome particles of metal which caused feeding irregularities and stoppages, and the large glass particles which contribute to slagging and clinkering. Photographs of the fuel bed on the stoker confirm the greater uniformity of the ash bed with Improved RDF. The Improved RDF produced significantly more uniform combustion conditions; this makes it possible to burn this material using less excess air, thus permitting the increase of boiler firing rate toward the limit of the available combustion air.

CONCLUSIONS

(a) The boiler produced 3.13 lb of steam per pound of Crude RDF (shredded MSW with 90% of ferrous removed). Fuel energy loss is about 2% of incoming MSW.

(b) The Rotary Drum Air-Classifier easily processed shredded MSW at rates in excess of 40 tons/hr (37 tph), using about 3 kW·h of electricity per ton processed.

(c) The unit experienced difficulty in processing unshredded MSW at 40 tons/hr because the transportable unit used was too small for that purpose. Occasional jams occurred.

(d) When used to air-classify shredded MSW at a 95%/4% "split," the resulting Light Fraction significantly improved boiler performance, as compared with performance when shredded MSW was burned. Combustion was more uniform, and slagging was greatly reduced, even through ash was reduced only from 23% to 20%. The boiler produced 3.52 lb of steam per pound of this product. Fuel energy loss was about 5.5% of incoming MSW. The combustion controls performed more stably with Improved RDF, offering the potential to reduce excess air and to operate the boilers consistently at higher steam output.

(e) When the unit is used to air-classify raw MSW or shear shredded MSW, it appears desirable to install a ½ in (1.3 cm) screen downstream from the air-classifier to screen the Light Fraction. Such screening reduces RDF yield to about 73% by weight, and results in a fuel energy loss of about 11% (based on incoming material), while reducing ash to about 10%. The boiler produced 4.12 lb of steam per pound of this product, in spite of the fact that too much combustion air was used.

(f) Each of the Improved RDF's produced more steam per pound of incoming MSW than was produced by the crude RDF.

TABLE 14 COMPARISON OF YIELD, ASH CONTENT AND FUEL ENERGY LOSS

	CRUDE RDF	AIR-CLASSIFIED CRUDE RDF 95% YIELD	AIR-CLASSIFIED AND SCREENED UNSHREDDED MSW
Yield of RDF as % of Incoming material	93%	89%	73%
Ash content, as produced at 23% moisture	23%	20%	10%
Ash content (dry basis)	30%	26%	12.3%
Lb RDF/mm Btu (dry basis	163	140	121
Lb Ash/mm Btu (dry basis)	49	36	15
Fuel energy loss (HHV)	2% Est.	5.5%	11.1%
Fuel energy of incoming waste in RDF (HHV)	98% Est.	94.5%	88.9%

(g) Processing MSW by Air-Classification and screening removes substantial amounts of acidic elements in municipal refuse, especially nitrogen, sulfur, and chlorine. The nitrogen and sulfur appear to be concentrated in food and yard waste, sulfur and chlorine in the rubber and dense plastics. The RDAC™ alone removed about 30% of these elements, whereas, with downstream screening, about 60% was removed. This degree of removal may reduce stack emissions by about 50%, but not down to the levels required in some localities. On the basis of these test data, to reduce acid gas emissions to 50 ppm of SO_2 and HCl might require 50–70% removal efficiency, which may be achievable with dry powder injection plus a fabric filter. Higher efficiencies, needed to meet more stringent regulations, can be achieved if necessary, with more complex control systems and spray-dryer scrubbers, with or without removing the acidic elements by processing the refuse. NO_x, however, can be reduced by lowering the nitrogen content of the fuel.

(h) The reduction of chlorine in the RDF may reduce high temperature stress corrosion on boiler parts, particularly the superheater tubes; this might permit operating the boiler at high steam temperatures, and thus produce electricity more efficiently.

(i) Air classifying as the first processing step greatly reduces and may virtually eliminate the possibility of explosions in RDF Plants.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the technical assistance and funding provided by the New York State Energy Research and Development Authority. NYSERDA Project Manager, Tom Fiesinger, demanded that we perform extensive hand-sorts, samplings, and laboratory tests well beyond those originally contemplated. These tests resulted in the flow diagram of Fig. 5. We are grateful that Joe Visalli suggested the tests that were conducted at the State Boiler Plant. NYSERDA also arranged for us to utilize a large drying oven, without which these tests would have been impossible.

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Key Words: Acid Gas; Air-Classifier; Chlorine; Ferrous; Fly Ash; Nitrogen; Nonferrous; Rotating Drum; Screening; Slag; Sulfur