OPERATING EXPERIENCE AND ECONOMICS OF A SIMPLIFIED MSW MATERIALS RECOVERY AND FUEL ENHANCEMENT FACILITY

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ABSTRACT

A municipal solid waste materials recovery and fuel enhancement facility has been in operation at the Sumner County (Gallatin, Tennessee) mass burn energy recovery facility for a period of 3 years. During this time the design and operation of the recovery equipment has been refined, providing system operation with high availability and high materials recovery efficiency. The development and engineering techniques used in the refinement process are presented, along with plant operating costs, availability data and separation efficiency test results.

INTRODUCTION

In August 1982 an MSW materials recovery facility began operation in conjunction with an ongoing municipal energy recovery operation. Enhanced fuel from the process is supplied to two mass burn rotary incinerators. The system was installed to investigate the feasibility of simplifying materials recovery processing, but developed into a commercial operation by December, 1983. During a number of months over 95% of the waste received by the energy recovery facility has been processed. The system uses two new separation processes in addition to a previously available eddy current aluminum separation unit.

The principal reason for development of the system was to reduce the capital and operating costs of MSW materials processing. Low cost separation of waste has a number of applications including: *(a)* Mass Burn Facilities—to reduce fuel variability and volume for improved combustion control and efficiency and increased capacity; *(b)* RDF Production—to reduce operating costs; *(c)* Transfer Station Operations—to reduce hauling costs and provide materials recycling; and *(d)* Landfill Operations—to reduce volume requirements and provide materials recycling.

DESIGN CONSIDERATIONS

The separation equipment was designed specifically for solid waste applications by National Recovery Technologies (NRT). NRT is the owner and operator of the Gallatin materials recovery facility. Removal of the metals, glass and other noncombustibles produces an enhanced Btu fuel which is conveyed to the energy recovery facility storage pit. The energy recovery facility is owned and operated by the Sumner County Resource Authority.

The design of the system was approached from the viewpoint that metal, glass and other noncombustible components of waste are readily separable without shredding. Impact shredding before separation pulverizes glass, embedding it in the combustibles. Shredding also tears the metals, entraining combustibles, and making separation more difficult. For energy recovery systems requiring shredding, e.g., fluidized bed units (Ref. [1]), removal of abrasive and heavy metallic components from the waste prior to shredding reduces shredder capital and operating costs.

Significant benefits may be derived from separation of the noncombustible components from municipal waste before energy recovery (Refs. [2–5]), including increased combustion efficiency and system availability with reduced flue gas emissions. These benefits are obtained at the expense of increased capital and operating costs associated with materials recovery. Currently, the energy value of waste is on the order of \$30–\$40 per ton. Testing at the Gallatin energy recovery facility shows an increase of approximately 20% in the combined boiler efficiency and availability (Ref. [6]), producing a revenue increase of approximately \$7.00/ton of waste. Thus, for materials recovery (Gallatin mass burn site) to be economic, net preprocessing costs must be less than this amount. To meet this requirement the materials recovery system was designed to minimize process steps, energy consumption, and combustible loss while maintaining high materials removal efficiency.

The Gallatin system has a processing capacity of 10 TPH (9.1 tph) of raw waste while maintaining 80% removal of ferrous metal and glass and grit with 75% recovery of aluminum beverage containers. A 25–30 TPH (23–27 tph) system is currently under construction and is scheduled for operation in 1986.

PROCESS DESCRIPTION

The materials recovery system utilizes three primary process components and a control system to provide separation of aluminum, ferrous metal and a glass/grit fraction from municipal waste. The system consists of: *(a)* a rotary separator (RFH); *(b)* an electronic/pneumatic aluminum concentrator (ELPAC); *(c)* a pulsed eddy current aluminum separator (PULSORT); and *(d)* a computer control and data acquisition system. A process diagram is shown in Fig. 1. The process components are discussed in detail in Ref. [7]. Power consumption for the process equipment, lighting and exhaust fans is 45 kW. The number of required components was minimized by combining liberation of the bagged waste, mixing, and ferrous and glass/grit removal in the rotary separator. In addition, aluminum concentration is provided by an electronically actuated air jet system. This allows aluminum from the full waste stream to be recovered with a single pulsed eddy current magnet. A microcomputer is used for process control and for acquisition of processing and maintenance information. The maintenance data provided by computer printouts and supplemental operator logs has facilitated an efficient evolution from a proof-of-concept process to a commercial system.

The rotary separator (RFH) is a solid wall cylinder. Rotation speed of the 9.5 × 16 ft (2.9 × 5.9 m) long cylinder is 12.5 rpm. Internal processing is divided into three sections. The input section contains lifters and cutters to open bagged waste and to break glass. This section comprises slightly less than half of the cylinder length. The following section is one quarter the total length. This section contains 14 longitudinal permanent magnet assemblies which attract and lift ferrous components away from the waste layer in the cylinder. Collected ferrous metal is removed from the magnets by an elastic wiper which drops the ferrous onto a vibrating pan conveyor. The conveyor removes the metal from the rotary separator.

The exit section of the cylinder contains 60 longitudinal, 1½ in. (3.8 cm) high elastic lifters which collect material that has migrated to the bottom of the refuse layer due to agitation during transport through the cylinder. The captured material, primarily glass and grit, drops from the lifters near the 10 o'clock position. This heavy fraction passes through a bar screen which covers a vibrating pan conveyor located at the drop point. The screen removes combustibles collected by the lifters and returns them to the cylinder interior. The heavy fraction exits the cylinder via the conveyor. Additional, combustible removal from both the ferrous and glass/grit fractions is provided by two 2 hp air knives located at the conveyor exits. The recovered combustibles are blown back into the fuel fraction.

The remaining material, composed primarily of the combustibles and aluminum present in the input feed, then exits the rotary separator. This material passes over a linear array of 10 metal detectors, each with an adjacent air jet. Aluminum components in the stream trigger the detectors which actuate the appropriate air jet. Residual ferrous metal is identified and ignored by the detectors. The removed aluminum concentrate is funneled onto a collection conveyor by an enclosure which also serves as an exit end dust seal for the rotary separator. The concentrate contains 8–10% aluminum by weight, a 25:1 increase over the 0.3–0.4% content of the raw waste.

The collection conveyor feeds the concentrate to a pulsed, eddy current magnet separator. To reduce power consumption and increase separation efficiency, the magnet is actuated by a metal detector similar to that used by the concentrator system. The magnet generates a sinusoidal magnetic field which induces electrical current flow in metallics (> 95% aluminum) in the feed stream. The force produced by interaction of the generated magnetic field and the induced current flow ejects the aluminum from the concentrate. A slide directs the aluminum to a flattener which also blows the product into a transfer trailer. The concentrate reject (primarily combustible) from the eddy current separator is recombined with the fuel stream and con-

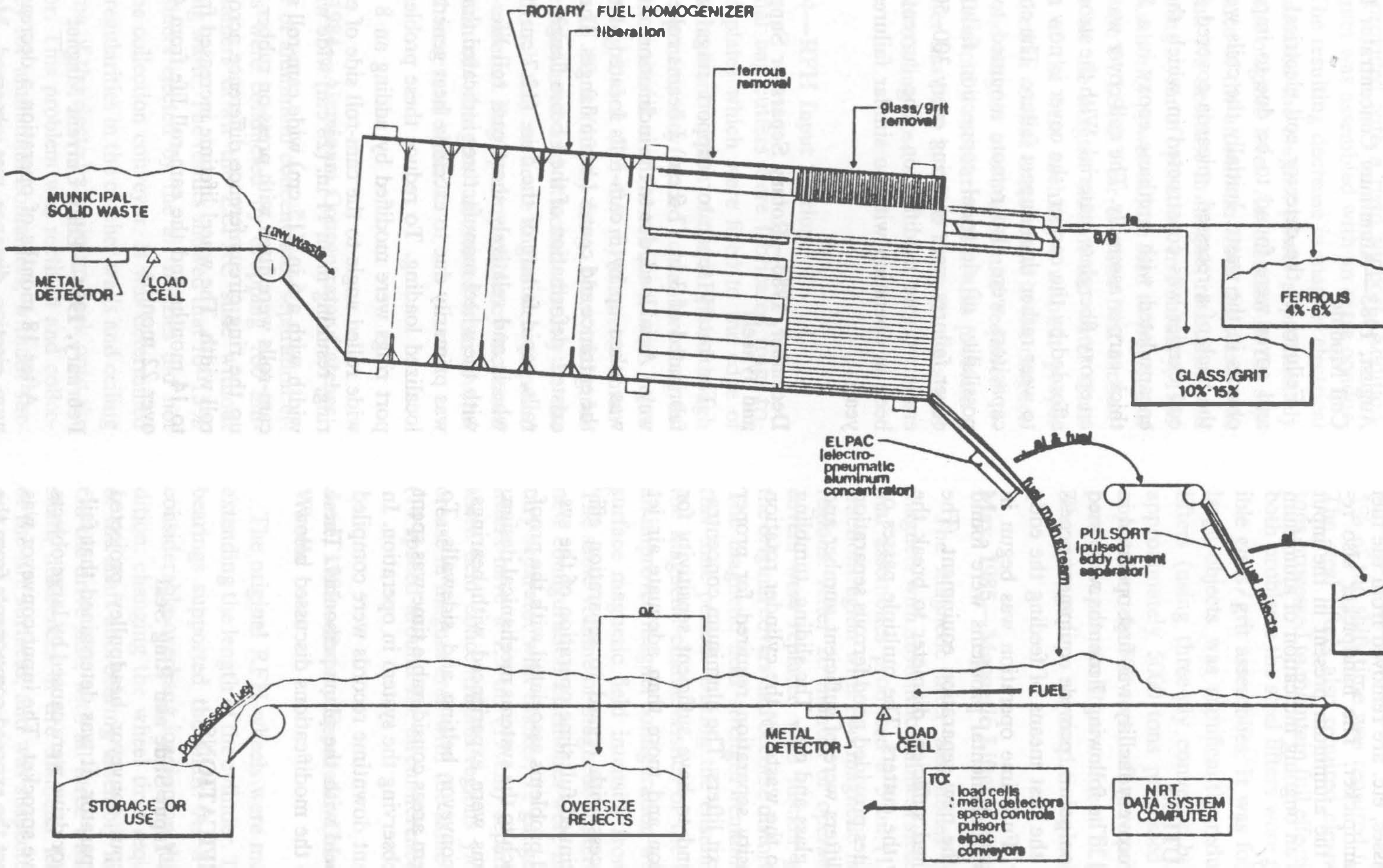


FIG. 1 MATERIALS RECOVERY PROCESS DIAGRAM

veyed to the energy facility storage pit. Bulky material is removed from the fuel conveyor by handpicking.

The concentrate and the main fuel stream are conveyed to a segregated portion of the energy facility storage pit. Bulky objects such as large drums, pallets, metal banding masses, etc. are removed from the fuel conveyor by a handpicker. The handpicker also removes 5–15% of the aluminum present in the input feed and provides an ongoing indication of aluminum recovery efficiency.

SYSTEM EVOLUTION

The materials recovery facility was first operated in December of 1981. The following 7 months were used to finalize transition points, provide equipment access and to determine the best means of feeding the eddy current separator. Full time operation was begun in August 1982. No fundamental problems were found in the design of the new separation equipment. The rotary separator had sufficient diameter to break the glass liberated by the cutters. The multiple passes of the 14 magnetic flites provided good ferrous separation and the exit end lifters were of sufficient number and length to capture glass and dirt. The sliding, tumbling action imparted to the waste by the cylinder rotation provided the density separation required for proper operation of the exit lifters. The aluminum concentration unit was found to have sufficient sensitivity for aluminum detection and more than adequate air jet force.

The initial success with regard to separation efficiency led to continued full time operation of the system. This revealed problems associated with the proof-of-concept approach to the systems mechanical design. Operating problems were experienced with bearings, support wheels, conveyor belting and sidewalls. To identify the problem areas considerable time was spent by the designers observing the system in operation. In addition, equipment downtime records were compiled and discussions held with the plant personnel. These procedures led to the modifications discussed below.

SYSTEM MODIFICATIONS

December, 1982—Input Slide and Ring Seal

Initially the input conveyor headpulley projected into the rotary separator. It was determined that failures of the conveyor drive were caused by large objects impacting the drive sprocket. The input conveyor was shortened to retract the exposed components from the falling waste. This also provided more effective use of the bag breaking front section of the RFH, and allowed inclusion of a metal ring and rubber curtain seal to improve dust containment.

August, 1983—Aluminum Concentrator Detector Coil Module

Failures of the detector coil electrical connections and cover were found to be due to impact by large objects in the waste. Initially the coils were bolted to the back of a recessed, micarda covered slide. A new coil carrier was constructed in which the coils were encapsulated with urethane epoxy in a 2 in. (5 cm) thick carrier assembly. The coil cover was changed to an epoxy-fiberglass material. With the stronger support afforded by the carrier, the cover is now replaced due to wear rather than impact failure. The coil resonance capacitors were also remote mounted to reduce the possibility of electrical connection failures. Coil or cover failures were ocurring every 300–500 hr of operation before modification. The current design has been in operation with no similar failures for over 2 years.

December, 1983—Rotary Separator Support Rings and Wheels

The rotary separator support rings were initially fabricated of 3 in. (7.6 cm) I beams rolled the "hard way." Axial load, due to the inclination of the cylinder, was taken up by 3 cam-rolls located at the edges of the entrance and center I beam flanges. Three problems existed: deformation of the I beam flanges by the cam-rolls, rapid failure of the 5 in. (12.7 cm) wide rubber wheels and relatively short cam roll life. Discussions with the wheel manufacturer indicated that the failure was primarily due to excessive heat generated by high localized loading. To reduce these problems the support rings were modified by adding an 8 in. (20 cm) wide rolled angle to the cam-roll side of each support ring, resulting in an 11 in. (28 cm) wide wheel contact width with a 6 in. (15 cm) wide cam-roll surface. The cam-rolls were fitted with press-on rubber tires to take up the ring circumference difference across the cam-roll width. The wheel lifetime increased from 6 weeks to 14 months and the cam-roll life from 4 months to over 22 months.

February, 1984—Eddy Current Magnet

After 18 months of operation a decrease in aluminum ejection distance was observed. Measurements showed an increase in the magnet electrical resistance. After disassembly and inspection it was found that the electrical supply wires to the magnet were degraded, likely due to vibration induced by pulsed operation of the magnet. To reduce vibration the electrical supply cables were provided with a rigid support. Additionally, the magnet was assembled with an extra conductor strand. The resulting decrease in magnet electrical resistance increased the magnet power approximately 50% above the original level. An increase in the separation distance of the aluminum from the waste was quite apparent. No decrease in magnet resistance was measured during a year of operation. In February, 1985 a Resource Authority power failure lead to freezing of the water in the PULSORT air-to-water heat exchanger which is on the magnet side of the water filter. Replacement of the heat exchanger without proper flushing resulted in residue entrapment in the magnet. As a result the magnet overheated and required replacement. To avoid a reoccurrence of this problem a secondary filter has been installed immediately ahead of the magnet cooling hose.

August, 1984—RFH Input Section

The original bag cutters were fabricated from triangular steel plates which were fixed to the edge of the lifters in the front section of the RFH. Although efficient bag openers, they tended to capture long industrial waste material and intertwine it with other material forming 2–3 ft (0.6–0.9 m) diameter entanglements up to 50 ft (15 m) long. New triangular cutters were fabricated and attached directly to the cylinder wall such that no acute angles were exposed to the waste material. Bag opening efficiency increased while formation of "stringers" decreased from several per shift to 1 in several shifts.

September, 1984—Aluminum Concentrator Catcher

A number of aluminum concentrator separation efficiency tests were conducted by dropping 100 aluminum containers down the ELPAC slide without accompanying waste. The results showed that 10–15% of the containers ejected by the air nozzles did not drop onto the collection conveyor. It was determined that small irregularities in the catcher walls and ceiling deflected some of the ejected aluminum back onto the fuel conveyor. This problem was rectified and collection efficiency for aluminum containers, without surrounding waste, increased to over 95%.

March, 1985—Glass/Grit Lifters

The original glass/grit lifters were constructed of steel angles which would occasionally lift large objects such as wooden pallets and building material into the glass/grit removal system. As a result an average of 5% of the shift time was required to clear such jams. The steel lifters also required cleaning every 50–100 tons processed to maintain full effectiveness. To reduce both problems the steel lifters were replaced with flexible glass/grit assemblies. It was found that lifting of large objects was significantly reduced. The flexible lifters (using three-ply conveyor belt) have a life of approximately 5000 tons processed and can process approximately 500 tons before requiring cleaning (dependent upon moisture content of processed waste). The average time required to replace a lifter is 8 min.

May, 1985—Magnetic Lifter Assembly

The magnetic lifter assemblies utilize permanent magnets with austenitic stainless steel covers. The original assemblies produced a 5 in. (12.7 cm) wide attraction region with two magnetic field concentration regions. After 20 months of operation the assembly covers were replaced with thicker gauge material as the original covers had become distorted due to impact. The magnetic field strength remained constant over this time period. During the ensuing year studies of the magnetic characteristics of the assemblies led to an improved magnet configuration which increased the surface magnetic field intensity from 1.3 to 2.0 kG. The same volume of magnetic material was used. The new configuration assemblies were installed in the rotary separator with thicker, 12 gauge covers. The new lifters have a 7.5 in. (19 cm) separation width with three field concentration regions yielding a 50% increase in magnet area with the same number of lifters (14 spaced around the circumference of the RFH).

June, 1985—Rotary Separator Drive and Support Wheels

The original RFH wheels were mounted on a shaft extending the length of the cylinder. Three pillow block bearings supported the shaft. As a result there was considerable overhang loading on the bearings. In addition, changing the wheel tires required disassembly of the shaft and bearing assembly for the entire side. On the drive side, with all three wheels locked by one shaft, differences in tire diameter led to "scrubbing" of the tire surfaces, and was suspected of causing several shafts to break due to constant torsional flexing.

To remedy these problems individual wheel assemblies were constructed and installed. Each assembly has two bearings which support a single short shaft and wheel. The cylinder is driven from one wheel with an extended shaft and additional bearing mount. Changeout of a wheel can now be accomplished in approximately 15 min, as compared to several hours with the original system.

July, 1985—Aluminum Concentration Unit

A new electronic detector circuit design was developed for the ELPAC unit during the last quarter of 1984 and the first quarter of 1985. The original circuit relied on a fixed time delay between detection and actuation of the air valve which supplied air to the nozzle. As a result only aluminum objects with a velocity between 2 ft (0.6 m) and 4 ft (1.2 m) per second were over the air nozzle during discharge. In addition, testing revealed considerable variation in the 'throw' direction of the aluminum, due to being caught either at the beginning or end of the air discharge interval. The new circuitry employs a microprocessor for each channel which stores a detection 'signature' from which the object velocity is calculated. The air valve delay time and object velocity is then used to determine the proper air valve actuation time. Testing of a prototype system indicates that object speeds in the range of 1 ft (0.3 m) to 10 ft (3.0 m) per second can be accommodated with the new system.

The inclusion of microprocessors in the system also allows the number of aluminum and ferrous objects passing over each channel to be recorded and downloaded to the plant process computer. This will provide continuous indication of the aluminum content of the input waste, the ferrous recovery efficiency, and operation status of the individual detectors. The new system is scheduled to be installed at the Gallatin facility in 1986. From prototype testing it is expected that the ELPAC separation efficiency will increase from 70% to 80% for the current system and from 80% to 90% for the new system.

August, 1985—Glass/Grit and Ferrous Removal System

The original system employed gravity slides to remove the ferrous and glass/grit fraction from the rotary separator. Due to the 6 o'clock to 10 o'clock position of the waste in the rotating cylinder the slides were placed near the down rotation wall of the cylinder. As a result, a significant portion of the glass/grit fraction collected by the lifters fell back into the fuel fraction before reaching the slide. To address this problem, the slide was replaced with a vibrating pan conveyor located near the up rotation wall at the point where the glass/grit fraction drops from the lifters. The ferrous slide was replaced with a vibrating pan conveyor 30% wider than the original slide. The increase in width and vertical clearance reduced the occurance of jams from 5 to 10 times per shift to less than 1 per shift. As improved magnet wiper support, installed with the ferrous conveyor, reduced wiper replacement time from two hours to one-half hour. The exit position of the vibrating conveyors is higher than that of the slides facilitating air knife removal of combustibles in the two fractions.

PROCESS EQUIPMENT AVAILABILITY

The process availability data are taken from computer and shift operator reports kept from the startup of plant operations. The reports record the time for each halt, reason for the halt, tons of waste processed per day, weight of each fraction removed, crane loads fed to the system per day and other information. When conditions require the processing system to be stopped, restart cannot be initiated until the reason for the halt has been entered into the plant control computer. Data from these reports were compiled into the following categories for each halt condition:

(a) Process Equipment
(b) Resource Authority Crane
(c) Other

The Equipment category documents all halts in plant operation due to recovery plant equipment downtime. The plant is operated by a two man crew (per shift) who also perform all repairs and maintenance on the process equipment during shift hours.

The Crane category represents time that feed was not available to the materials recovery plant. Waste is supplied to the materials recovery input conveyor by the Resource Authority crane. Due to the location of the input conveyor only one of the two energy recovery plant cranes can reach the input conveyor hopper. At times this crane is inoperative. In addition, during some periods the materials recovery plant had processed all available raw waste.

The Other category includes all other time during which the system was not processing waste on a production basis. This category includes loss of production due to noncombustible material bins not being available, R & D testing, cleanup, breaks, and power outages.

Availability is defined here as Operating Time/(Operating Time + Equipment Downtime). This fraction is then multiplied by 100 to obtain percentage availability. The materials recovery process availability data for the years from August, 1982 through August, 1985 is tabulated in Fig. 2. Average availability for 1984 was 88%, and through August, 1985, 81%. The equipment availability is graphed in Fig. 3 and summarizes plant operations for 37 months of operation.

The rotary separator initially had the highest average equipment downtime. This was due primarily to drive component problems which have been rectified as discussed previously. Availability of the aluminum separation equipment (eddy current separator and aluminum concentrator) is consistently above 95%. The tabulated downtime for the concentrator unit does not show that for this first year one or more of the 10 channels were at times inoperative while the majority of the system was still in operation. The electronic equipment, including the belt weighing system, detectors, and plant microcomputer exhibit the least downtime of the process equipment. Plant personnel have experienced few difficulties working with the computer and electronic equipment.

PROCESS SEPARATION EFFICIENCY

During the three years of materials recovery system operation a number of tests have been conducted to determine waste composition and separation efficiency. In general it has been found that "grab sample" testing produces results which vary widely from test to test, requiring many tests to establish a believable average. When waste components, such as aluminum, are a small fraction of the total waste stream, grab sample testing is inadequate. At Gallatin, testing for aluminum content is conducted on 2–3 ton (1.8–2.7 t) samples by operating the system at a 5 TPH (4.6 tph) feedrate and handpicking all aluminum missed by the concentrator and eddy current system.

To determine the system separation efficiency a 2 day test was conducted after installation of the glass/grit and ferrous conveyors and air knives. Five tests were conducted, at varying feedrates, with sample weights ranging from 288 lb to 1000 lb (130–453 kg). A total of 3135 lb (1420 kg) of waste was processed. The tests were performed by processing a sample of waste (primarily residential) from the storage pit through the system, and handpicking all the fractions. The processing time was recorded and used along with the total sample weight to determine the feedrate during processing. The system output conveyor was hand operated to retain the fuel fraction for handsorting. All system components and collection containers were cleaned before each test to avoid inaccuracy from residual waste.

Each system output fraction was handsorted into: *(a)* combustibles (paper, plastic, wood, textiles, etc.; *(b)* wet organics; *(c)* ferrous metal; *(d)* glass; *(e)* −¼ in. (0.6 cm) fines; and *(f)* aluminum. The handsorting procedure was to first remove and record the weight of large paper and other combustibles from each fraction. This facilitated the remaining sorting. Each fraction was then sorted until the remaining material was approximately 1 in. (2.5 cm) or less in size. The minus 1 in. (2.5 cm) material was then coned and quartered and a representative sample taken which comprised at least 10% of the total fraction. This separated fraction was then hand-sorted into the above listed categories and weighed. The content of the full fraction was then projected from the content of sample fraction. This procedure allows hand-sorting of much larger samples than would otherwise be possible. Totals from each sort were then added to obtain the overall percentage of each category for each of the fractions.

For fractions with relatively few components, e.g., ferrous metal, the sample was sorted down to the −¼ in. (0.6 cm) fines. In these samples the relatively small number of total particles precluded accurate composition projection from a portion of the sample, and little sorting time would have been saved. In general, a selected sample from a fraction should contain at least several hundred particles to provide an accurate projection for the total fraction.

The test results are tabulated in Fig. 4. Two tests were run at the 7.7 TPH (7 tph) feedrate and the results averaged; the recovery efficiency for the ferrous and glass/grit fraction were within 8% for the two tests. The design feedrate of the system is 7.5 TPH (6.8 tph), but testing shows 80% separation efficiency for ferrous metal up to 11 TPH (10 tph) and 80% glass/grit removal up to 14 TPH (12.7 tph), and in operation the system is normally run at 12.5 TPH (11.4 tph). During the test the combined glass and fines stream was passed through the air knife. Most of the fines were returned to the fuel fraction by the action of the air knife. Samples of the fuel and glass/grit fines were dried and burned using the ASTM method E-955. It was found that the fines were 80% noncombustible with a 20% moisture content. As a result of this testing, a modification of the glass/grit conveyor is planned which will allow the fines to bypass the air knife.

	Hours	Tons	HOURS OFF-LINE						Equipment
Month	Feed	Thru	RFH	Convyrs	Pulsort	Elpac	Other	Crane	Avalablty
AUG82	124.6	1022	46.9	7.8	0.0	0.0	29.7	1.1	69.5%
SEP82	126.3	1985	56.0	15.5	0.0	0.0	43.7	18.5	63.9%
OCT82	199.0	2021	26.6	31.6	0.0	0.0	42.6	26.3	77.4%
NOV82	155.3	1753	21.0	81.6	0.0	0.0	27.0	6.6	60.2%
DEC82	61.3	804	10.8	3.6	0.0	0.0	13.3	9.2	81.0%
JAN83	103.5	1676	38.6	25.7	0.0	0.0	58.0	2.9	61.7%
FEB83	98.8	1004	74.5	15.5	0.0	0.3	32.6	30.1	52.3%
MAR83	104.6	1474	11.3	16.7	0.0	0.0	59.7	42.0	78.9%
APR83	120.4	1866	26.0	19.2	0.0	0.0	39.0	24.6	72.8%
MAY83	192.7	3300	57.6	8.5	0.1	0.0	22.8	27.9	74.4%
JUN83	189.7	2874	50.9	2.9	0.4	0.0	19.8	53.4	77.8%
JUL83	185.9	2145	65.5	3.9	0.0	0.5	46.0	19.2	72.7%
AUG83	215.4	2619	23.0	12.1	0.0	0.0	36.3	39.5	86.0%
SEP83	87.2	1022	18.7	2.8	0.0	0.3	17.7	192.6	80.0%
OCT83	System off line for testing & negotiations								
NOV83		"		"	"	"			
DEC83	145.4	1508	28.7	8.6	2.2	0.0	29.4	19.4	78.6%
JAN84	155.8	2070	15.9	0.6	0.0	0.4	23.1	83.1	90.2%
FEB84	172.1	2020	28.0	3.9	8.0	0.0	43.6	54.7	81.2%
MAR84	259.6	3500	36.2	6.0	0.0	0.0	11.7	71.9	86.0%
APR84	232.5	3023	45.4	11.4	0.0	1.4	16.6	68.1	80.0%
MAY84	268.6	3677	15.0	4.2	0.0	0.0	18.5	38.0	93.3%
JUN84	165.1	1345	15.1	7.4	0.0	0.0	13.4	86.1	88.0%
JUL84	151.0	1666	23.6	4.6	0.0	0.0	24.5	137.1	84.3%
AUG84	276.6	3231	9.9	8.6	0.0	0.1	30.9	55.6	93.7%
SEP84	114.4	1348	6.3	17.4	0.0	0.0	13.3	96.0	82.8%
OCT84	111.8	1274	5.2	6.3	0.0	0.0	136.9	60.4	90.7%
NOV84	116.3	1338	11.2	2.9	0.0	0.0	20.7	152.5	89.2%
DEC84	115.4	1351	7.9	0.1	0.0	0.0	18.1	142.0	93.5%
JAN85	155.3	1781	14.5	2.8	0.0	0.1	35.7	114.0	89.9%
FEB85	168.9	1928	42.6	6.0	8.0	0.0	22.6	76.0	74.9%
MAR85	128.8	1291	38.3	1.3	0.0	0.2	24.4	147.0	76.4%
APR85	227.4	1990	18.5	0.0	0.0	0.0	26.1	87.3	92.5%
MAY85	94.4	934	45.5	0.0	0.0	0.0	142.5*	25.8	67.5%
JUN85	177.1	1846	20.0	9.7	0.0	0.0	73.1*	23.9	85.6%
JUL85	38.9	416	2.1	0.0	0.0	0.0	167.9*	87.6	94.9%
AUG85	45.0	401	0.0	2.5	0.0	0.0	79.3*	210.0	94.7%
TOTALS	5285	63503	957.0	351.5	18.7	3.2	1460.4	2330.2	

* DOE MODIFICATIONS

FIG. 2 NRT MATERIALS RECOVERY SYSTEM AVAILABILITY SUMMARY
(August, 1982 Through August, 1985)

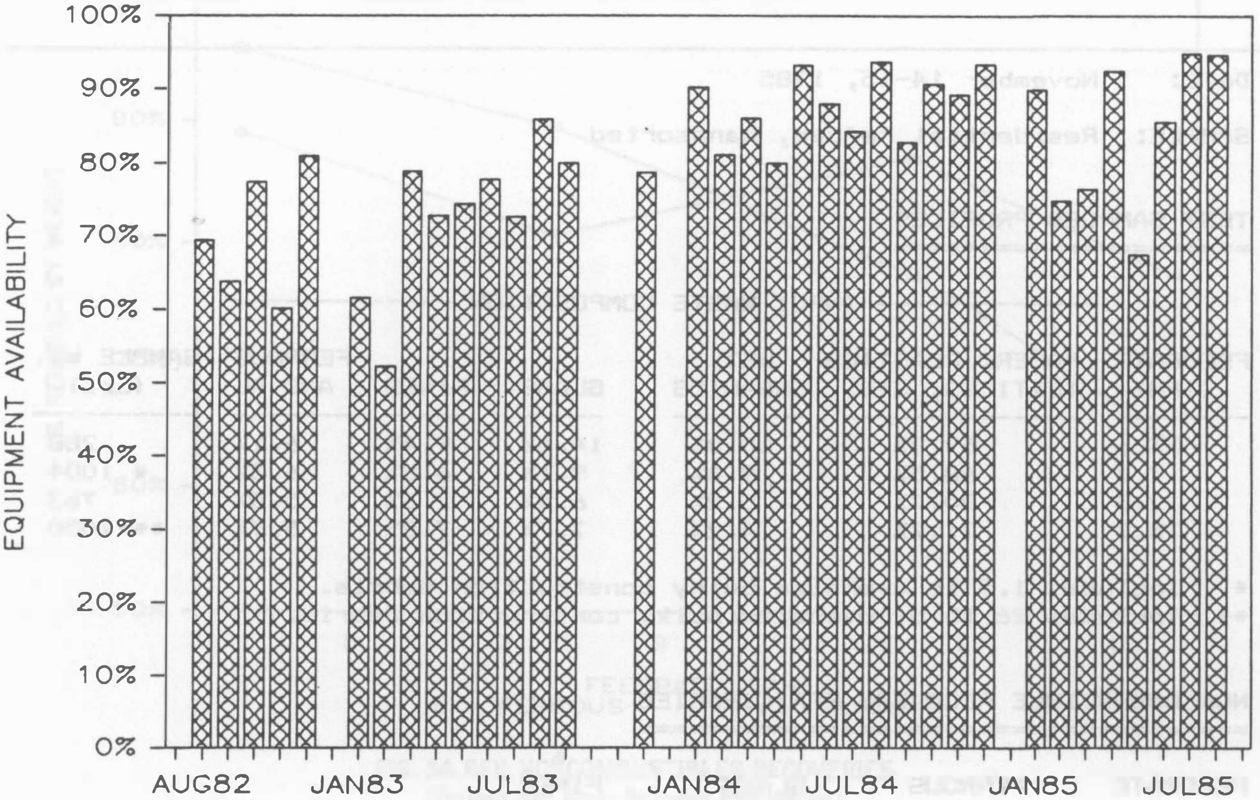


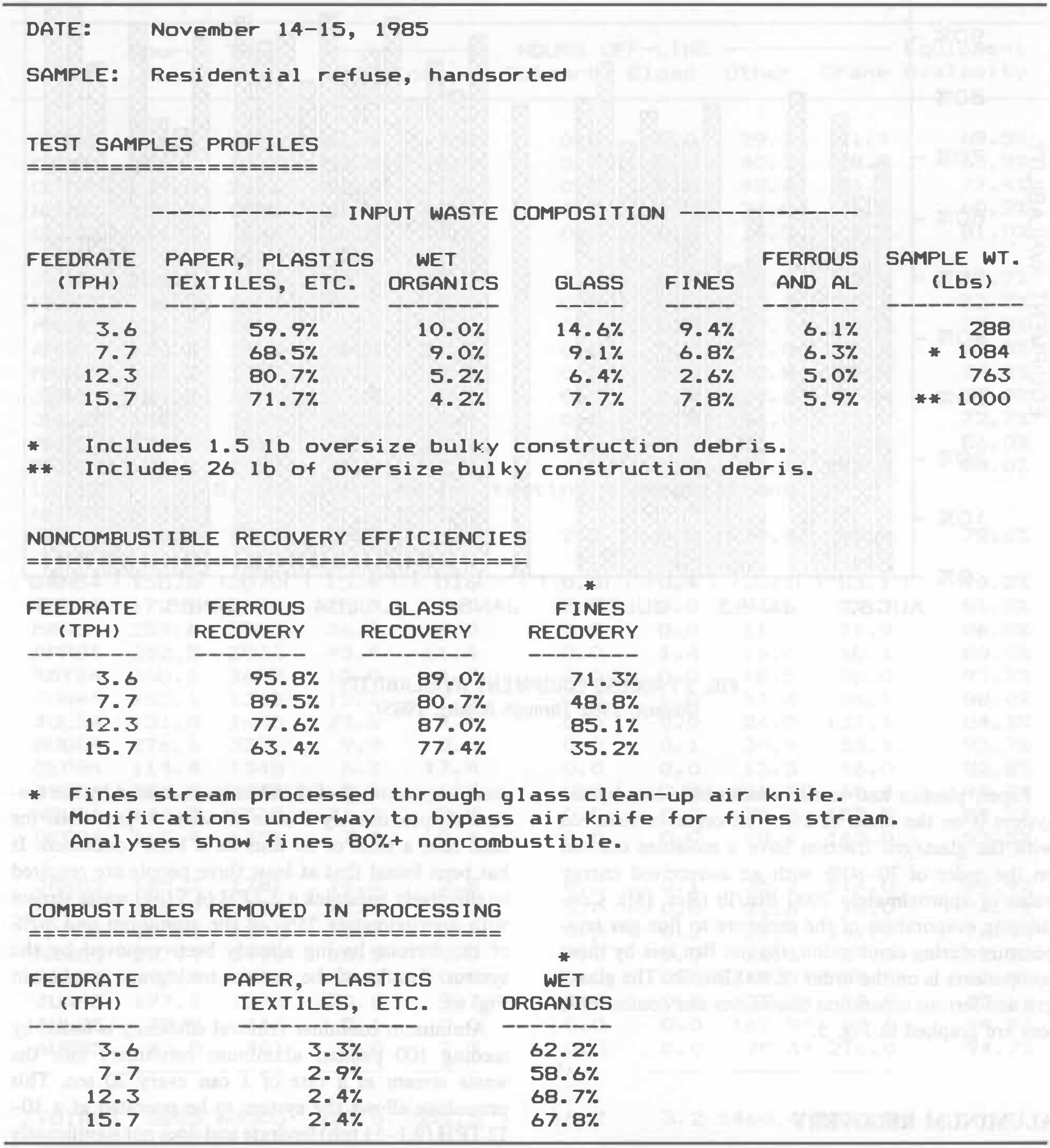
FIG. 3 PROCESS EQUIPMENT AVAILABILITY
(August, 1982 Through August, 1985)

Paper, plastics and textile combustible loss by the system is on the order of 3%. The organics removed with the glass/grit fraction have a moisture content on the order of 70–80% with an as-received energy value of approximately 2000 Btu/lb (Ref. [8]). Considering evaporation of the moisture to flue gas temperature during combustion, the net Btu loss by these components is on the order of 800 Btu/lb. The glass/grit and ferrous separation efficiencies and combustible loss are graphed in Fig. 5.

ALUMINUM RECOVERY

Aluminum beverage container recovery for the Gallatin facility has averaged 76% from mid-1983 through August, 1985. The data was obtained from testing and is consistent with aluminum sold per ton of waste processed. Aluminum container content is tracked by handpicking the aluminum remaining in the fuel stream after processing (as discussed previously). The system is operated at the reduced feedrate to allow complete recovery of the aluminum missed by the system. Approximately 5 tons of waste is processed for each test; a total of 60 tests have been conducted. It has been found that at least three people are required to effectively handpick a 5 TPH (4.5 tph) waste stream with approximately 75% of the aluminum and 90% of the ferrous having already been removed by the system. Results of the content testing are graphed in Fig. 6a.

Aluminum container removal efficiency is tested by seeding 100 painted aluminum containers into the waste stream at a rate of 1 can every 20 sec. This procedure allows the system to be operated at a 10–12 TPH (9.1–11 tph) feedrate and does not significantly alter the average aluminum content of the waste. The tagged (painted) aluminum containers recovered by the system are then separated from the other aluminum removed by the system and counted. The results of the recovery testing are graphed in Fig. 6b. The graph includes the 5–10% aluminum removed by the handpicker. The primary function of the handpicker is to remove bulky materials from the fuel conveyor.



DATE: November 14-15, 1985

SAMPLE: Residential refuse, handsorted

TEST SAMPLES PROFILES

INPUT WASTE COMPOSITION

FEEDRATE (TPH)	PAPER, PLASTICS TEXTILES, ETC.	WET ORGANICS	GLASS	FINES	FERROUS AND AL	SAMPLE WT. (Lbs)
3.6	59.9%	10.0%	14.6%	9.4%	6.1%	288
7.7	68.5%	9.0%	9.1%	6.8%	6.3%	* 1084
12.3	80.7%	5.2%	6.4%	2.6%	5.0%	763
15.7	71.7%	4.2%	7.7%	7.8%	5.9%	** 1000

* Includes 1.5 lb oversize bulky construction debris.
** Includes 26 lb of oversize bulky construction debris.

NONCOMBUSTIBLE RECOVERY EFFICIENCIES

FEEDRATE (TPH)	FERROUS RECOVERY	GLASS RECOVERY	* FINES RECOVERY
3.6	95.8%	89.0%	71.3%
7.7	89.5%	80.7%	48.8%
12.3	77.6%	87.0%	85.1%
15.7	63.4%	77.4%	35.2%

* Fines stream processed through glass clean-up air knife. Modifications underway to bypass air knife for fines stream. Analyses show fines 80%+ noncombustible.

COMBUSTIBLES REMOVED IN PROCESSING

FEEDRATE (TPH)	PAPER, PLASTICS TEXTILES, ETC.	* WET ORGANICS
3.6	3.3%	62.2%
7.7	2.9%	58.6%
12.3	2.4%	68.7%
15.7	2.4%	67.8%

* Wet organics are high moisture/low BTU food waste present in the glass stream. Further processing of this stream can return these to the fuel fraction if desired.

FIG. 4 ROTARY FUEL HOMOGENIZER RECOVERY EFFICIENCIES TESTING

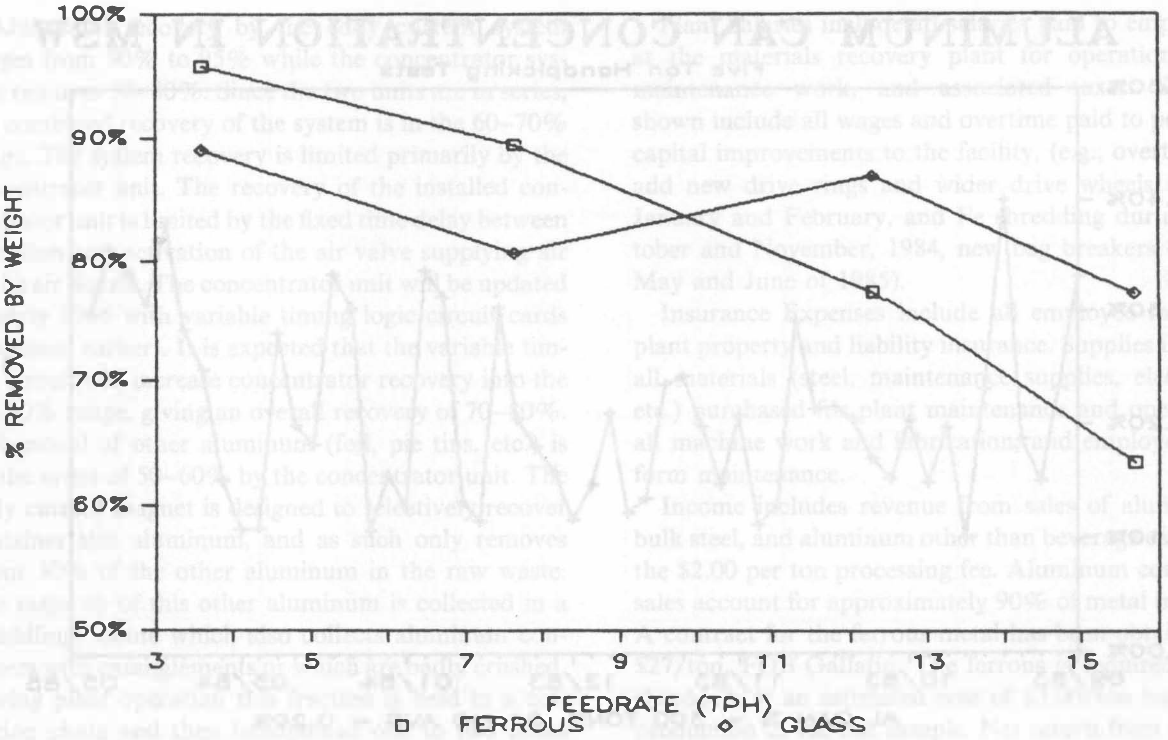


FIG. 5A RFH NONCOMBUSTIBLES RECOVERIES
(Ferrous and Glass Removal Efficiencies)

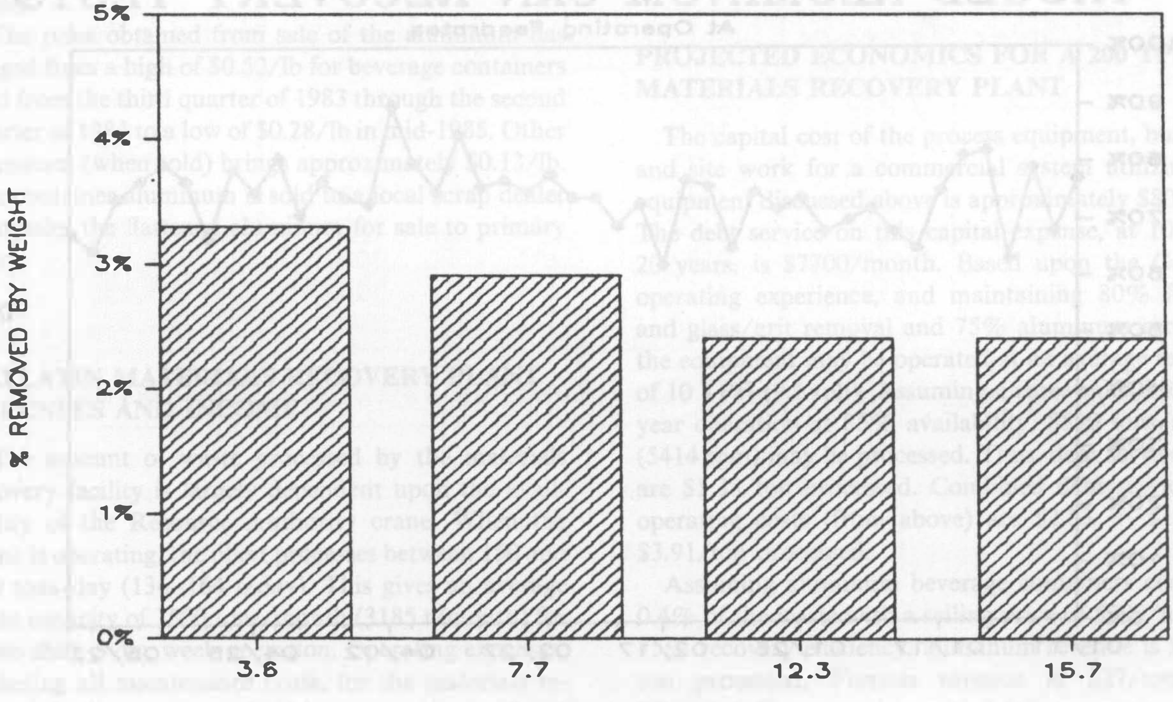


FIG. 5B RFH COMBUSTIBLE LOSS
(Paper, Plastics, Textiles, Wood, etc.)

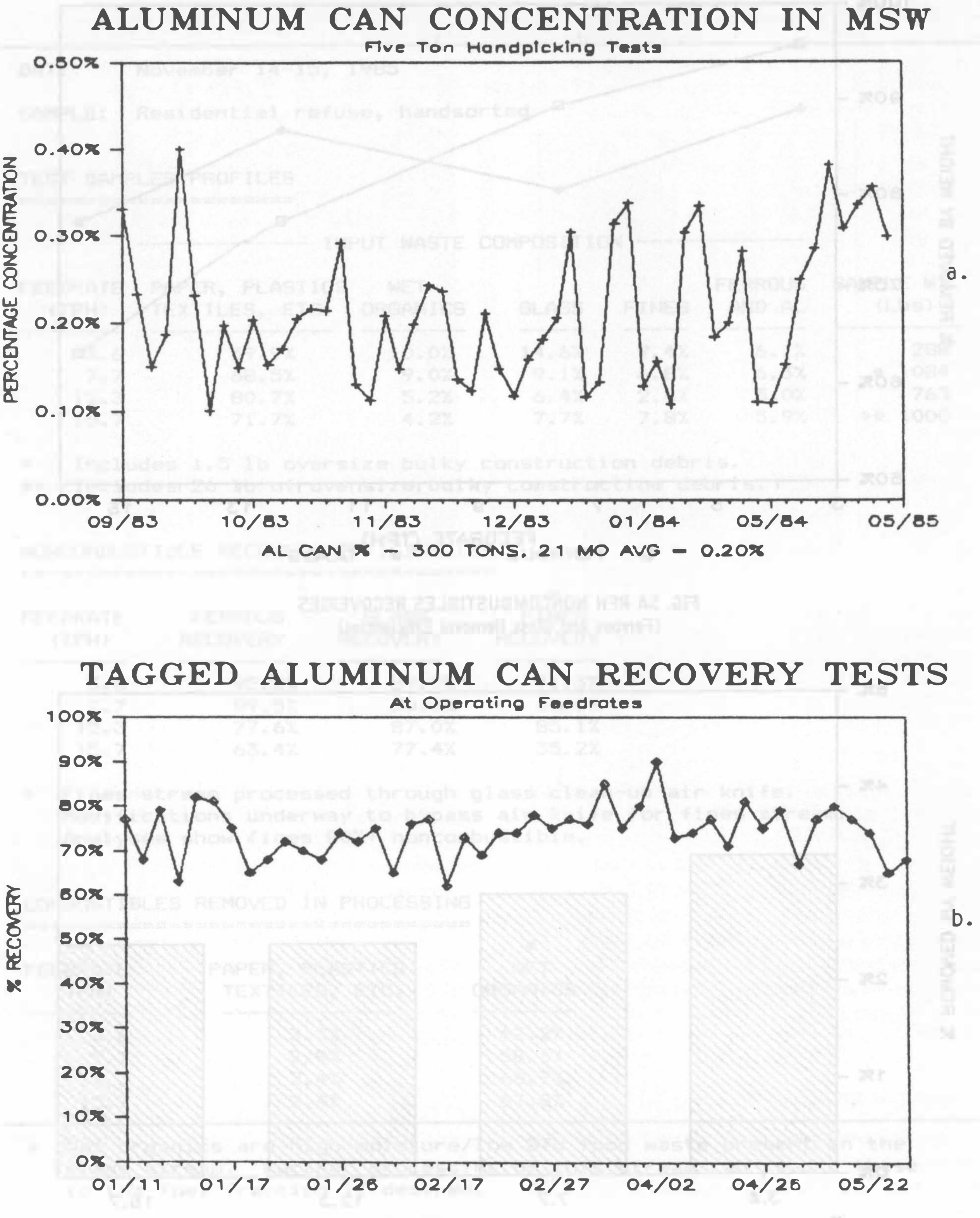

ALUMINUM CAN CONCENTRATION IN MSW
Five Ton Handpicking Tests
PERCENTAGE CONCENTRATION
0.50%
0.40%
0.30%
0.20%
0.10%
0.00%
09/83
10/83
11/83
12/83
01/84
05/84
05/85
AL CAN % - 300 TONS, 21 MO AVG - 0.20%
a.
TAGGED ALUMINUM CAN RECOVERY TESTS
At Operating Feedrates
% RECOVERY
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
01/11
01/17
01/26
02/17
02/27
04/02
04/26
05/22
b.

FIGURE 6

Aluminum recovery by the eddy current system ranges from 90% to 95% while the concentrator system removes 70–80%. Since the two units are in series, the combined recovery of the system is in the 60–70% range. The system recovery is limited primarily by the concentrator unit. The recovery of the installed concentrator unit is limited by the fixed time delay between detection and activation of the air valve supplying air to the air nozzle. The concentrator unit will be updated in early 1986 with variable timing logic circuit cards (discussed earlier). It is expected that the variable timing circuit will increase concentrator recovery into the 80–90% range, giving an overall recovery of 70–80%.

Removal of other aluminum (foil, pie tins, etc.) is on the order of 50–60% by the concentrator unit. The eddy current magnet is designed to selectively recover container size aluminum, and as such only removes about 30% of the other aluminum in the raw waste. The majority of this other aluminum is collected in a "middling" chute which also collects aluminum containers with entanglements or which are badly crushed. During plant operation this fraction is held in a collection chute and then handpicked one to two times per hour to remove contaminates from the aluminum containers. The "product" aluminum is carried directly, by chute, from the eddy current magnet to a flattener which also blows the aluminum into a transfer trailer.

The price obtained from sale of the aluminum has ranged from a high of $0.52/lb for beverage containers paid from the third quarter of 1983 through the second quarter of 1984 to a low of $0.28/lb in mid-1985. Other aluminum (when sold) brings approximately $0.13/lb. The container aluminum is sold to a local scrap dealer who bales the flattened aluminum for sale to primary users.

GALLATIN MATERIALS RECOVERY PLANT EXPENSES AND INCOME

The amount of waste processed by the materials recovery facility is largely dependent upon the availability of the Resource Authority crane. When the crane is operating, the plant processes between 150 and 180 tons/day (136–164 t/day). This gives an average plant capacity of 3500 tons/month (3185 t/month) for a two shift, 5 day week operation. Operating expenses, including all maintenance costs, for the materials recovery facility averages $8850 per month or $2.53/ton. The Gallatin Materials Recovery Facility O & M costs and metal and processing revenues are given in Fig. 7.

Plant Salaries include all salaries paid to employees at the materials recovery plant for operations and maintenance work, and associated taxes. Salaries shown include all wages and overtime paid to perform capital improvements to the facility, (e.g., overtime to add new drive rings and wider drive wheels during January and February, and Fe shredding during October and November, 1984, new bag breakers during May and June of 1985).

Insurance Expenses include all employee medical, plant property and liability insurance. Supplies include all materials (steel, maintenance supplies, electrical, etc.) purchased for plant maintenance and operation, all machine work and fabrication, and employee uniform maintenance.

Income includes revenue from sales of aluminum, bulk steel, and aluminum other than beverage cans and the $2.00 per ton processing fee. Aluminum container sales account for approximately 90% of metal income. A contract for the ferrous metal has been obtained at $27/ton, FOB Gallatin. The ferrous is required to be shredded; at an estimated cost of $3.00/ton based on production of the test sample. Net return from sale of the shredded ferrous product is projected to provide a potential net revenue increase of $3200/month. Revenue from ferrous sales shown in Fig. 7 includes only sales of bulky steel at $1.00/ton.

PROJECTED ECONOMICS FOR A 200 TPD MATERIALS RECOVERY PLANT

The capital cost of the process equipment, building, and site work for a commercial system utilizing the equipment discussed above is approximately $800,000. The debt service on this capital expense, at 10% for 20 years, is $7700/month. Based upon the Gallatin operating experience, and maintaining 80% ferrous and glass/grit removal and 75% aluminum recovery, the equipment may be operated at an average feedrate of 10 TPH (9.1 tph). Assuming a three shift, 350 day/year operation at 85% availability, 5590 tons/month (5414 tpm) may be processed. Thus, debt service costs are $1.38/ton processed. Combined debt service and operating costs (from above) are $2.53 + $1.38 or $3.91/ton processed.

Assuming aluminum beverage containers comprise 0.4% of the waste with a selling price of $700/ton and 75% recovery efficiency, aluminum revenue is $2.10/ton processed. Ferrous revenue at $27/ton, less $3.00/ton for processing, with 5.0% content and 80% recovery is $0.96/ton processed. Hauling costs for the metal are included in the price paid per ton. Glass/grit hauling may be an additional cost if the system is

	EXPENSES					INCOME
Month	Salaries	Insurance	Supplies	Utilities	Accounting	Metal + Processing
Jan 84	7047	454	3953	530	300	12,406
Feb 84	3991	455	2983	661	300	11,850
Mar 84	6377	468	1235	596	300	11,905
Apr 84	6457	424	2270	596	300	13,217
May 84	6007	424	1808	612	300	12,768
Jun 84	6046	341	1461	558	300	13,290
Jul 84	6454	374	2089	558	300	12,801
Aug 84	5833	374	1110	564	300	10,180
Sep 84	5432	462	1548	605	300	11,362
Oct 84	5815	401	245	427	300	9,556
Nov 84	5620	401	1212	464	300	10,609
Dec 84	5348	401	762	430	300	11,789
1984 Totals	70,427	4,979	20,678	6,601	3,600	141,210

Total 1984 Plant Expenses..........$106,285

Total 1984 Operating Profit.......$ 34,925

Month	Salaries	Insurance	Supplies	Utilities	Accounting	Metal + Processing
Jan 85	5822	385	1322	350	300	9,862
Feb 85	6102	385	1083	545	300	10,640
Mar 85	5792	385	1279	418	300	8,083
Apr 85	4881	385	832	461	300	13,732
May 85	6088	385	1100	482	300	9,284
Jun 85	5183	385	2233	436	300	9,269
Jul 85	5756	385	1064	434	300	10,638
Aug 85	5187	398	1480	360	300	10,040
1985 Totals	44,811	3,093	10,393	3,486	2,400	72,548

Sub Total 1985 Plant Expenses.......$64,183

Sub Total 1985 Operating Profit...$ 8,365

Price obtained for aluminum beverage containers was a high of $0.52 per pound in 1984. During late 1984 and through 1985 price averaged $0.35 per pound.

FIG. 7 MATERIALS RECOVERY SYSTEM OPERATING AND MAINTENANCE COSTS
(All Plant O & M Costs are Included, Debt Service not Included)

67,000 tons per year processed
3 shifts, 350 days/yr, 10 TPH, 85% availability

INCOME		
Aluminum Sales	(0.4%, 75% recovery, $700/ton)	140,700
Ferrous Sales	(5.0%, 80% recovery, $24/ton)	64,300
Increased Energy Production Efficiency	(9.5%)	183,300
Increased Energy Production Availability	(10%)	193,000
	TOTAL ANNUAL INCOME	$581,300
EXPENSES		
Salaries		120,700
Insurance		6,700
Supplies		26,800
Utilities		10,100
Accounting		5,400
Debt service	$800,000 @ 10% for 20 years	92,400
	TOTAL ANNUAL EXPENSES	$262,100
	NET ANNUAL PROFIT	$319,200

NOTES:

1) Energy production based upon 3 lbs-steam per lb of raw waste, an energy value of $36.00 per ton of raw waste and 80% of increased steam sold.

2) Credit for energy plant increased tipping revenue is not included.

3) Combustible loss is included in increased energy production percentage.

4) Capital cost assumes utilization of energy facility storage and feeding capacity (crane or front-end loaders).

5) Ferrous revenue includes $3.00 per ferrous ton shredding costs.

6) Supplies includes all maintenance item costs.

FIG. 8 PROJECTED MATERIALS RECOVERY FACILITY ECONOMICS
(Operation in Conjunction With an Energy Recovery Facility)

not operated in conjunction with an energy recovery facility where this component would otherwise be hauled as ash.

Thus, the net operating costs, after revenue, with debt service, for a materials recovery facility with the above assumptions, are \$4752/month for 5590 tons processed, or \$0.85/ton. With no other income (reduced landfill cost credit, transfer station, or energy production increases), an aluminum beverage container content of 0.56% would be required for break-even operation at \$0.35/lb aluminum selling price.

Operation of the materials recovery facility in conjunction with the Gallatin energy recovery facility provides increased availability, disposal capacity and steam production rate for the energy facility (Ref. [9]). An increase in energy production of approximately 20% has been measured; this is due to the combined effects of increased availability and steaming rate with processed fuel. This figure includes combustible loss from materials recovery processing. With an energy value of \$36.00/ton of waste (\$6.00/1000 lb steam, 3 lb/steam/lb waste), the value of this increase averages \$7.20/ton of waste. If 80% of the additional energy is sold, a revenue increase of \$5.76 is obtained per ton of waste processed and combusted.

For the case where a materials recovery facility is operated in conjunction with a mass burn facility similar to Gallatin, and with the above assumptions, a net per ton profit of \$4.91 (\$5.76−\$0.85) is derived from the combined operation. Tipping fee revenue from increased capacity and reduced maintenance costs provide an additional benefit (15% increased disposal capacity, reduced abrasive content of fuel). These financial projections for a combined materials and energy recovery facility are summarized in Fig. 8.

The capital cost of the materials recovery facility is approximately \$4000/ton/day of capacity while energy recovery facility capital costs are on the order of \$50,000–\$80,000/ton/day of capacity. Construction of a materials recovery facility in conjunction with a mass burn facility would reduce the required capacity of the mass burn plant by 15–20% due to removal of the metals and glass/grit from the raw waste. A 5–8% savings in capital cost of the energy plant, due to reduced capacity requirement, would offset the capital cost of the materials recovery plant. For the case where the capital cost is offset and with metal sales of aluminum only (at \$2.00/processed ton), a benefit of \$0.53/ton to the energy recovery facility would be required for break-even operation of the materials facility. The revenue benefit is to be derived from availability and efficiency increases and maintenance cost decreases for energy recovery operations. At Gallatin, this revenue could be obtained solely from the measured reduction in ash drag maintenance costs (Ref. [9]).

CONCLUSIONS

The separation efficiencies, operating costs, and process description have been presented for an operating municipal waste materials recovery facility. The facility can process 10 TPH (9.1 tph) of municipal solid waste with glass/grit removal and ferrous recovery of at least 80% and aluminum recovery efficiency of 75% with 85% operation availability. Combustible loss for the system is on the order of 3% with operating costs of \$2.50/processed ton of waste. Power consumption for the plant is less than 50 kW. Capital cost of the facility is approximately \$4000/ton/day of capacity.

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Key Words: Aluminum; Concentration; Magnet; Materials Recovery; Nonferrous; Refuse Derived Finel; Rotary Drum; Separating