tions are made by actually sampling the flue gas in a scientific manner, filtering the dust from the sampling stream, drying and weighing the dust, and comparing the dust weight with the weight or volume of gas flowing. Correction is made to a constant excess air content of the stack gases, so that the comparison with a standard or results from other plants would be on the same basis and thus meaningful. For this purpose the flue gas is analyzed for the volumetric proportions of the principal gases.

The example dust loading may be expressed in several equivalent ways:

Lb per ton of refuse charged	=	3.0 lb
Lb per 1,000 lb actual flue gas corrected to 50% excess air	=	0.270
Grains per cu ft of actual flue gas at 50% excess air, 68 F, 29.92 in. Hg	=	0.139
Milligrams per cubic meter at 0 deg C, 760 mm Hg and 7.0 percent CO_2	=	211

U.S. dust emissions standards range from 0.85 to 0.20 lb per 1,000 lb of flue gas at 50 percent excess air. The standard applicable throughout West Germany is 150 mg per standard cubic meter, which is equivalent to 0.192 lb per 1,000 lb of flue gas at 50 percent excess air, or 0.099 grains per cubic foot. To meet the West German standard, the example incinerator would have to have a dust emission of 2.13 lb per ton of refuse.

The more restrictive new U.S. and European standards can be met by the use of electrostatic precipitators, gas scrubbers, and bag filters of high efficiency. Such equipment has been in industrial use for years. Gas scrubbers have been applied to several large incinerators. It is expected that electrostatic precipitators will soon be installed on incinerators in this country.

European Incinerator Art

In Europe under conditions of high fuels costs, lower labor costs, and a high technological level of construction and plant operation, as well as the desire to conserve land area, the incinerator art has flourished since 1962. The objective of reducing refuse to minimum volume has been combined with the desires for heat economy and low air pollution. The combination is mutually assisting. As a member of the U.S. Study Team of June-July, 1967, led by Mr. Leo Weaver, Chief of the Solid Wastes Program, Public Health Service, it was my privilege to see several of these plants. Descriptions and technical information are also available in several excellent papers published by the American Society of Mechanical Engineers in the proceedings of the 1964 and 1966 National Incinerator Conferences.

These new-type refuse reduction plants consist of refuse receiving pits, cranes with grapples to elevate the refuse to hoppers, stoker-fired boilers, electrostatic precipitators to trap the flue dust, and chimneys 260 to 390 feet high.

Because of the water-tubed furnaces, the refuse can be burned with 1.6 times the stoichiometric air, instead of 3 times as in U.S. practice; the weight and volume of flue gas to be cleaned is reduced considerably. The cooling of the gases to 500 to 600 F in the boiler-superheater-economizer contracts the gas volume without the addition of spray water. The electrostatic precipitators, although large, are half the volume that would be required without the boiler.[8] The precipitators are guaranteed at 98 to 99 percent collection efficiency, with test results exceeding guarantees. Finally, the gases are dispersed from high chimneys.

The steam generated is used for the production of electric power and for district heating, in conjunction with the local electric utility. For district heating, high-pressure hot water can also be produced for circulation through mains. U.S. refuse is lower in moisture and ash, higher in calorific value, and hence capable of generating more steam per ton of refuse.

American Incinerator Art

The U.S. incinerator art is on the threshold of a rapid evolution to meet rising requirements for capacity to consume refuse, better plant appearance, low emission of odor and air pollutants, minimum putrescibles in the residue, and less effluent water. The possibilities for steam and power generation from refuse are being restudied. The disposal of incinerator residue, salvage of metals, and utilization of residue are also under investigation. The plants will be more highly engineered, and will require better control and operating personnel to match. Close engineering ties are maintained with European progress.

The burning of oversized burnable waste with or without prior shredding is being developed. Trees, furniture, pallets, mattresses, truck and auto tires, and demolition lumber reduce to even less final residue volume than does the equivalent weight of normal refuse.

A major stimulation is the Solid Wastes Program of the Public Health Service. Through research and demonstration grants, conferences, educational and field efforts, and allied activities, new advances and trained personnel are resulting.

As public officials and the general public become aware of the long-range implications and opportunities of waste management programs, larger capital investments will become available for incineration plants and allied facilities. The regional approach to waste disposal will lead to larger and better incinerators. Engineers look forward to the opportunity to design plants which are in the long-range interest of the public, rather than to satisfy minimum first cost. The total annual cost of refuse incineration will thereby not exceed about $6 per inhabitant served.

Destructive Distillation and Gasification of Refuse

Experimentation here and abroad indicates that the organic matter in municipal refuse can be converted to gaseous, liquid and solid products by heating to 1,300 to 1,500 F out of contact with air. After the distillation of the moisture, the organic matter is converted to roughly equal weight percentages of water vapor, gases, liquids and char.

In descending order of volumes, the fixed gases are mainly CO_2, CO, CH_4 plus higher hydrocarbons, hydrogen, and nitrogen. The liquids range from alcohols to tars. The char is primarily carbon and ash.[9]

Refuse can also be gasified in a deep bed gas producer supplied by air at less than half the stoichiometric combustion requirement.

Pilot-scale work is in progress to determine yields and costs. It is too early for predictions of the outcome. However, as a method of reducing waste, the residue would require the same landfill space as the residue from incineration.

Acknowledgment

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RECYCLING AND UTILIZATION

C. I. Harding *

MOST RECYCLING and utilization schemes involve some type of salvage and composting. A working definition of refuse composting is "the aerobic, thermophilic degradation of putrescible material in refuse by micro-organisms." There is no clear definition at this time of when a material becomes "compost" nor is there any general agreement upon the composition of the material which is referred to as compost. Operationally, the stabilized refuse or compost should not go anaerobic during storage either in bags or in bulk. With this crude criterion for what constitutes refuse compost we can examine the bases for the various composting systems available today.

Anaerobic decomposition of waste materials has been practiced to produce soil additives in Asia for centuries. Aerobic composting has been practiced in Europe since the 1920's and 1930's but the European practices are not directly applicable to refuse composting in the United States because of the difference of refuse composition in the two areas.[1] Studies by Wiley[2] and Schultze[3] showed that the majority of putrescible material in U.S. refuse can be stabilized in five to seven days with aerated bin processes. This work and subsequent commercial developments served as a basis for the selecting of five to six days as the average decomposition time for the ground refuse in U.S. mechanical composting processes. Windrow systems require a much longer composting period. From two weeks to three months are required for adequate stabilization of refuse in a windrow operation.

The temperature achieved during composting should exceed 140° F for a minimum of four days to insure adequate stabilization. The refuse should be ground to a particle size less than one inch, the moisture content of the ground refuse should be increased to about 55 percent (based on total weight) and the carbon-to-nitrogen ratio should be adjusted to approximately 40 for most rapid stabilization. Mixed refuse has a very high paper content. The carbon-to-nitrogen ratio of this material can be expected to exceed 70 most of the time. This requires the addition of either sewage solids or nitrogen solutions to adjust the carbon-to-nitrogen ratio prior to digestion.

Mixed refuse has a wide variation in chemical and physical composition. Data on composition are found in the book entitled *Municipal Refuse*

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Disposal prepared jointly at APWA and APHA.[4] Recently contracts have been let by the Public Health Service for development of current data on refuse composition and quantities. The composition data presented in Table I is of primary interest to designers and operators of compost plants.

TABLE I

COMPOSITION OF MIXED REFUSE RECEIVED AT TWO MECHANICAL COMPOSTING PLANTS (TABLE ENTRIES ARE WEIGHT PERCENTAGE)

Component	Metrowaste plant[5] Houston, Texas	IDC plant[6] St. Petersburg, Florida
Newsprint	1.7	Not separated
Corrigated cardboard	0.5	Not separated
Ferrous metal, total		10
Ferrous metal, cans	7.1	—
Ferrous metal, tramp	1.8	—
Rags	0.2	Not separated
Noncompostable (tailings)	2.1	10
Compostable	86.6	80

U.S. Composting Systems

All composting operations can be broken into three basic steps: refuse preparation; stabilization; and product upgrading. The preparation includes receiving, sorting and salvaging operations, grinding, and the addition of moisture and nitrogen. Stability or aerobic digestion can be accomplished either in windrows in the open or in mechanical plants. Product upgrading consists of grinding, enrichment, granulation, shipment, and marketing. The details of refuse preparation, product upgrading and the composting systems available will be discussed separately.

Refuse Preparation

Some degree of hand and mechanical sorting of the incoming refuse is required in any of the composting operations in use in the United States. This sorting is required to remove noncompostable material, bulky items, and items which may have some salvage value. Most U.S. systems use hand picking from a slowly moving belt and magnetic separation of ferrous metals. Some systems include inertial separation in an attempt to further separate noncompostable items from the organic matter.

Grinding is required for efficient composting. This can be accomplished in either hammermills, chainmills, a rasp type grinder, or with wet pulping followed by screw-press dewatering. This latter method of grinding would be successful with only one of the four types of composting systems in use in the U.S. today. The power required to operate the grinders varies from

3 to about 30 hp. per ton per hour grinder capacity. In most plants now being constructed, grinders are sized large enough to permit all grinding to be accomplished on a one-shift operating basis. Thus the capacity of the plant could be tripled by simply adding additional digester capacity and operating the pre-and post-treatment units on a three-shift basis.

Figure 1 shows the inertial separation phase planned for the Gainesville Compost Plant. The primary grinder is a Centriblast unit which does impart a certain trajectory to the materials leaving the unit. A secondary, inertial separation is imparted by the jet slinger located on the Centriblast exit. The material leaving the Centriblast will then pass through magnetic separation.

Two stages of grinding are usually used. The first stage or coarse grinding reduces particle size to about 2 to 3 inches. The second stage grinding usually produces particle size of approximately 0.25 to 1 inch. After grinding, the material is moistened with either sewage sludge, water or dilute ammonium nitrate solution, then conveyed to the digestion phase.

Product Upgrading

The upgrading operations which follow digestion consist of some or all of the following: curing, grinding, screening, pelletizing or granulating, drying, magnetic separation, and bagging. Storage of refuse which has been stabilized to compost by high temperature for 5 to 7 days results in a slow curing or maturing process. This has the net result of producing a darker color material with a shorter fiber length, both changes make the material esthetically more desirable. Curing can be omitted in some plants providing the carbon-to-nitrogen ratio is adjusted to insure that a minimum of 1.5 to 2 percent nitrogen will be in the material when it is used for agricultural purposes. Most plants cure from 10 days to 2 months. When properly stabilized by high-temperature composting the material can be piled 15 to 20 feet high and left without turning for up to six months without going anaerobic. During this curing the temperature in the pile will remain near 140° F. The material removed from this type of pile will be very dark brown in color and should serve as an excellent soil conditioner or fertilizer filler.

Granulation can be accomplished by use of a short granulator followed by a dryer. The best example of an operating system of this type is found in the Altoona, Pennsylvania, plant where an attractive granular product is produced. The moisture content of the material as shipped in granular form averages about 10 percent versus the 40 to 50 percent moisture which is found in the run-of-the-plant compost produced in most other systems.

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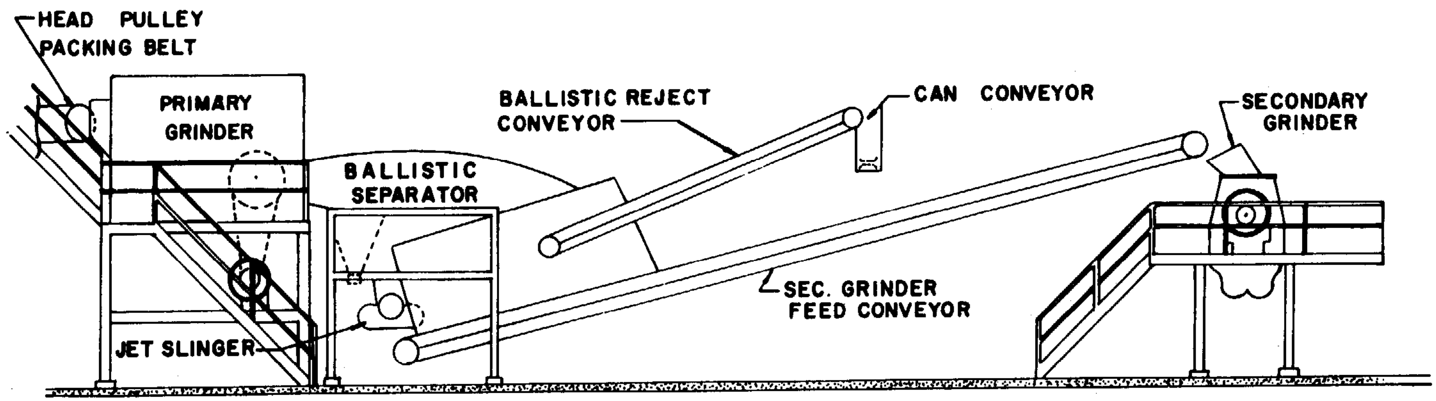

FIGURE 1
Section through the grinders and ballistic separator at the Gainesville, Florida, Metrowaste plant.

Windrow Composting

The new TVA–PHS Demonstration Compost Plant at Johnson City, Tennessee, is of the windrow type. Refuse is brought into the plant, hand sorted, ground in either a Williams hammermill or a Dorr Oliver rasping machine, then is moistened and conveyed to the outdoor decomposition area where it is placed in windrows. The windrows are turned 5 to 10 times with a Cobey-Windrow turner during about 5 weeks of composting. After composting, the material is cured for 2 to 4 weeks. Windrow composting of this type has been practiced successfully in many locations. This process requires a moderately large area since the windrows are outside and the material is retained on-site in discrete windrows from one to two months. Calculations contained in Appendix A indicate that about 30 acres will be required for a windrow plant to serve a city of 100,000 population. This type of compost operation should be best suited for smaller cities with adequate land available and around which there exists a strong market for the compost produced.

Mechanical Composting Systems

Three mechanical systems have proved successful in composting U.S. refuse. They are: the Fairfield system; the Internationl Disposal Corporation (IDC) system (formerly known as the Naturizer system); and the Metrowaste system. The land required for these plants is much less than that required for windrow plants of comparable capacity. A 5-acre site should serve a city of 100,000 population.

The Fairfield System

A pilot plant which receives approximately 25 tons of segregated refuse from the city of Altoona, Pennsylvania, has been operating using this type of digestion equipment for several years. A schematic diagram of the process is shown in Figure 2. A Williams hammermill is used as a primary grinder with no prior hand sorting since trash and rubbish are supposedly collected separately. The secondary grinding is done in a wet pulper or hydro pulper. In this unit, sewage solids can be added as the moistening agent and the filtrate from the screw press which follows the hydro pulper can be returned to the sewage plant. A bar screen is located between the hydro pulper and the screw press to remove film plastics, tin cans, and other noncompostable items. The wet pulp at 55 percent moisture is fed into a circular digester. This digester is the only one of the three mechanical digesters mentioned in this paper which is a continuous process unit. Air is blown through the perforated bottom to keep the mixture aerobic. Differing amounts of air are fed to various sections of the digester to provide any

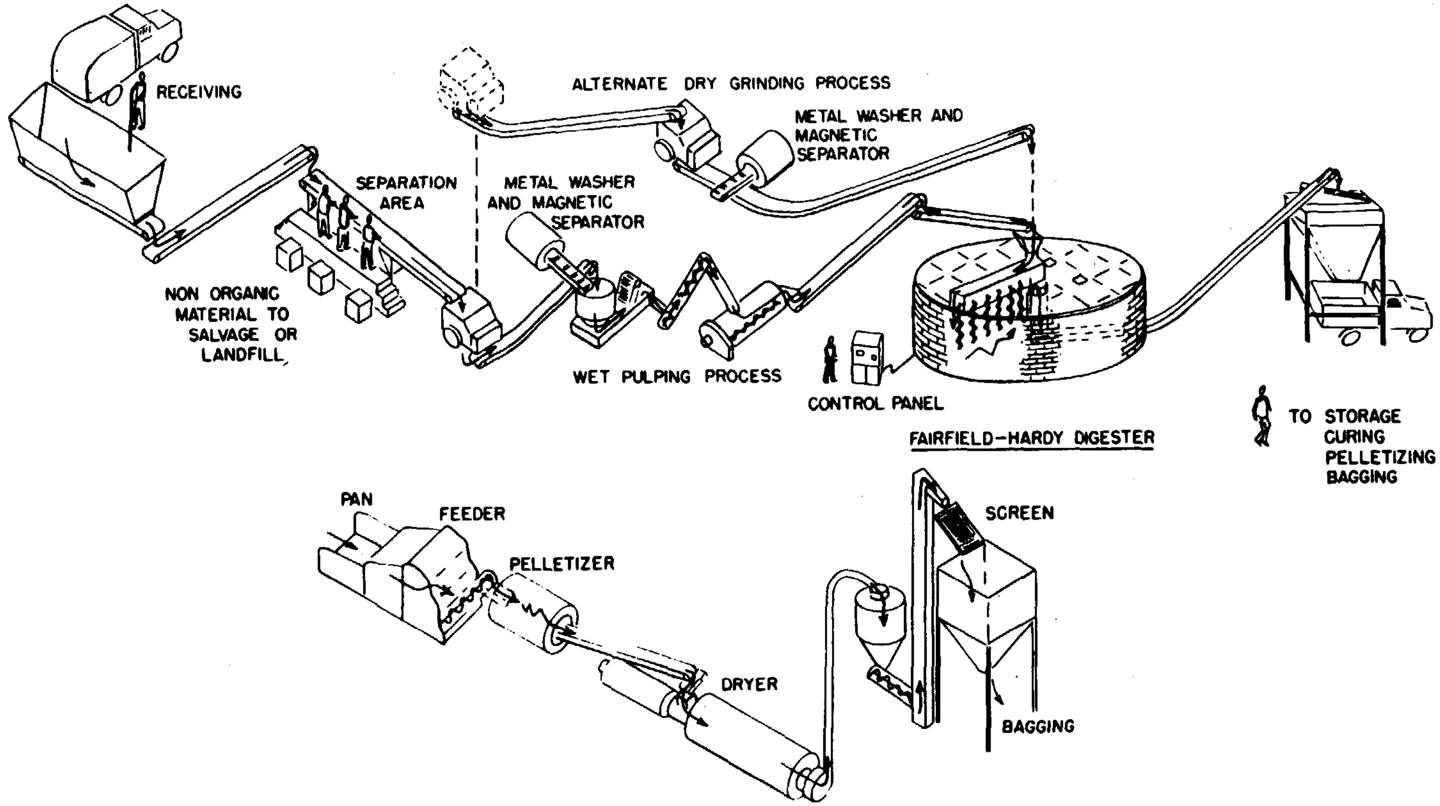

FIGURE 2

Typical design for Fairfield Hardy Digester installation and related equipment.

desired temperature profile. The augers which operate on a revolving arm, continuously mix the material and immediately integrate the wet pulp into the composting mixture. Only this digester arrangement is suited for the acceptance of ground refuse from the hydro pulper. After a nominal 5-day detention time in the digester the material is removed and cured in windrows for about three weeks. The cured material is moistened with a starch suspension, granulated, and dried to provide an excellent quality granular product. For much larger installations it is anticipated that a picking belt will be installed as an integral part of the pre-treatment operations. The horsepower requirements for this type of digester are relatively high as are the operating costs since the agitation operates continuously. Expansion of capacity would require the construction of a complete new digester since the through-put of a digester is limited.

The International Disposal Corporation System

A 105-ton-per-day IDC plant has been in operation for approximately one year in St. Petersburg, Florida. Incoming refuse is sorted to remove large noncompostable items, then is run through a magnetic separator to remove ferrous metals and cans. The next unit, as shown in Figure 3, is a rotary mixer called a pulveriator into which is fed the refuse and a moistening agent, ammonium nitrate solution. The refuse leaving the pulveriator enters a patented flail mill grinder which shreds the refuse effectively but does not remove or shred rags and plastic items which enter the composting process almost intact. The plug flow digester is housed in a vertical building with horizontal, moving belts on which the ground refuse composts. Air is blown into the pile just above the belt to provide adequate aeration. Temperatures are in the thermophilic range. The material is reground after 2 day of the process. Then, at the end of 5 days detention time the material is removed, passed through a pentagonal trommel screen with 0.75-inch openings. This screen provides an excellent separation of noncompostable materials such as rags and plastics from the compost which is then ground and conveyed to outdoor curing piles. The material is cured for approximately ten days. It is then sold in bulk or enriched for bag sale. Expansion of digester capacity will require construction of a complete new digestion unit or the reduction of detention time in the digestion units which may result in improperly stabilized refuse if the time is cut too short.

The Metrowaste System

A 350-ton-per-day plant of this design has been in operation for approximately seven months at Houston, Texas. A 150-ton-per-day Metrowaste plant is under construction in Gainesville, Florida, scheduled to begin

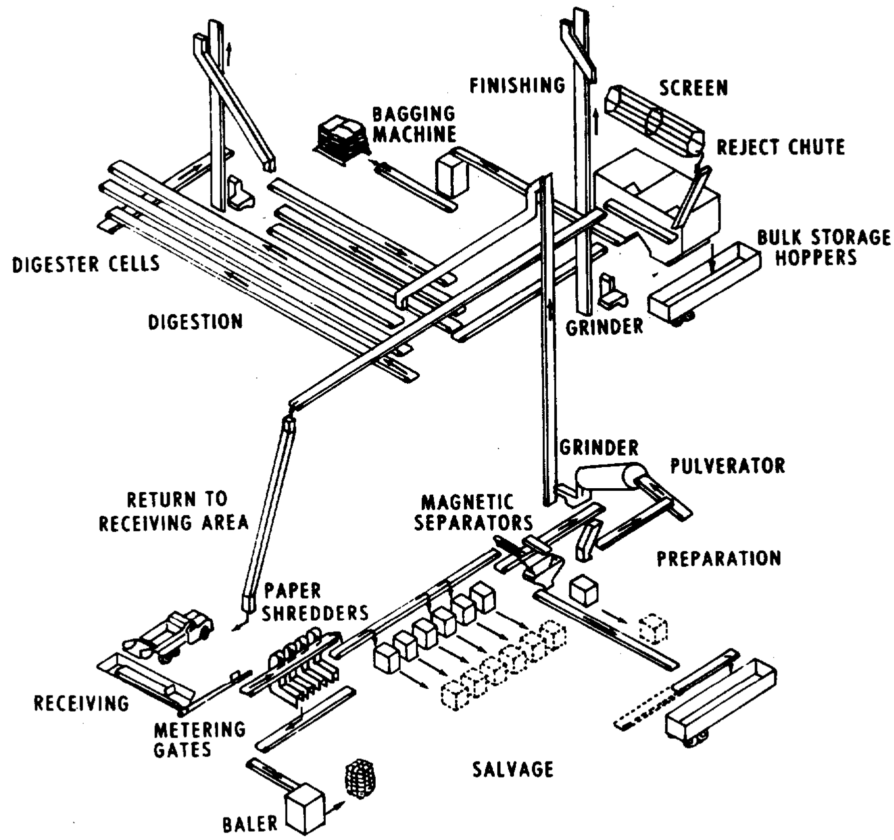

FIGURE 3
Schematic diagram of the Naturizer System.

operation October 1967. In this process, shown schematically in Figure 4, the incoming refuse is hand sorted, ground in either a hammermill or a Joy Centriblast unit which provides inertial separation, passed through a magnetic separator, a secondary grinder, and is moistened with sewage solids or nitrogen solution prior to composting. The batch digesters used in this process are horizontal tanks with perforated bottoms. The ground refuse is kept in the tanks for 4 to 6 days depending on plant operating conditions. Air can be blown through the bottom either on a periodic cycle or continuously. A special agitator-unloader is used to mix the material or to unload it at the completion of the composting period. These tanks are usually built in pairs with a center belt serving for both feed and take off from each pair. One agitator can be used for the two tanks with a transfer table to shift from one tank to the other.

Experiments conducted with the use of oxygen enrichment during the first 12 to 24 hours of composting with this system have shown that enrichment materially reduces the time required to reach thermophilic temperature ranges. The oxygen content of the inlet air is increased to about 30 volume percent. This reduces the necessary detention time in the digester by one to two days.

Expansion of digestion capacity can be accomplished by adding additional digester length and still using the same agitator for the tank. This provides the cheapest additional capacity of any of the three mechanical systems. Upon completion of composting in the Metrowaste system the material is passed through secondary grinders, screened and either cured or granulated for sale.

A process utilized in the Metrowaste system which is not being utilized currently by other compost operators, is the use of air suction on the discharge side of the primary grinders to remove film plastics. Some quantities of the dryer paper and many glass fragments are removed also by this suction. These materials are burned in a suspension dryer to provide heat for burning out cans and drying of the material after curing and/or granulating.

The manpower required for operation of compost plants can vary between 1 man per each 6 tons of refuse processed per day to 1 man for each 15 tons of refuse processed per day. Capital costs, energy and labor requirements for the three mechanical systems are compared in Table II. A major operating cost which is not well documented at this time is the cost of hammerwear for grinding operations. This is reported to vary from 65 cents to $1.25 per ton of refuse processed.[6, 7] All three of the mechanical systems use forced aeration. The aeration requirements vary between 0.2 and 2 cfm per cubic foot of digester capacity.

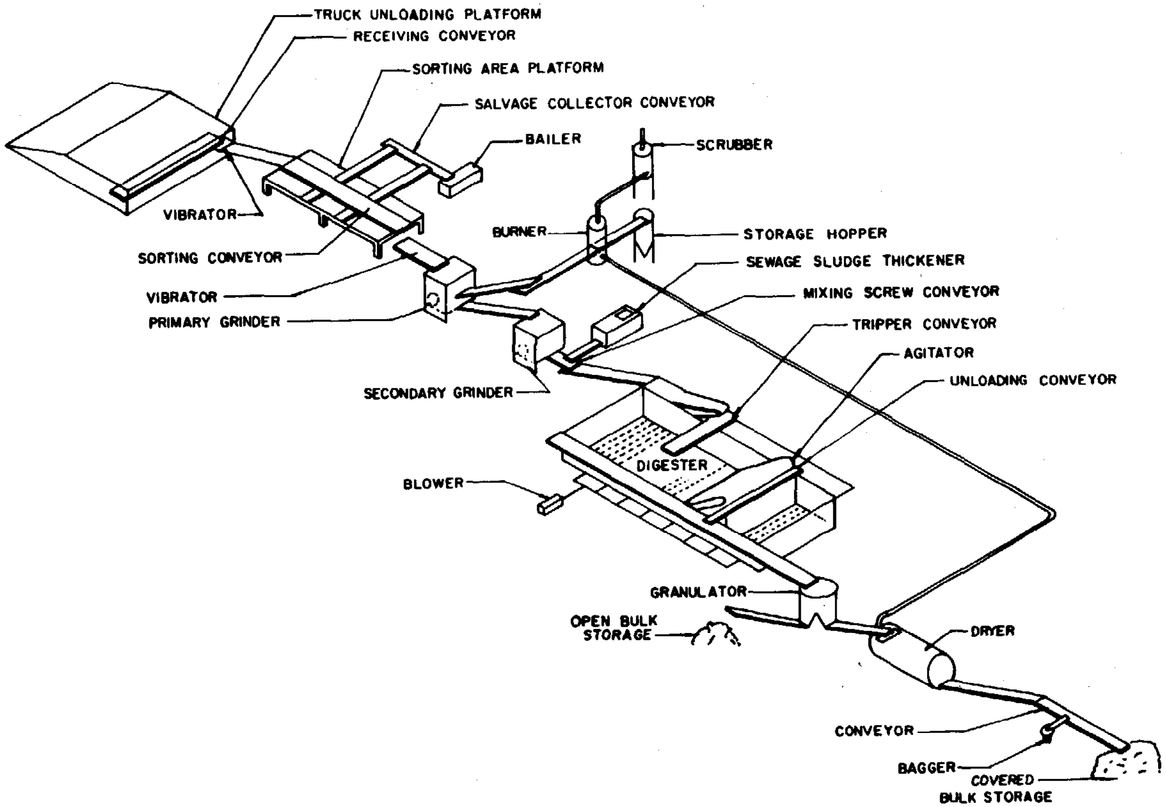

FIGURE 4

Compost plant schematic flow diagram, Gainesville Municipal Waste Conversion Authority Incorporated.

TABLE II

COMPARISON OF ESTIMATED CAPITAL COSTS [a]
ENERGY AND MANPOWER REQUIREMENTS FOR MECHANICAL COMPOST PLANTS

Capacity (t/d)	Fairfield [8]			Metrowaste [7]			IDC [6]		
	$ x 10⁶	HP	Labor	$ x 10⁶	HP	Labor	$ x 10⁶	HP	Labor
100	1.4 [b]	900 [b]	8 [b]	0.9	1,250	12	1.4	600	20
200	2.1 [b]	1,400 [b]	11 [b]	1.2	1,700	17	2.1 [b]	800 [b]	28 [b]
300	2.5	1,700	14	1.5	1,900	25	2.7 [b]	950 [b]	36 [b]
400	3.2	2,500	20	1.6	2,000	30	3.2 [b]	1,100 [b]	45 [b]

[a] Exclusive of cost or land and special foundation problems (fill and/or piling).
[b] Author's estimate based on chemical engineering estimating procedures.

SALVAGE RECOVERY AND MARKETING

Most salvage is accomplished by hand sortings and magnetic separation. The items which have salvage value are newsprint, corrugated cardboard, certain classes of rags, ferrous metal, cans, nonferrous metal (when separated) and glass. The market for any and all of these items is subject to wide variation from time to time and from location to location. Whenever salvage is being considered, it is best to contact the Executive Director of the National Association of Secondary Material Industries, Inc., whose address is 330 Madison Avenue, New York, N.Y. 10017, and request the name of salvage dealers in the vicinity under consideration. The salvage market is old and reasonably well established so nearly all salvaged material is sold through salvage brokers.

At this time the sale of paper salvaged from compost plants is meeting resistance because of "psychological warfare" being waged by long-time suppliers of salvaged paper through implication that the paper is somehow unsatisfactory.[9] Only dry, clean paper should be sorted and recovered for salvage purposes. It has been successfully used in food containers and other applications. The instability of the paper market and the psychological factor are the only drawbacks on the salvage of paper goods. The paper market is depressed at this time so the prices quoted are nominal only. Baled newsprint may sell for $12 to $15 per ton and baled corrugated boxes from $7 to $12 per ton.[10]

Mixed rags are now at their lowest value in years.[11] Prices vary from $2 to $30 per ton.[11, 12] Wiping rags, which in general are large garments of absorbant characteristics such as cotton, have a much higher value which can vary between $40 to $200 per ton. Assistance of a local textile salvage dealer should be sought in training personnel to pick only the proper types of rags for wiping purposes.

Glass or cullet can be sold in special circumstanctes to glass plants. Since glass is a supercooled liquid rather than a crystalline material, it melts at a much lower temperature than does silica (sand); hence some glass is recycled in glass manufacture to reduce the heat necessary to melt the sand. Again specific details should be worked out with a purchaser of the glass concerning the color and characteristics desired prior to attempting any salvage of glass at a compost plant. Usually glass is left in the compost and is abraided sufficiently during the process to be reasonably safe in the final product.

The only domestic market for tin cans is in the copper smelting industry located in the Western States. Unless there are special circumstances or special needs close by, it is impractical to consider salvaging of cans anywhere east of a north-south line passing through Chicago.[12] The closer the cans are to the mines in Arizona and New Mexico, the higher the price they will bring. Cans must be burned out and shredded prior to use in copper smelting. Much of this work is usually done by a salvage broker. Shredded, burned and baled cans may be suitable for export buyers at East Coast ports. This requires the seller to seek out possible markets. Routine scrap ferrous metals, known as tramp metal, can be sold in bales through normal scrap dealers located all over the country. Prices for properly baled material can reach $25 per ton.[10] Periodic prices can be found for all salvage material in the journal published by the National Association of Secondary Material Industries, Inc., published by Market News Publishing Corp., 156 Fifth Avenue, New York, N.Y. 10010.

Some hand sorting to remove noncompostable items is mandatory in most composting plants. The use of extended hand sorting should be weighed against the probable market for the materials separated by this process. Decisions to enter extensive sorting should be made only on the basis of firm contractual commitments for purchase of the products produced.

Compost Production and Marketing

From one-third to one-half of the materials entering a compost plant will become compost. Over three-fourths of the material entering the plant will enter the digester and a certain portion of this will be lost through biological activity. The length of curing, the type of upgrading operations, and the moisture content of the material as shipped determine what the ratio of final product to incoming refuse might be. At the present time, undried compost is being sold by Metrowaste and by International Disposal Corp. for approximately $16 per ton F.O.B. plant site.[6,7] The Altoona-FAM Co.

markets their granular compost at 10 percent moisture for approximately $16 per ton F.O.B. the plant.[8] Bag sales have not proved successful at the three plants now successfully composting municipal refuse in the U.S. The best potential bulk market for compost is as a building material in the fertilizer industry. The increasing popularity of organic fillers in fertilizers should provide an ample developmental market for compost. Some manufacturers of compost consider enrichment as the most desirable method to follow. The enriched compost can then compete directly with the fertilizer compound. Once enrichment is undertaken and a labeled material is being produced, fertilizer laws must be followed in the production of the material. The marketing work necessary for a large plant to move compost successfully is extensive. This is beyond the scope of most municipalities. A large private company would appear to have a potential advantage to providing adequate marketing services to move the final product.

Recently some rail carriers have established a new classification for compost materials.[7] The classification, "waste products," carries a 30 percent lower freight rate than fertilizer products. There still remains room for improvement since earth or stone can be moved by rail 60 percent cheaper than fertilizer products. If lower rates could be provided by rail carriers to compost producers this would make possible distribution of compost to a much larger area. At the fertilizer shipping rates the compost must be distributed within 50 to 100 miles of its point of production. With the reduced freight rates the radius of distribution can be extended considerably and still the product can be marketed profitably.

Financing Composting Plants

Financial personnel and engineers have worked together to develop a concept on which most of the current compost plant financing is based.[18] Since composting is a municipal refuse disposal function it should be underwritten by adequate dumping fees. These fees should cover the disposal phase of the operation which includes amortization of all capital outlays, a sinking or equipment replacement fund, all operating costs including the cost of transporting the compost to an ultimate disposal site for at least two years while market development is progressing, and a safety factor to provide for adequate charges for an alternate method of disposal during compost plant downtime. The alternate method may be landfill or incineration and would have to be conducted by contract or at standby facilities. All of these items should be covered by a guaranteed minimum dumping fee for the contract's period. A realistic escalation clause should be included in the contract to cover increase in labor and operating costs. The materials and the plant can be amortized over as much as a 30-year period if engineering data can substantiate the successful operation of the equipment for that length of time. In financing the plants no credit is given for sale of salvage material and an incineration cost should be included in the disposal phase to handle the disposal of plastics and other noncompostable but combustible items which are undesirable in the final product.

The second phase of the financing operation is the by-product phase. This includes final grinding, upgrading, marketing, granulating, etc., and should be financed by revenue received from the sale of the compost. Should this venture be undertaken by a private concern, the sale of the product would also serve to provide the profit for the operation. By separating the financing of composting into two phases — disposal phase underwritten by dumping fees and by-product phase paid for by compost sales, a realistic approach to financing composting plants can be taken.

For moderate-to-large size communities where space is a problem and pollution is a problem, composting can compete effectively with incineration particularly if the operators of the compost system have initiative and ingenuity in developing markets for the compost and salvageable items. The most advantageous situation for refuse composting is when it can be combined with sewage treatment. A city can save about 30 percent of the cost of sewage treatment by pumping raw sludge to a compost plant for use as a moistening agent and a source of nitrogen in the compost. When the savings in sewage treatment cost are taken as a credit against the cost of refuse composting, the economics of composting become attractive. This is particularly true when the process also eliminates a potential air pollution problem.

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Appendix

Calculation of Area Required for a Windrow Composting Plant To Serve a Population of 100,000

Quantity of refuse $= \dfrac{(4 \text{ lb/c/d})\ (100{,}000)}{(2{,}000 \text{ lb/ton})} = 200$ t/d

Compostable quantity (80% from Table I) = (200 t/d) (0.8) = 160 t/d if density = 400 lb/yd^3

Volume $= \dfrac{(160 \text{ t/d})\ (2{,}000 \text{ lb/ton})}{(400 \text{ lb/yd}^3)} = 800$ yd^3/d

With a windrow 5.5′ high, 10′ wide at the base and 6′ wide at the top, the cross-sectional area = 5 yd^2

Daily length of windrow $= \dfrac{800 \text{ yd}^3\text{/d}}{5 \text{ yd}^2} = 160$ yd/d = 480 ft/d

Assume: 60-day composting period
20′-gap between piles
15′-driveway between windrows

Total daily length = 480′ + 20′ = 500′

Total length on plant site — (60 days) (500 ft/day) = 30,000 ft

Area per foot or windrow = (10 + 15) (1) = 25 ft^2/ft

Total windrow area $= \dfrac{(25 \text{ ft}^2\text{/ft})\ (30{,}000 \text{ ft})}{(43{,}560 \text{ ft}^2\text{/acre})} = 17.2$ acres

Add a 60% safety factor — 10.2 acres	= 10.2 acres
Add area for buildings, etc.	= 2.5 acres
Total area required	30.0 acres

OPEN DISCUSSION: PANEL B

Abraham Michaels, Panel Chairman*

MR. R. R. DALTON†: What do you know about tepee burners with afterburners?

MR. ELMER R. KAISER: I had a paper in the *American Public Works Association Yearbook of 1960* in which that point was discussed. I made calculations at that time and as I remember it takes about 125 or so gallons of oil to heat the flue gas from a ton of refuse burned in the tepee unit to 1,500° F for the afterburning effect. Now, that's entirely too much oil. The reason there is such a high excess of air, 400 or more percent is to protect the tepee and not burn out the screen at the top. An afterburner is only useful when you can keep the excess air quantities in a low range. And then, I dare say, if you do that, you would need a refractory furnace, and you would get enough temperature automatically without the afterburner. Therefore, they have had to go to the scrubber concept in order to clean up the flue gas.

MR. W. HARRINGTON‡: What percentage of the total refuse quantity as delivered is finally converted to compost?

DR. CHARLES I. HARDING: Let's take that on dry solids basis, because I think we are going to have to ultimately get to that. If you take refuse received in a plant, it is about 25 percent moisture. Then about 80 percent of this material (possibly with good film plastic and artifacts removal, 65 percent) will go to the digester.

There is about one-third loss in the digester of the material going in. Thus, on a dry solids basis you would come out with about 30 percent of the dry solids delivered to the plant as product. If you sell it at 100 percent moisture on a dry solids basis, then you are going to have about 60 percent of the material delivered to the plant which would be product by weight. By volume it would be much smaller; the density received from packer trucks is somewhere around a low of 10 to a high of 20 pounds per cubic foot and the compost is sold from 32 to 40 pounds per cubic foot. So there is a marked volume reduction in the material.

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MR. HARRINGTON: I am quite interested in the percentage as delivered that actually gets converted. I don't care what the end product is. But if you get 5 tons, how much of that on a dry solids basis, or however you want to put it, how much of that do you actually compost? Because you are salvaging, you are getting rid of your plastic and some of your paper.

DR. HARDING: Of the material that *enters* the composting process? About two-thirds.

DR. G. C. SZEGO*: How about burning by using natural gas jets buried by the rubbish being combusted?

MR. BOWERMAN: This is a process that comes up for consideration from time to time because "in-place" burning sounds as though it might be really cheap, and maybe an efficient way of getting volume reduction. The one attempt that I am personally familiar with was done in the San Francisco area on buried demolition wastes with an earth cover. An attempt was made to control the combustion process, but frankly, the manner in which you can control an underground burning operation is rather limited. You don't have many controls, once you ignite the solid wastes. You're pretty well at the whim of the way it was put together, and if that wasn't quite right, then there's nothing much you can do about it. In this one instance, the operation seemed to start off fairly well. Then it started smoking, and the smoke brought the fire department; the fire department hosed down the earth cover and made holes in it. The whole thing then went up in one grand debacle.

A controlled burning operation was tried on a much smaller scale at one of the Los Angeles District sanitary landfills. We built a pyramid, about 20 feet high and provided open space on the bottom by putting in a bunch of palm-tree logs, crisscrossed. The rubbish pile was placed on top of that, and an earth cover placed on top to create a virtual Vesuvius. A hole was left in the top for a chimney, and the material was allowed to decompose aerobically. Eventually it spontaneously combusted and burned so well that it was still burning about three months later. It just doesn't appear that under these field conditions you can hope to get the type of combustion that's going to meet air pollution control standards.

MR. T. W. BENDIXEN†: What will incineration do to reduce oxides of nitrogen, when air pollution control authorities require control of nitrogen oxide?

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† Thomas W. Bendixen, U.S. Public Health Service, Cincinnati, Ohio.

MR. KAISER: In the example I gave you, the nitrogen oxides were 93 parts per million. We get less nitrogen oxides in incineration than they do in the burning of coal or oil in power boilers. The reason is that we operate at lower temperatures. In the first place, our fuel has more moisture and inerts, which take up heat; secondly, we try to stay below 1,800° F in the refractory line units, in order not to have the ash form slag on the walls. And that is a big help in holding down the nitrogen oxides. What to do about them to get a further reduction, I certainly don't know. Whether the water spray treatment that we often give the gases afterwards will take some of it out, I am not sure either. But certainly with stacks that extend 200 to 300 feet high, the dispersion of that little nitrogen oxide is not going to be any problem. That subject is being researched in connection with the big oil- and coal-fired power boilers, and after they work it out, perhaps we can adopt something if that is still necessary.

MR. WARD BARSTOW*: How does the quality and quantity of refuse in Europe differ from that in the United States?

MR. ROBERT D. BUGHER: It's difficult to generalize on that kind of a question. I can say this: Last month Abe and I had the pleasure of attending the Ninth International Public Cleansing Association meeting in Paris. James Sumner of Great Britain presented a paper which summarized the characteristics of waste in different countries. As I recall it indicated that the percentage of organics in the northern countries was in the neighborhood of 20 to 30 percent, but one of the striking things that I recall was that some southern countries, particularly Israel, reported that their percentage of organics was as high as 70 percent. The percentage of paper obviously is much greater here in this country. They are much more thrifty in Europe and do not produce as much waste. I asked this question of one gentleman from England and he told me that their refuse is becoming more like ours — they are getting a lot more paper. He also indicated that the quantity and quality of their wastes is similar to what ours was about 20 to 30 years ago. Incidently, if you want more specific information on this question we will be glad to make it available.

FROM AUDIENCE: I'd just like to ask if you don't consider paper as organic; it composts perfectly well.

MR. BUGHER: When I use the term organics, I mean mostly vegetable wastes, i.e., putrescible organics.

FROM AUDIENCE: I think the paper and the organics would be con-

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sidered one, don't you, along with leather and anything else which is organic, anything which will compost?

MR. MICHAELS: Yes, it's true. The amount of paper certainly affects the carbon:nitrogen ratio which affects the quality of the compost. The numbers (paper percentages) that I remember that are significant are that in Europe about 30 percent of the refuse was paper, whereas in the United States paper or paper products are over 50 percent. I think this represents the significant difference between the two types of refuse.

MR. WISMAN: Why, if you believe in recycling metals back to industry, do you not believe in recycling organics back to the soil which feeds us and which we are depleting?

MR. KAISER: Personally, I intend to remain objective about such matters. If the compost people can develop their processes and a market for the product, more power to them. Refuse not disposed of as compost will be incinerated and landfilled. I happen to specialize in incineration, which takes all of my time, which means I can only try to encompass that much of the field. If there is also a place for compost, the judgment as to its future must be made in the marketplace.

DR. HARDING: We have been working with some pretty sharp agricultural people and they tell me (although I'm not a farmer and I couldn't grow anything if I had to) that if you want to show a net increase in organic content particularly in a sandy soil, you'd have to put into the top two inches of the sandy soil each year a six-inch layer of compost. So this is somewhat of a myth — that you're going to increase the organic content of the soil by adding compost to it. It sounds good, and that's what I referred to at the very beginning — it's a romantic idea that really appeals to people. I don't want to play it down, but I want to be realistic about it. We aren't going to increase the organic content of our soils which we are depleting, materially in this way. In my opinion, the way composting has a reasonable chance of success is by courtship and marriage with the fertilizer industry. There is now a big move to use organic fillers in fertilizers. Compost has rather low nitrogen and so it doesn't compete very well with waste-activated sludge; but I think the future of composting on a bulk, large-scale basis, is intimately involved with the future of the fertilizer business. In that way I think there will be some recycling.

MR. S. EHRLICH†: When do you expect the slag-tap process, which you touched on, to become commercial? Could you briefly give us more details?

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MR. KAISER: Taking up a few details first — the slag has a density of about 2.4, which is about the same as glass. I have measured the density of this material — if you could cast large chunks of it and bury those, you would get up to this 3,000 to 3,800 pounds per cubic yard. However, if it is run into water it breaks up into a black, glassy sand. So there are voids. The slag sand would have a density of approximately 2,500 pounds per cubic yard. If you have a mixture of chunks and fines you will have an intermediate density. When will this become commercial? I can't predict that. More demonstration work must be done on it and studies made of it. In Europe at the Volkswagen Works they have had a slag-tap operation for quite some time. In regard to the Melt-Zit process in Massachusetts, there will be some tests a little later this year.

ANONYMOUS: What progress can be reported in the problem of making beer (and other disposable) cans from early-deteriorating materials?

MR. BOWERMAN: Well, my good friend, Dr. McGauhey of the University of California, Berkeley, says that the ideal container is the ice cream cone. Maybe someday somebody is going to come up with a container for beer that's edible, but I think that in the meantime the transition will be from a metal to a fiber; I think we'll find that we cannot afford to use our mineral reserves in a non-conservative manner, and go over to fibers where we can grow and regrow and continue to grow new resources indefinitely. Thus, I think that we'll see more fiber containers and less metal.

MR. MICHAELS: Actually the container industry is probably the one industry that is more responsible for the predicament we are in today than any other industry. All reports that I have heard are that they have no intention at the present time of concerning themselves with the waste disposal problem; that, in fact, their job is to sell more and more containers. Hopefully, they will come up with something that will be degradable but as of now I don't think there is any indication that the industry contemplates changes that will significantly reduce the refuse disposal problem.

ANONYMOUS: Why are not private utilities, that is, electric and gas and particularly electric, regulated as closely as other industrial entities on waste disposal?

MR. MICHAELS: I don't know that this is so, necessarily. Certainly, recent legislation in New York City and legislation in other major communities which set limits on air pollution emissions, indicates, considerable control of public utilities; I don't know whether anybody else in the Panel or in the audience has any comments to make on this . . . I'm inclined to feel the premise is not a correct one. Any comments at all?