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EUROPEAN DEVELOPMENTS IN THE RECOVERY OF ENERGY AND MATERIALS FROM MUNICIPAL SOLID WASTE

Interagency Energy-Environment Research and Development Program Report

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes energy and materials recovery operations in Europe observed during the summer of 1975. A summary of key findings is also included.

Francis T. Mayo, Director
Municipal Environmental
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ABSTRACT

This is the report of a study which set out to determine whether priorities in Western Europe with respect to energy and materials recovery from municipal solid waste are the same as those in the United States, which include (a) the use of refuse as a supplementary fuel, (b) pyrolysis, and (c) resource recovery. The study also attempted to identify solid waste/energy processes in Europe (both existing and under development) that appear to offer potential advantages over processes currently employed in the United States.

Recovery activities in Belgium, Denmark, England, France, Italy, Luxembourg, Netherlands, Spain, Sweden, Switzerland, and West Germany are reported. For each country, a national overview is given, followed (where appropriate) by a description of particularly significant developments. Systems involving household sorting and separate collection, front-end materials/fuel separation, the burning of refuse-derived fuel in electricity generating plants and cement kilns, pyrolysis, incineration with heat recovery, and materials recovery from post-incinerator residues are discussed in the report. A summary of key findings is also included.

Most of the information was collected between July and September, 1975. The report contains the names and addresses of all persons contacted in the study.

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INTRODUCTION

Current (summer, 1975) priorities in the United States with respect to energy and materials recovery from municipal solid waste include (a) the use of refuse as a supplementary fuel, (b) pyrolysis, and (c) resource recovery. Reported here is a study which set out to determine whether the same priorities apply in Western Europe and to identify solid waste/energy processes there (both existing and under development) that appear to offer potential advantages over processes currently employed in the United States.

The study included a review of published and unpublished literature, telephone and letter contacts, and selected visits by the Principal Investigator. The information is presented as received; time and resources have not permitted an independent verification of its accuracy and completeness. Most information was collected prior to September 10th, 1975.

SUMMARY OF KEY FINDINGS

Landfill generally remains the preferred method of disposal in Western Europe where suitable sites are available, but these are becoming increasingly difficult to find, particularly near the large cities.

In some countries, composting is considered viable, but only on a limited scale. There is a demand for the product from vineyards, etc.

Incinerators are in common use, especially in urban areas, but costs have increased so rapidly that several governments are discouraging the construction of new plants. Increasingly stringent air pollution regulations necessitating the use of gas scrubbers (e.g. in West Germany) can cause the costs to rise even higher.

Provision for heat recovery is made in many incinerators, especially the larger plants. The technical difficulties (notably corrosion) are now reasonably well understood, although unexpected problems can still arise. The problem of matching supply with demand remains a significant barrier to heat recovery, especially for electricity generation (which is generally considered worthwhile only in the very largest plants). The recovery of heat for district heating and/or industrial use is preferred, particularly when an incinerator can provide the base load throughout the year. Rising fuel costs are making the economics of heat recovery more attractive.

Most countries are interested in the possibilities offered by the new technologies of materials/fuel separation, pyrolysis, etc. On the whole, they are awaiting "hard data" from the United States but in some places development is proceeding independently.

Countries in which front-end materials/fuel separation processes are being developed include England, Italy, Spain, Sweden, and West Germany. Of particular interest is the burning of refuse-derived fuel in cement kilns.

Countries in which pyrolysis processes are being developed include Denmark, England, Netherlands, Sweden, and West Germany.

Some work has been done on materials recovery from post-incinerator residues (notably in England and France) but there seems to be little enthusiasm from incinerator operators for installing a full-scale system.

Several countries are experimenting with household sorting and separate collection systems, the discouragement of non-returnable containers, etc.

BELGIUM

NATIONAL OVERVIEW

Other than separate collection, there are no systems for the recovery of energy/materials from municipal solid waste operating in Belgium at the present time although a cryogenic process for separating 99% pure ferrous metal using liquid nitrogen is reputedly being tested in Liegge by George and Sons (no further information was obtained). However, careful study is being made of recovery possibilities.

DENMARK

NATIONAL OVERVIEW

The principal government agency concerned with solid waste management is the Miljøstyrelsen (Ministry of Environmental Control).

Approximately 60% of refuse in Denmark is incinerated in fairly modern incinerators, one-third of which have been constructed in the past 5-6 years. Two large plants serve the Copenhagen area (representing 2 million out of the total Danish population of 5 million). Emission standards can readily be met using electrostatic precipitators so that pollution control is not a major constraint on incineration (as it is in Germany). No financial assistance is provided by the central government for the construction of disposal facilities.

Many of the incinerators recover heat; for example, one supplies heat to a power station and another will soon do so to a new 1000 bed hospital (which is not yet completed). There is a tradition of district heating based on hot water rather than steam, because the Danes prefer to operate their incinerators at lower temperatures and pressures than those used in steam systems, in order to reduce maintenance problems. However, district heating is no longer considered as economically attractive as before, and there has been a tendency to build newer incinerators, especially the smaller ones, without heat recovery.

Although the Minister has made a statement to Parliament in favor of resource recovery, etc., no government support has been forthcoming. In some municipalities, refuse is separated by households into three bags (metal and glass, paper, and the rest); this is organized by the local authorities in collaboration with consultants and with the company selling the bags. (This is an offshoot of a Swedish program; see below.) For example, in Birkerød (population 20,000) success is claimed as there is 90% participation. However, it may be that waste is increased, as families are happy to have three bags instead of one. Furthermore there are problems in marketing the recovered materials.

There is a Danish tradition of using returnable beverage bottles, and this still holds. Non-returnable bottles are relatively rare, although there are quite a few cans. The government has made an agreement with the Danish breweries to restrict non-returnable containers to 2-5% of the total market. A large supermarket has experimented with returnable wine bottles, but was not successful because of the diversity of bottles involved.

NOTABLE DEVELOPMENT

Development by Pollution Control Ltd: A pilot/demonstration pyrolysis plant utilizing the "Destrugas" process has been constructed at Kalundborg (about 100 km west of Copenhagen) by Pollution Control Ltd. The company is a limited partnership formed by Messrs. Karl Kroyer (inventor-and engineering-company) and Superfos Ltd. (The largest industrial chemical company in Denmark.)

The pilot plant has been proven at slightly over 5 tons*/24 hours. A single retort is used which would not be scaled up in a full-scale plant (as the heat transfer characteristics must be maintained); instead, banks of retorts would be used. The company's target is to construct plants of around 100-500 tons/day (rather small than some of the U.S. facilities).

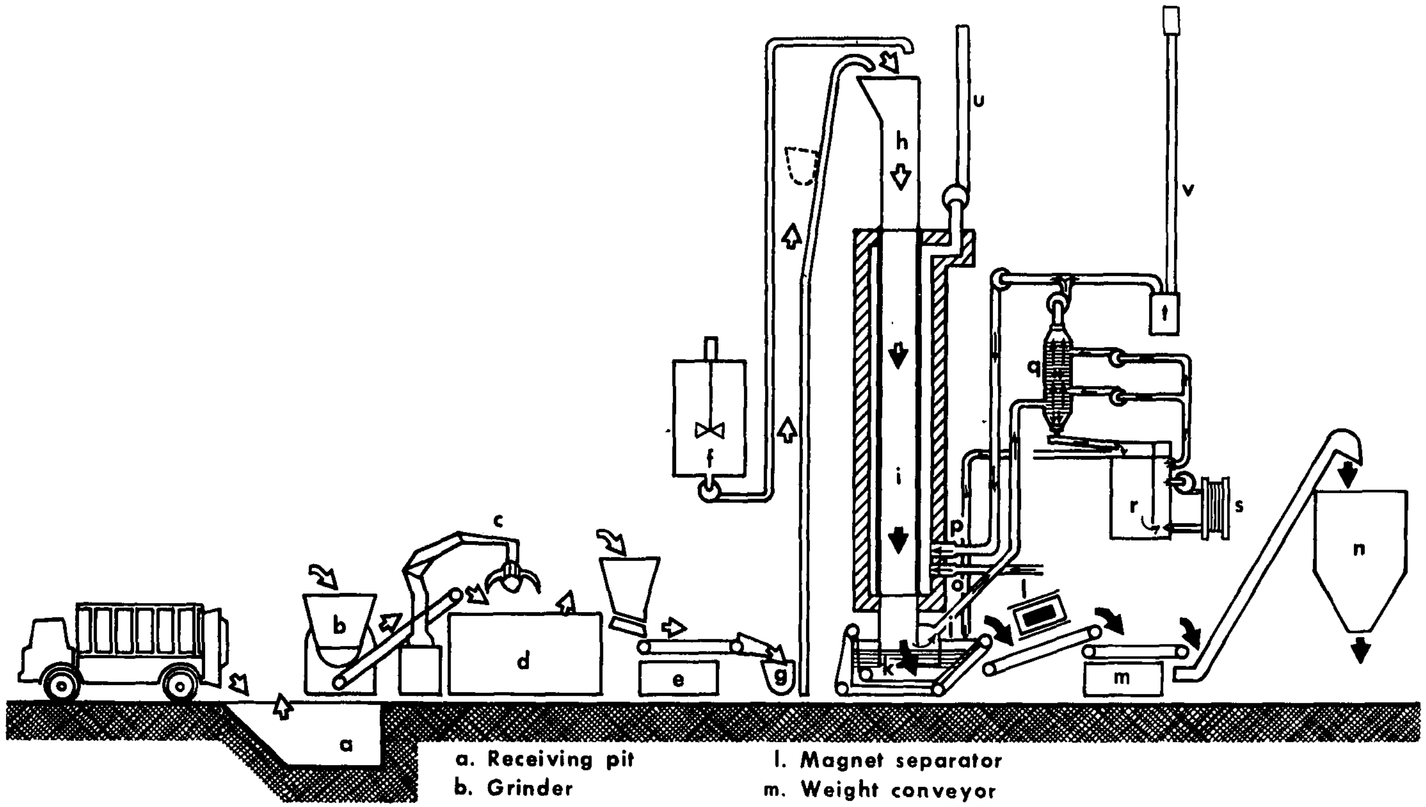
After pulverizing in a hammermill to minus 100mm (larger particles may be acceptable, especially if they are flexible), the waste materials are fed into a vertical, indirectly heated retort tube, where they are pyrolytically decomposed in the absence of oxygen at temperatures up to 1000°C (Fig. 1). The process produces a sterile char, free of biologically decomposable material, and a gas with a composition resembling that of coal gas. Part of the gas is fed back into the system to be used as fuel; the remainder is available for use elsewhere. It can be mixed with natural gas (giving a mixture with a calorific value substantially less than that of natural gas alone) or, more likely, it can be used industrially. The evaporated water from the waste materials condenses in the scrubber system and is led to the quench tank to cool the char. Provided that the moisture content of the incoming wastes is no more than 40%, all of the water is absorbed by the char (otherwise there might be some surplus, requiring treatment). Atmospheric emissions from the stack are claimed to be less than 10% of the emissions from a modern incinerator of comparable size.

Instead of using the char to absorb the water (which would therefore require alternative treatment) it could be used as a fuel, as a filter (it could possibly be converted into a high grade activated charcoal), or in combination with sewage sludge as a soil conditioner.

Pollution Control Ltd. has established links in various countries, including West Germany, England, Japan, Norway and New Zealand. In Japan, a demonstration plant similar to the Kalundborg plant is to be built under license in the city of Hitachi (design work currently being started). Prospects in Japan are considered very good, and negotiations are proceeding with several local authorities.

In West Germany, a joint venture is being established with Wibau Matthias and Co. The Bavarian Ministry requested a 3-5 week demonstration at Kalundborg with independent monitoring; the West German government then took over the research and contributed financial support. The trial was run by the University of Stuttgart over a six week period in summer, 1974, using four

* Metric Tons Used Throughout Report.



a. Receiving pit
b. Grinder
c. Crane
d. Silo
e. Weight conveyor
f. Tank for liquid waste
g. Elevator
h. Feeding tube
i. Retort
j. Gas outlet
k. Slag outlet
l. Magnet separator
m. Weight conveyor
n. Slag silo
o. Burners for LPG
p. Burners for "destrugas"
q. Scrubber
r. Tar separator
s. Cooler
t. Trap
u. Stack
v. Flare

Refuse ⇨
Slag ➡
Gas ⟶
Water ⟶

Figure 1. PC-PYROLYSIS PLANT, KALUNDBORG, DENMARK.

different kinds of waste (Danish refuse, German refuse, refuse plus sludge, and refuse plus waste tires). The results are still confidential but are claimed to support those of Pollution Control.

The Bavarian Ministry requested proposals for a 180 tons/24 hour facility to be built in the Munich area. In competition with Torrax, Union Carbide, etc., Pollution Control won the right to negotiate, and is currently submitting a quotation for detailed engineering studies. The intention is to initially install furnaces handling 90 tons/24 hour day, but to increase this capacity after one year if the operation is successful. The plant should run for at least 8000 hours/year, leaving about 30 days for outages, but it is claimed that the plant could run longer. The construction is such that the whole heated zone should be maintained continuously at full heat. Based on experience with coal gasification plants, a retort should have a 10-15 year lifetime; repairs and maintenance should be mainly confined to the handling facilities, fans, etc.

The Bavarian Ministry has not received financial support from the West German Government which may instead support the construction of a pilot plant to be owned by the Berlin Solid Waste Authority in collaboration with the Technical University of Berlin. If constructed, the plant would have a capacity of at least 15 tons/day (possibly 30 tons/day). A contract for the predesign stage is currently being negotiated.

Estimates of costs have been made carefully and are thought to be accurate to within about 10%. The capital costs include design and construction fees, etc., based on a normal site but do not include the cost of the site itself nor the provision of services, fences, etc. For a 120 tons/24 hour plant, total capital and operating costs would amount to 106.8 Danish Kroner (kr) per tone (made up of capital costs, 66.8 kr; repair and maintenance, 9.5 kr; operation, 10 kr; salaries and wages, 20.5 kr). Assuming an income of 45 kr per ton from the sale of surplus gas, ferrous metals, and carbon char, the net cost per ton would be 61.8 kr. The cost decreases as the plant size increases, up to a 360 ton/24 hour plant for which the gross cost per ton would be 87.8 kr (net, 36.8 kr).

ENGLAND

NATIONAL OVERVIEW

The principal government agencies concerned with energy/materials recovery from municipal solid waste are (i) the Department of the Environment and (ii) the Waste Disposal Authorities (the County Councils).

The three U.S. priorities are thought generally applicable, but two important factors must be borne in mind: (i) local government recently underwent a major reorganization and many of the newly constituted Waste Disposal Authorities are still in early stages of planning; and (ii) the Control of Pollution Act 1974, which has major provisions affecting the disposal of municipal solid waste (e.g. in requiring the Waste Disposal Authorities to prepare plans and issue disposal licenses), has not yet been implemented owing to the unavailability of financial assistance from the central government. The situation is therefore somewhat transitory, although some interesting developments are occurring (see below).

The Department of the Environment (DOE) until 1970 was required to approve solid waste projects where loan sanction was sought by local authorities but this nc longer applies. It now sets a figure each year for capital investment, leaving the local authorities discretion over how it is spent. The DOE gives "advice on how to select options" and this is generally to use sanitary landfill whenever possible (as it is considered the least expensive method of disposal). Where landfill sites have been unavailable in the past, many local authorities have built direct incineration plants (some 20-30 authorities built them prior to 1970) but costs have doubled in the past four years or so and the DOE now advises against their construction. Present advice is to hold off heavy investment in conventional equipment until the new processes (i.e. pyrolysis, fuel/materials separation, etc.) have been fully examined.

A Waste Management Advisory Council has been established and is currently looking into resource recovery (although no actions have yet been taken). In order to stabilize waste paper markets, a buffer stock scheme is being considered, in which industry would be paid to hold stocks. Packaging is being examined, and three industry reports (on glass, metals, and plastics) have been published.

NOTABLE DEVELOPMENTS

1. Research at the Warren Spring Laboratory (operated by the Department of Industry): An early project on the extraction of non-ferrous metals from

incinerator clinker (Fig. 2) has been completed. Research (funded by the DOE) is progressing on (i) fuel/materials separation, (ii) pyrolysis, and (iii) the pneumatic conveyance of pulverized refuse.

(i) In the fuel/materials separation project, an attempt is being made to separate as many components as possible, notwithstanding present market conditions, which are thought likely to change at any time. However, any given commercial plant would be designed according to the particular circumstances then existing. A pilot system has been constructed at Warren Spring (Fig. 3). A key feature of the process is the absence of a hammermill or other shredder at the front end (allowing appreciable energy savings). Other features include a ballistic drum (rather than plate) separator (to prevent nylons, etc., from becoming caught) and a thrower/separator which relies on a combination of aerodynamic, impact, and sliding friction effects to separate a low density product (mainly small pieces of paper, vegetable and garden wastes, and low density plastics, etc.) and a high density product (mainly dense vegetable matter, broken glass, bones, etc.). No attempt is made to color-sort the glass, because unless the white fraction can be made clean enough for the manufacture of flint glass (which is currently thought unlikely), it is not thought worthwhile to separate at all.* Some 50% by weight (or about 20% by volume) of the incoming refuse forms a residue that remains for disposal. The froth flotation circuit produces a contaminated liquid effluent.

An economic assessment of the process is currently being prepared. It is tentatively considered that a 200 tons/day plant could break even (including the cost of residue disposal). The process is about ready to go commercial, and discussions are being held with local authorities and some industrial companies. The first plant will probably produce mainly a fuel, together with cans, non-ferrous metals, and glass. (The construction of two separation plants (each 300 tons/day) has since been announced, one to be built for South Yorkshire, the second for Tyne and Wear.)

(ii) The project on pyrolysis has proceeded in three stages (Fig. 4). Following bench-scale tests, a retort with indirect heating was built and operated at temperatures of 600-1000°C to provide background data as well as products for further examination. The major disadvantage of this design stems from the poor thermal conductivity of the refuse, necessitating a considerable retention time for peripherally supplied heat to conduct to the center of the charge. The second stage of research utilized an induction heating system; the incoming refuse was mixed with 4 cm diameter steel balls and passed down the reactor tube and through an induction coil. The advantage

* Some experimentation with glass color sorting has been conducted. The color-mixed froth floated product currently produced contains more carbon particles than does the U.S. product, giving it a gray cast. The carbon burns off during glass melt, thereby providing some fuel value; as a result, British manufacturers have suggested that the glass should carry a premium price compared with material containing less carbon.

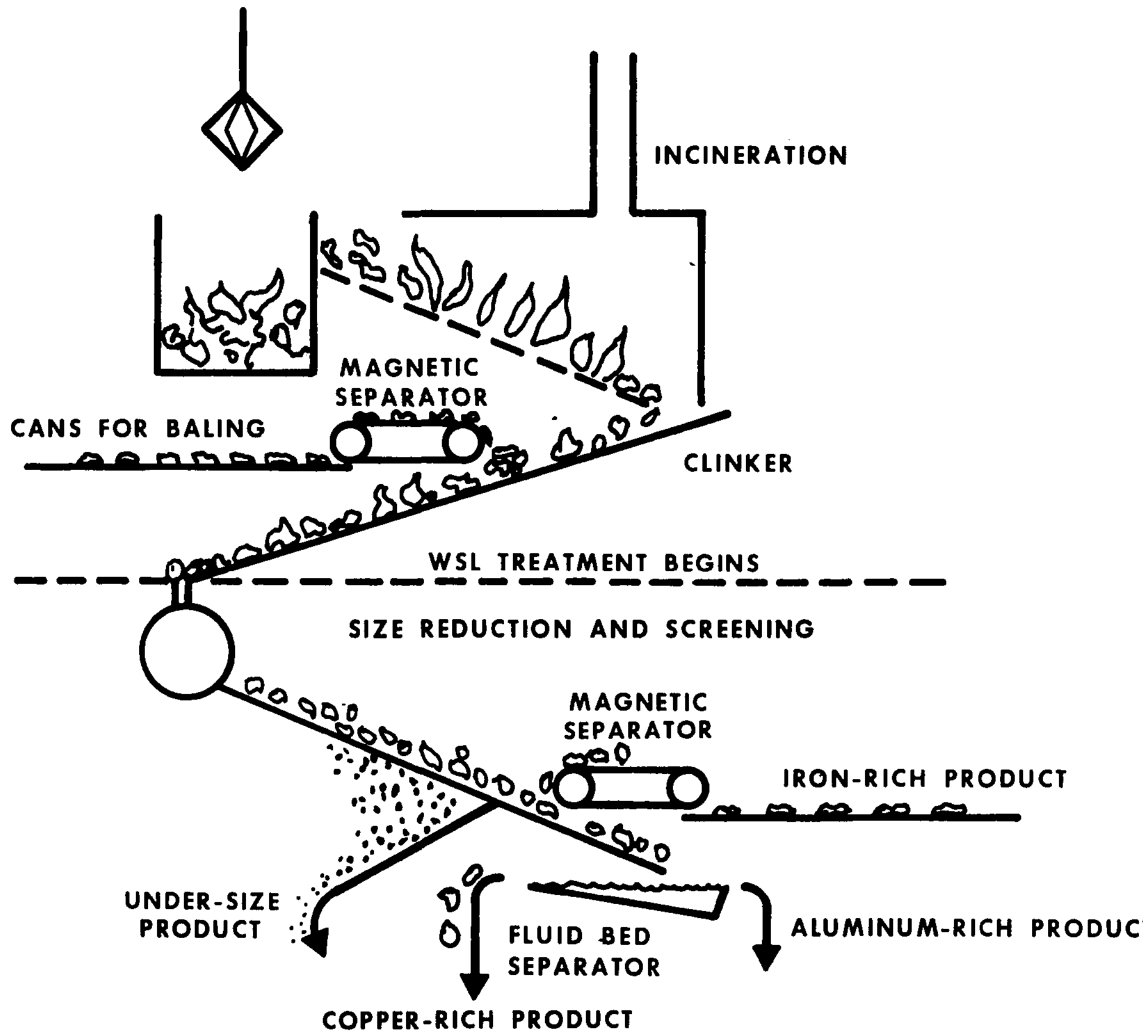


Figure 2. WARREN SPRINGS PROCESS FOR IMPROVED METAL RECOVERY FROM INCINERATOR CLINKER.

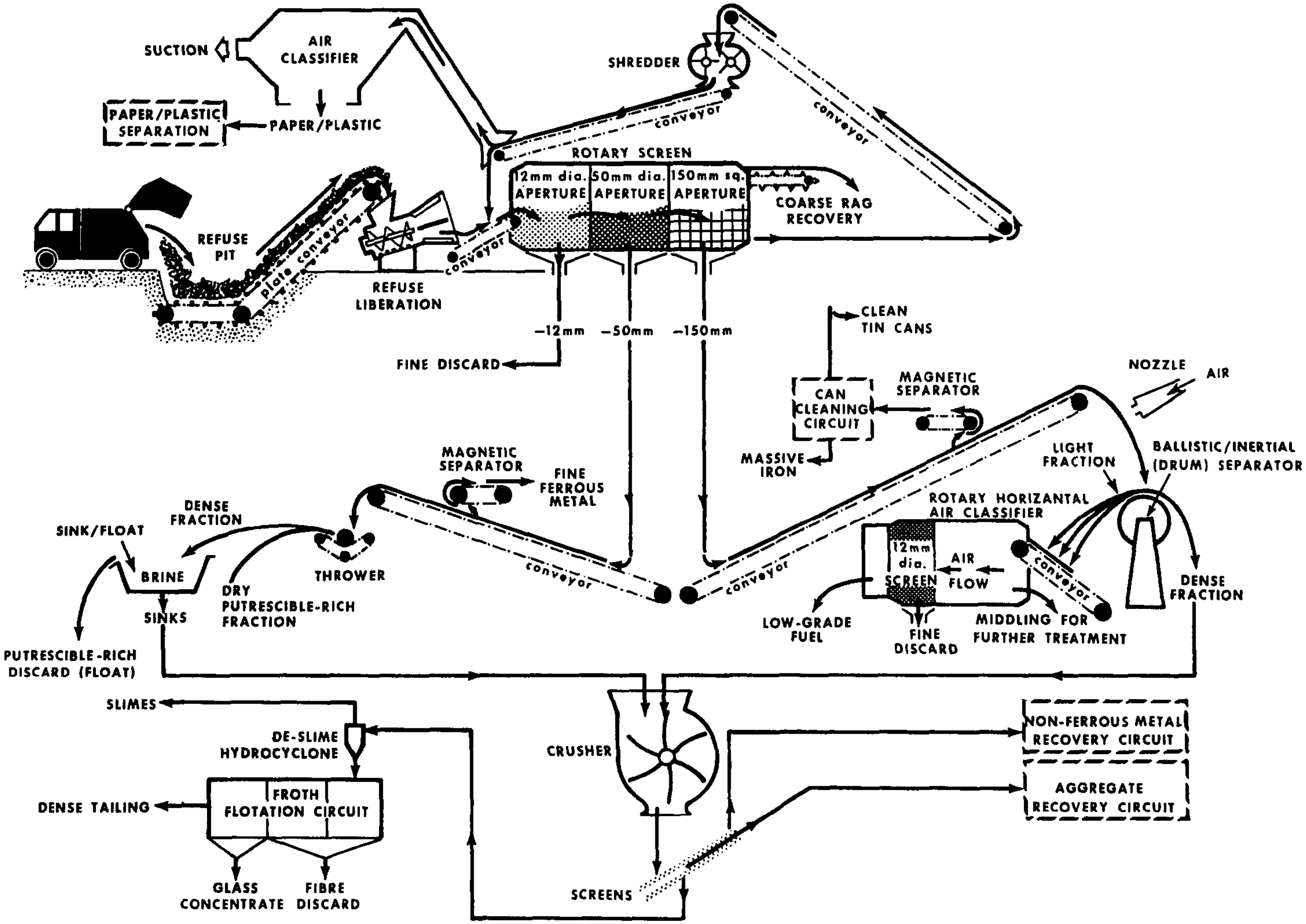


Figure 3. WARREN SPRINGS LABORATORY - SCRAP AND WASTE SECTION. PHYSICAL SORTING OF DOMESTIC REFUSE.

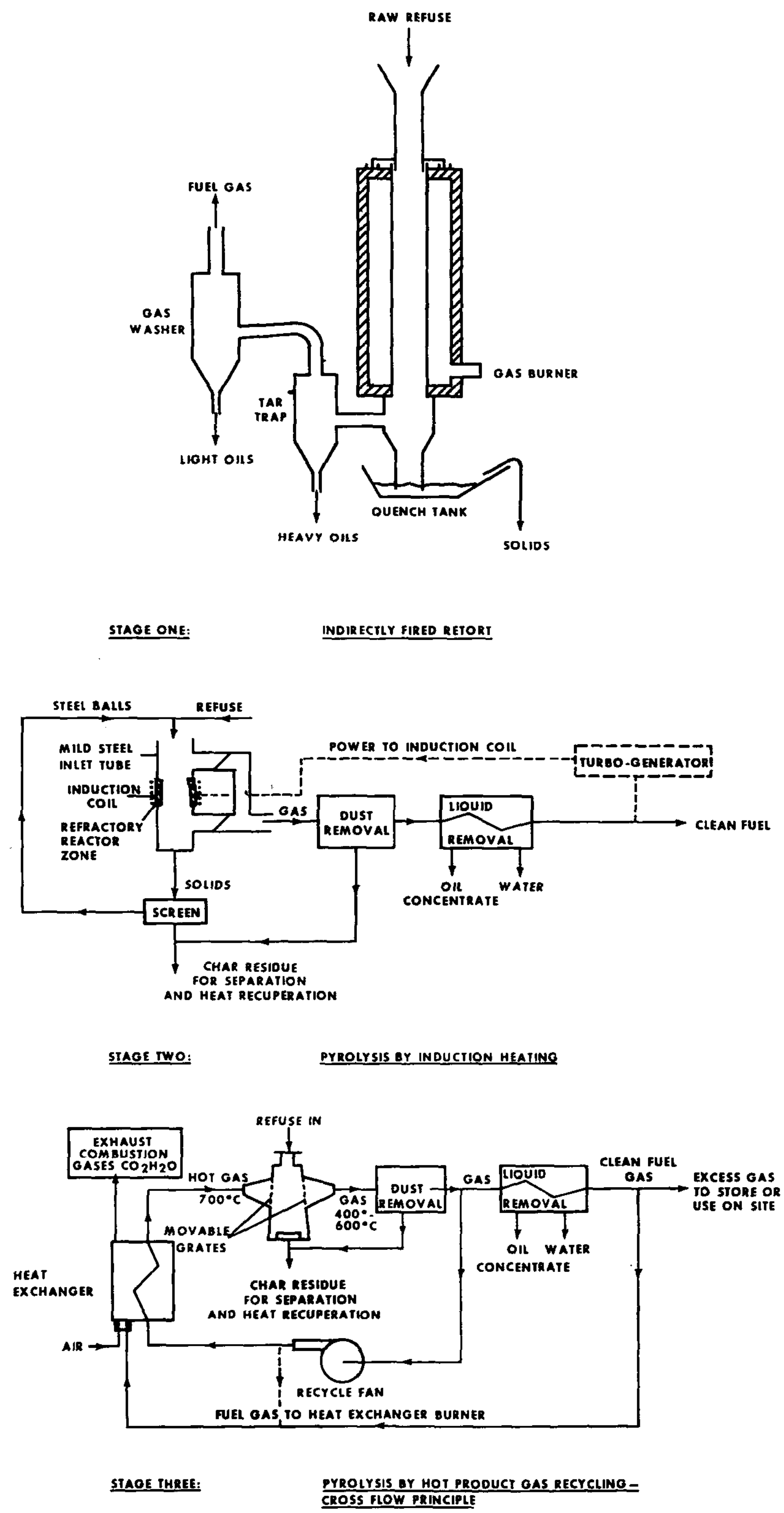


Figure 4. WARREN SPRING LABORATORY: PYROLYSIS.

is that in some instances, working temperatures can be reached in one-tenth of the time required in an externally-heated retort, but the circuit is complicated; in a full-scale plant, capital and operating costs would be high. In order to be self-sustaining, the energy from the char and the gas would be needed to generate electricity. The process might be economic on a large scale (the size of the coil being a limitation) or in special applications (e.g. in an enclosed system for the disposal of radio-active waste).

The third stage process utilizes a cross-flow heating system in which a combination of fuel from the char and some gas is used in a heat-exchanger to heat and pyrolyze the incoming refuse. Based on a calorific value for the incoming refuse of 4500 Btu/lb, the net energy output (as excess fuel gas) is estimated at 40% of the input energy. The costs are currently being worked out; the heat exchanger and fan are particularly expensive items, but the overall costs for a 100 tons/day plant are expected to be about two-thirds those of an equivalent-sized incinerator. The pyrolysis plant would be roughly equivalent in size to the gas-conditioning plant of the incinerator. Problems might arise in the treatment of the liquid effluent (depending on the conditions, about 2-20 gallons/ton of very highly contaminated effluent would be produced, which would be treated using activated sludge) and in the preliminary gas cleaning prior to recirculation (as some organic material and carbon might be deposited due to cracking of the gases; results so far suggest not much of a problem, and the remedy would be scrubbing with an inexpensive scrubbing medium). Air pollution should not be a problem; the combustion gases from the heat exchanger should be clean unless the char is also used as a fuel, in which case there might be some particulates. However, there should be less problem than with pulverized fuel combustion, and an electrostatic precipitator would probably be unnecessary.

(iii) The project on the pneumatic conveyance of pulverized refuse utilizes an 8" diameter line and has so far been proven over a distance of 350 feet (intending to increase to 1000 feet). The refuse is injected into the line by means of a screw mechanism, and is conveyed in "plugs" with air cushions in between. The pressure is low (2½ psi), there is no filtering requirement, and the system is inexpensive to operate. The system may be tried at the IMI facility (see below).

2. Developments at the Greater London Council (GLC): The GLC handles just under 3 million tons of refuse per year, or about 11,000 tons per working day. Its policy is to employ several methods for disposal rather than relying on only one, although it looks for facilities with capacities of no less than about 600 tons/day.

Sanitary landfill remains the preferred method when available, but the shortage of sites is critical. Membranes are being considered at marginal landfill sites, but the GLC is also looking at pyrolysis, fibre reclamation etc. Although the GLC operates a major new heat recovery incinerator at Edmonton (see below), it is unlikely to build another incinerator in the foreseeable future because of high costs and the difficulty of finding appropriate sites.

In partnership with Warren Spring Laboratory and Foster Wheeler (equipment manufacturer) the GLC may test out the Warren Spring pyrolysis system still being negotiated). It may also send ½ million tons/year of refuse to the APCM system (see below).

The Edmonton incinerator was designed for an average input of 1800 tons/day, five days per week, with a plant throughput of 1300 tons every 24 hours and a peak of 1670 tons. The electric power output was designed to be within the range of 25 MW and 35 MW but with a peak of 45 MW according to calorific value and throughput of refuse type roller grates; the boilers are single drum water tube boilers with partially water-cooled combustion chambers.

Commissioning of the plant took place during 1970/71. Teething troubles were aggravated by unexpected failures due to boiler tube erosion and corrosion. The failures were extensively investigated, and various modifications were made at the end of 1972. The plant did not become fully operational until April 1974. In the subsequent 12 months, 378,000 tons of refuse were incinerated (averaging more than 1000 tons/day) and 162 units of electricity were generated. Approximately 94% of the planned boiler availability (i.e. 4 out of 5 boilers in continuous use) was achieved, but only 77% of the refuse throughput. The difference was due to limitations placed on incinerating capacity by higher-than-acceptable steam temperatures at the superheaters when the furnaces worked at full load (new modifications will cope with this problem).

The total capital cost of the plant, including all major modifications to be boilers, was approximately £13.5 million. After deducting an income (from electricity, baled ferrous metal, and furnace ash) of £788,000, the net operating expenditure for the 12 months from April 1974 was £2,160,540, including debt charges; this represented a net unit cost of £5.72 per ton. These costs are considered "encouraging" as the costs of alternative systems of long distance haulage to landfill sites are thought likely to rise at a greater rate than those of the Edmonton plant.

3. Development by Associated Portland Cement Manufacturers (APCM): APCM has been working on a system for recovering fuel from refuse for about 5 years. A contract has been signed with Wiltshire County Council for the delivery of 60,000-80,000 tons/year of crude refuse. This will be pulverized in a hammermill (probably), passed through a magnetic separator to remove the ferrous, screened in a trommel, and then pulverized again in a shredder or hammermill (trials still under way); experiments have shown that air classification is not necessary. The resulting material (about 30-50 mm diameter) will be conveyed 1000 feet and fired directly into a rotary cement kiln. The residue will be absorbed into the resulting cement, and careful tests have shown that there are no adverse effects on the properties of the cement. The use of 4 tons of crude refuse will save 1 ton of clay or alternative raw material (presumably as a filler).

An abrasion problem is anticipated and is being designed for. The kiln temperature is 1450°C. The resulting gases will be scrubbed in a heat exchanger; hydrogen chloride will be neutralized, leaving a minute concentration of chlorine in the cement (difficult even to detect). Chlorine will also be present in the particulates trapped by the electrostatic precipitator, but this should pose no problems. Even if the plastic content of the refuse rises to 5%, with one-fifth of this being PVC, no problem is anticipated. All drainage from the building (inside and out) will go into a well and be used to blend slurries which then go into the kiln (therefore, no problems).

The gross calorific value of the refuse is estimated at about 4000 Btu/lb, depending on conditions. Some heat will be lost up the chimney, some will be used to dry the refuse (about 30% moisture content), and some to heat up incoming air. APCM seeks to replace about 10% of the fuel equivalent with refuse.

Start-up is expected by August/September, 1976. Wiltshire will pay a dump fee; the 10 year contract allows for variations if fuel costs increase, etc. APCM is currently in active negotiation with 4 other county councils (including the GLC). If all present cement works were converted, it is estimated that between one-sixth and one-seventh of the total UK municipal waste could be absorbed. It might also be possible to inject more unpleasant wastes into the pneumatic line (especially organics, which would easily be destroyed in the kiln). The process is provisionally patented in the UK and a patent is pending in the U.S.

4. Developments at the West Midlands County Council (WMCC): The WMCC disposes of approximately 1 million tons of solid wastes per year, mostly from domestic and commercial premises. Approximately 50% is disposed of by landfill, and 50% by incineration. A new incinerator has recently been opened at Coventry, and another is being built in Birmingham.

The Coventry Incinerator plant, costing about £4,138,000 at November 1974 prices (mechanical and electrical equipment, £2,300,000; civil engineering and building works, £1,500,000; land acquisition, design and supervision of construction, £338,000) has three boilers having 12 tons/hour capacity. Two boilers normally operate on a continuous basis. The boilers have water wall combustion chambers as well as shell and tube heat exchangers for heat recovery. The resulting steam is currently used in the plant to drive steam turbines, the excess steam being condensed in air cooled condensers. Within the next 12 months a heat transfer station will be completed and the heat will be used to provide hot water to an adjacent factory.

WMCC will soon by supplying up to 15,000 tons of refuse per year to the IMI waste utilization project (see below).

5. Development at Imperial Metal Industries Ltd. (IMI): IMI operates its own power plant at Birmingham with a steam raising capability to satisfy the factory's entire electrical power requirements as well as providing low pressure steam for space heating and process needs. The boilers currently burn coal, heavy fuel oil or natural gas in any combination. A refuse preparation plant is being constructed at which refuse will be shredded in a Tollemache vertical shaft pulverizer (100% minus 150 mm and 80% minus 50 mm). Ferrous scrap will be separated magnetically. The remaining refuse will be conveyed by container one mile to the power plant, where it will be fired in one of three modified boilers (Babcock and Wilcox water tube boilers fitted

with chain grate on which there is an established coal fire). A 50/50 refuse/coal mixture is thought achievable, with the possibility of increasing the refuse fraction to 75%. The plant includes grit arrestors and an electrostatic precipitator, and air pollution problems are not anticipated.

IMI originally intended to include air classification of the refuse but further study convinced them of difficulties that were apparently borne out by their visit to St. Louis. The difficulties are the loss of potential burning power in the heavy fraction, and mechanical problems (e.g. blockages).

In the future, IMI might employ the pneumatic conveyance system developed at Warren Springs to transport the shredded refuse from the processing station to the power station.

IMI has a five year initial contract with the West Midlands County Council which will pay £2 per ton for the first 15,000 tons disposed of in each of the first two years of the contract. Any additional refuse in the first two years will be disposed of without charge. It is uncertain whether charges will be made after the first two years. IMI is interested solely in the fuel value of the refuse (and not in its disposal) and the operation should be self-supporting.

6. Development at the Open University: Dr. Andrew Porteus is continuing his work on the acid hydrolysis of refuse (reported, for example, in Drobny, N.L., H.E. Hull and R.F. Testin, Recovery and Utilization of Municipal Solid Waste, Report SW-10c, Environmental Protection Agency, 1971). Alternative products include ethanol or edible proteins.

Despite analyses by Porteus indicating that the process is economically viable, little interest has been shown by local authorities. This may be partly because of the high proportion (50-60%) of the wastes left for disposal (i.e. the process is not a disposal process per se, but rather a recovery process).

Other work on hydrolysis is reportedly being done at the University of Wales by Professor D.E. Hughes and Dr. C.E. Forster.

FRANCE

NATIONAL OVERVIEW

The principal government agencies concerned with energy/materials recovery from municipal solid waste are (i) Ministère de la Qualité de la Vie (Ministry of the Quality of Life) and (ii) Ministère de l'Industrie et de la Recherche (Ministry of Industry and Research), as well as the Delegations for the Saving of Raw Materials, for the Saving of Energy, and for New Forms of Energy.

A new lab (Law No. 75-633, 15th July 1975) is similar in philosophy to the U.S. Resource Recovery Act. Furthermore, it provides the possibility of controlling methods of manufacture and of constraining certain activities (e.g. prohibiting or taxing non-returnable containers); where recycled materials are not significantly different from virgin materials, it prohibits advertising on the basis of virgin content. It is not clear when and to what extent these provisions will be implemented.

The central government gives the local authorities up to 20% support for disposal facilities, but until recently this could be applied only to the basic plant (e.g. an incinerator) and not to associated recovery equipment (this is now changing). Old fashioned ideas, fluctuating markets, and product specifications requiring virgin materials are among the factors that have militated against recovery.

At the present time, somewhat more than 30% of the municipal solid waste produced in France is disposed of by incineration, about 10% by composting, and about 60% by landfill (including 15% by sanitary landfill). Composting is still considered viable under certain circumstances, as orchards and vineyards are good markets (the plastics content can pose an aesthetic problem, although it may be good for binding the soil). A mechanised plant with capacity 60,000 tons/year (175 tons/day) was opened in 1974 in Reims.

Approximately 60% of the incinerator plants have heat recovery, mostly in the form of district heating (although some electricity generation, e.g. in Paris). It is considered worthwhile to install recovery in plants of capacity exceeding about 200 tons/day. Provision is usually made to meet only a proportion (i.e. about 5-10%) of the demand for heat during the winter, so that the supply and the total demand are well matched in the summer. However, incineration is now so expensive that the central government is discouraging its selection. Despite low interest charges (about 7-8%) and the 20% capital cost contribution, it can cost a local authority up to 60-70 francs/ton (approximately 50/50 capital/operating costs). Compare composting at about

35 francs/ton (mechanised) or about 25 francs/ton (non-mechanised) (assuming and including credit for sales), or landfill at about 15 francs/ton (unshredded) or about 20 francs/ton (with shredding).

Pyrolysis, fuel separation, etc., are being examined. A small pilot plant (based on the Garret pyrolysis process) was constructed by Sodeteg Engineering about two years ago near Rouen, but there were problems in maintaining continuous operation and the project was abandoned. Work is also being done at Orleans (see below).

In materials recovery, a committee is considering means to stabilize prices, possibly by maintaining a flexible stock. Work on de-inking is also proceeding. Glass manufacturers have expressed themselves ready to accept all recovered glass at a firm price equivalent to the price of alternative raw materials (possibly in order to avoid legislation on returnable bottles). The central government may give grants to several towns to promote separate collection of paper, glass, and plastic; a new process called ENERGY has been developed to reuse mixed waste plastics (even if soiled) in making a product which can be reformed.

NOTABLE DEVELOPMENTS

1. Heat recovery incinerators in the Paris area: There are incinerators at Issy (555,000 tons/year), Ivry (630,000 tons/year), and St. Ouen (360,000 tons/year). The plants serve a population of about 5 million, and handle about 1,650,000-1,700,000 tons of refuse per year, together with about 50,000 tons/year of industrial waste. While St. Ouen produces just steam for district heating, Issy and Ivry produce both electricity and steam for district heating in flexible proportions, depending on demand, etc. The electricity is sold to Electricite de France (at a price maintained artifically low) and the excess steam is sold to Chauffage Urbain, which has a 219 km district heating network in Paris (also at an artifically low price, namely one-half of the cost of producing steam from an alternative fuel). Experience has shown that the higher the steam pressure, the greater the problems (thus Ivry, operating at 90 bars, has more breakdowns than the older plant at St. Ouen, operating at 20 bars, although this is partly offset by the reduced maintenance problems at Ivry).

Although the plants are owned by the City of Paris, they are operated by Traitement Industriel des Residues Urbains (TIRU) which is staffed by personnel from Electricité de France.

2. Research at the Bureau of Geologic and Mining Research (BRGM), Orleans: BRGM is a pseudo-public company which does research funded by its customers. It has been working on recovery from post-incinerator waste, using a process similar to (but a little simpler than) the U.S. Bureau of Mines process. It has a pilot plant of capacity 1 ton/hour but it is hoping to construct a full-scale, 20 tons/hour facility, possibly in Paris (although TIRU is not yet convinced of its viability).

BRGM is monitoring existing work on front-end fuel/materials separation in the United States and United Kingdom. A consortium (including the Ministry of the Quality of Life and waste treatment equipment manufacturers) is funding a $1 million project that should lead to a pilot fuel/materials separation plant within 2-3 years.

ITALY

NATIONAL OVERVIEW

General information was not obtained from Italian sources.

NOTABLE DEVELOPMENTS

Recovery plants in Rome*: Four companies are responsible for the disposal of about 750,000 tons/year of refuse, in the northern, eastern, southern, and western sectors of the city, respectively. The plant in the western section, receiving about 29% of the total refuse, converts it by biostabilizer into fine compost (28% of the input) and medium compost (29%); 28% is incinerated, 2% recovered as ferrous metal, and 13% is lost as moisture.

The other three plants recover paper, animal food, compost and ferrous materials, the remainder being incinerated. The most up-to-date of the plants (in the eastern sector) has three 12.5 ton/hour sorting lines and treats on average 600 tons/day (Fig. 5). A fourth line, receiving wastes from special sources such as markets, street sweeping, etc., conveys them unsorted to the composting section.

Wastes entering the three sorting lines pass through a device that tears the plastic bags in which they are contained, and they are then jet-steamed to hinder the decay process. The wastes then enter a series of screens to separate (i) bulky refuse or discards which, after magnetic separation of ferrous materials, are conveyed to the incinerators; (ii) medium-bulky material, from which ferrous items are extracted magnetically and paper is separated by means of an air stream is directed tangentially at the conveyor, the residue going to the composting section; (iii) medium-size material which undergoes magnetic separation before being conveyed to the animal food section; and (iv) fine material which goes directly to the composting section.

The section handling the recovered ferrous material includes a rotary furnace fired by liquid fuel in which the metal is de-tinned, cleaned, and

* The Principal Investigator's visit to Rome proved fruitless as the plants were unexpectedly shut down. This description is based on a translation provided by the U.S. Embassy of the paper by Frangipane and Bozzini (see bibliography). The Scientific Attache of the U.S. Embassy has, however, visited one of the plants and (despite some skepticism voiced by contacts elsewhere in Europe) sees no reason to suppose that it does not operate as described. The system is being marketed in the U.S. under license by Grumman Ecosystems Corporation, Bethpage, New York.

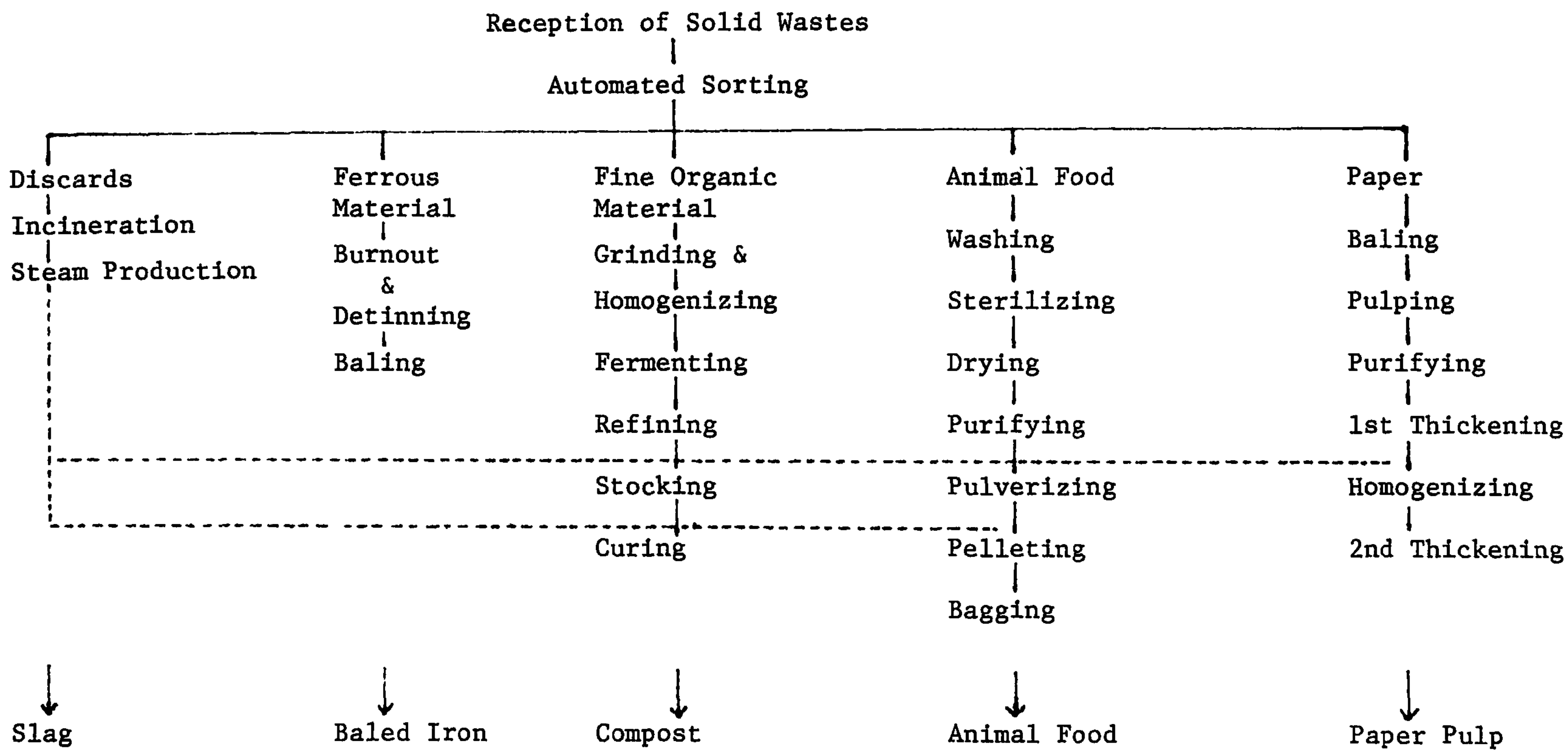


Figure 5. ROME SOLID WASTE PLANT (EASTERN SECTOR)

oxidized. Material going to the paper section is baled and then pulped; foreign matter is removed by screening, etc., and the pulp is passed via a prethickener and dewatering press to a grinding-homogenizing machine where it is finally treated with saturated steam to separate and remove paraffin and tar residues as well as to open the fibres.

In the animal food section, the vegetable material is first separated from the remainder, the latter being conveyed to the composting section or to the incinerators. The separation is performed by a special hydraulic-mechanical system which also washes and rinses the material and precipitates the inerts. The vegetable material is homogenized and sterilized in autoclaves using saturated steam produced by the incinerators. The product is dried to 10% moisture, further purified in pneumatic cyclone collectors, ground finely, and then pressed to facilitate packing. The food is sterile and can be preserved for several months.

Material entering the composting section is subjected to a fermenting process under controlled conditions, to a screening process, and finally to a curing process in a compost stabilization area. Other products may be added to provide enrichment.

The incineration and steam generation section consists of three furnaces producing steam which is used in the various sections of the overall plant (especially the animal food section); some steam is also conveyed to a nearby industry. Water used in the plant is treated and recycled.

Tests are now being carried out on the further recovery of plastics and glass; the former causes problems particularly in the paper and incineration sections, while the latter causes difficulties in the composting section. Glass recovery will involve the use of an optical separator.

Estimated costs range from 7,300-8,100 lire/ton for amortization plus operation, less 3,400-3,050 lire/ton proceeds from sales of materials (42% paper pulp, 41% animal food, 12% ferrous metals, and 5% compost), making net costs 3,900-5,050 lire/ton. These compare favorably with an estimated 3,374 lire/ton for "controlled dumping" in Milan, and 10,450 lire/ton for incineration with electricity generation, also in Milan.

LUXEMBOURG

NATIONAL OVERVIEW

No information was obtained from sources in Luxembourg, but contacts elsewhere mentioned that an incineration plant at Leudelingen, formerly planned to have three conventional 8 ton/day furnaces, would have one of these furnaces replaced by a high temperature Torrax system. Start up is due in 1976.

NETHERLANDS

NATIONAL OVERVIEW

The Sticting Verwijdering Afvalstoffen (Institute for Waste Disposal) has been established as a government institute for the purpose of advising both the government and the local authorities about waste disposal problems and energy/materials recovery. It is supported largely by the Ministry of Environment and Public Health, although about 10% of its budget comes from sponsored projects.

Some 30% of municipal waste is currently incinerated, 17% deposited after composting, 47% dumped (uncontrolled) and 6% placed in a sanitary landfill. The most important company in the composting field is N.V. Vuil Afvoer Maatschappij Amsterdam.

The central government provides no money for the construction or operation of disposal/recovery facilities, thus recovery can be carried out only if it is economic to do so. There is some research on recovery being undertaken at private companies and at universities, etc., such as the Institute for Applied Research and Technology (TNO).

Priorities are much the same as in the U.S., but pyrolysis is not considered ready for implementation at the present time. There are no pilot pyrolysis plants operating in the Netherlands, but two bench-scale fluidized bed processes are being set up at TNO (160 kg/hour) and the University of Enthoven (10 kg/hour), respectively.

A paper study is being conducted on fuel separation from refuse. A 1 ton/hour line separating paper and plastics has been set up at TNO but the recovered paper is of poor quality compared with paper which has been recycled directly, and the economics are questionable. The University of Enthoven is also experimenting with plastics separation and air classification. Some other research is being carried out on tin can separation and de-tinning.

NOTABLE DEVELOPMENT

Incineration with heat recovery: There are four heat recovery incinerators in the Netherlands, each generating electricity. The largest plant (at Rotterdam-Botlek) has a 20 ton/hour capacity, and the exhaust steam from the turbines is used to heat the brine stream in a multi-stage, flash-type desalination plant (capacity 3x 450 m^3/hour). The iron from the slag, and also the slag itself from most of the incinerators, is ocassionally reused (although markets are difficult to find).

There have been boiler corrosion problems in the three incinerators predating the Rotterdam plant. The latter operates at a relatively low temperature (360° C) and pressure (26 kg/sq cm) and has experienced no corrosion problems since 1972. However, due to the present adverse economic situation, growth in the Rotterdam area has been less than expected; thus the incinerator is operating below capacity and produces insufficient steam for the full-scale operation of the desalination facilities. In addition, two small rotary kilns designed to burn hazardous wastes have had problems in meeting air pollution standards, as well as other operating difficulties.

It is thought that new incinerators will probably be constructed without electricity generation because the capital costs are so high and there is insufficient return from the electricity produced. The prospects are better for the recovery of steam for industrial use.

SPAIN

NATIONAL OVERVIEW

No general information was obtained from Spanish sources, although contacts elsewhere suggested that apart from the recent construction of a 1000 tons/day incinerator with heat recovery in Barcelona, the only significant development is taking place at the Empresa National Adaro.

NOTABLE DEVELOPMENT

Research program at the Empresa National Adaro: This private laboratory is doing research on the front-end separation of municipal solid waste. The process used is based on the system developed at the U.S. Bureau of Mines, with modifications to allow for differences in the refuse composition, etc. (e.g. a much higher proportion, up to 60%, of fermentable organic material). A first-generation pilot plant was completed in 1974, and a second-generation plant was expected to start operations in September, 1975.

SWEDEN

NATIONAL OVERVIEW

The government agencies principally concerned with energy/materials recovery from solid waste are (i) the Ministry of Agriculture (particularly the National Environment Protection Board), (ii) the Ministry of Health and Social Affairs, (iii) the Ministry of Industry (particularly the National Board for Technical Development), and (iv) the 24 county administrative boards (nature conservancy sections).

Solid waste disposal is covered by tough environmental controls (e.g. regulations governing consent procedures for waste treatment plants, the prevention of pollution, etc.). The government strongly encourages energy/materials recovery and provides financial support for construction (e.g. up to 50% of the cost of recovery plant) as well as supporting research and development.

No particular system is favored at this time; several are being investigated, including composting (e.g., one to test the composting of municipal refuse with sewage sludge), pyrolysis, fuel separation, etc. The population density is fairly low outside the cities, and the predominant method of disposal currently is landfill. Stockholm has two incinerators: one is old and has no heat recovery other than provision for some drying of sewage sludge; the other is new and generates electricity. Gothenborg has a new incinerator (owned by a special company formed by the towns in the region); the plant handles industrial as well as municipal waste and provides heat for a district heating system. There are several other incinerator plants in Sweden, but there are no plans to build more in the foreseeable future.

Separation of paper by households and separate collection by communities will be mandatory within five years (other materials may follow). The two largest paper plants are currently installing the necessary recycling (de-inking) equipment, and a third is to follow, so that all of the paper can be absorbed.

Experiments are now in progress in various parts of Sweden involving the continuous separation of refuse in about 130,000 households. The materials separated are dry paper (i.e. newspapers, magazines, corrugated cardboard, cartons, bags), glass (bottles and jars), and sheet metal (tins). The experiments involved both multi-family dwellings and detached houses and are being conducted under the auspices of the ÅSAB foundation (including representatives from the scrap trade, the packaging industry , the Swedish Association of Local Authorities, and other interests). Random checks have shown that there is very little usable paper and glass left in the refuse sacks.

There is a government tax on the sale of beverage containers, and high deposits have been introduced on returnables (though not government required). So far, while cans seem to have retained their share of the market, there has been a shift from non-returnable to returnable bottles.

NOTABLE DEVELOPMENTS

1. Fuel/materials separation system at the Högdalen incinerator in Stockholm: In collaboration with the National Board for Technical Development, the Fläkt Company is installing a 5 tons/hour research facility adjacent to the reception hall of the incinerator. The overall cost of the project is estimated at approximately 4 million Swedish Kroner (about $900,000) of which the National Board will contribute about one-third.

A mainly dry process is being used (Fig. 6). The refuse will pass through a primary shredder and trommel screen into an air classifier. The light fraction, consisting of about 65% of the original input, will pass via a cyclone into a secondary shredder. Heat will be used to contract the plastics content (primarily thermoplastics) and thus be readily separated from the cellulosic fibres in a second air classifier (the plastics will be more dense and will drop). Meanwhile the heavy fraction from the first air classifier will undergo magnetic separation of the ferrous material, followed by screening, froth flotation, and further air classification to separate ceramics, glass, metals, etc.

2. Development of the Motala Pyrogas pyrolysis system: The Motala Company had conducted extensive pilot trials involving the pyrolysis of municipal waste at a lime-works where gas generators (of the kind used to generate coal gas) are still in use. Based on these trials they designed the Pyrogas system (Fig. 7), which can be used to gasify various solid fuels including municipal and industrial wastes, peat, sludge, etc. The generator comprises two stages with an internal cross-section of 10 square meters. The fuel passes through various zones in the generator, its temperature rising as high as 1500°C. The outputs include a gaseous fuel, a tar, and a slag. The tar can be burned in an oil-fired boiler and the slag, which is sterile, can be deposited without risk of pollution.

It is thought that a Pyrogas unit can pyrolyze at least 2 tons/hour of municipal waste. The first plant was to begin operation in autumn, 1975, at Gislaved (in southern Sweden) where 0.8 tons/hour of coal will initially be added. The process is guaranteed by the manufacturers to work with this input, but it is thought that the amount of coal can be subsequently reduced, thereby raising the capacity for refuse. The first six months' operation will represent a trial period in which it is hoped to answer remaining questions about the materials and energy flows as well as about pollution problems.

It is known that 1 ton of Swedish refuse will substitute about 0.2 m^3 of oil. With the 2 tons/hour guaranteed capacity, the Gislaved plant will give about 15,000 tons annual capacity, substituting about 300 m^3 of oil.

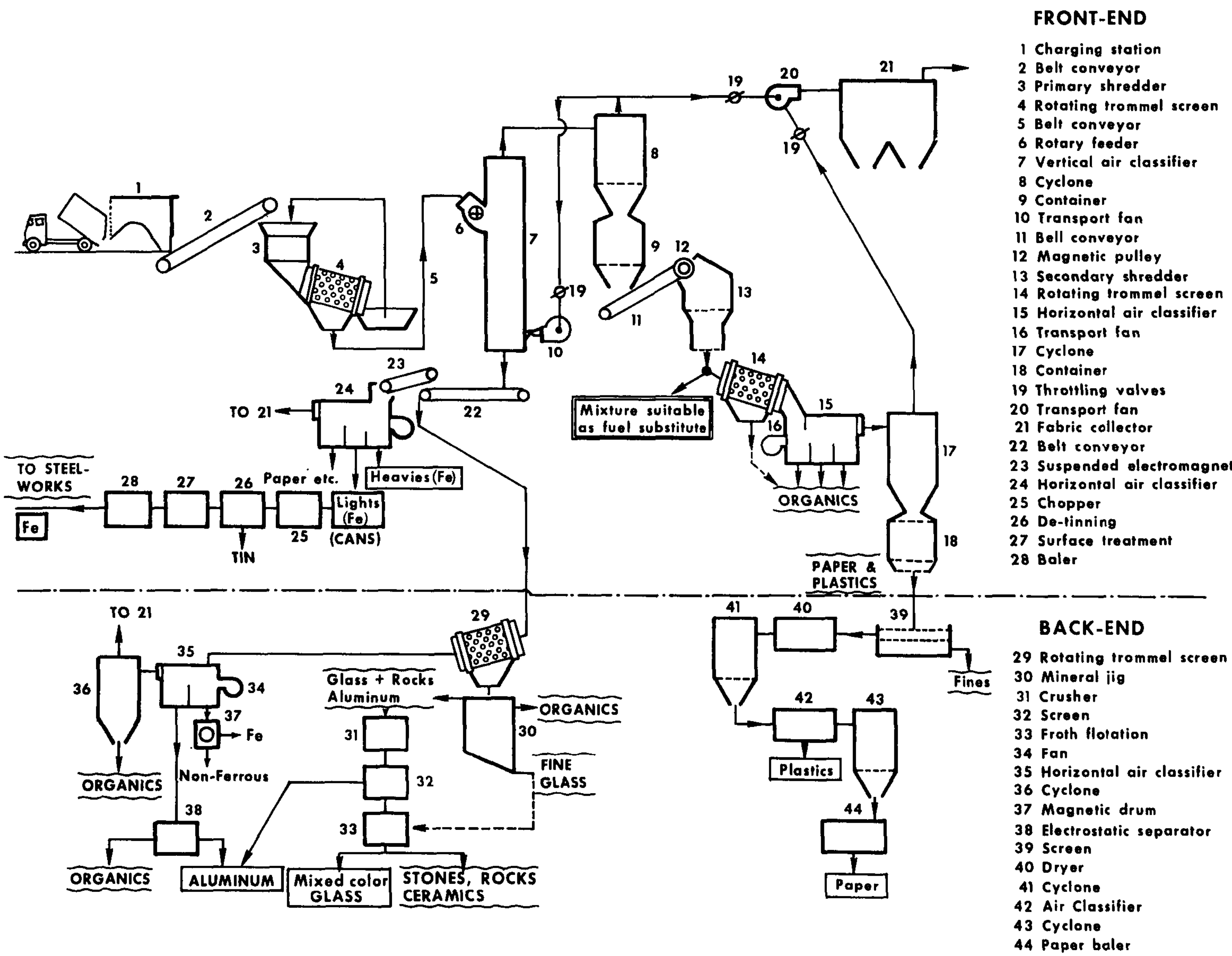


Figure 6. FLÄKT'S RRR-SYSTEM (RESOURCES RECYCLING FROM REFUSE).

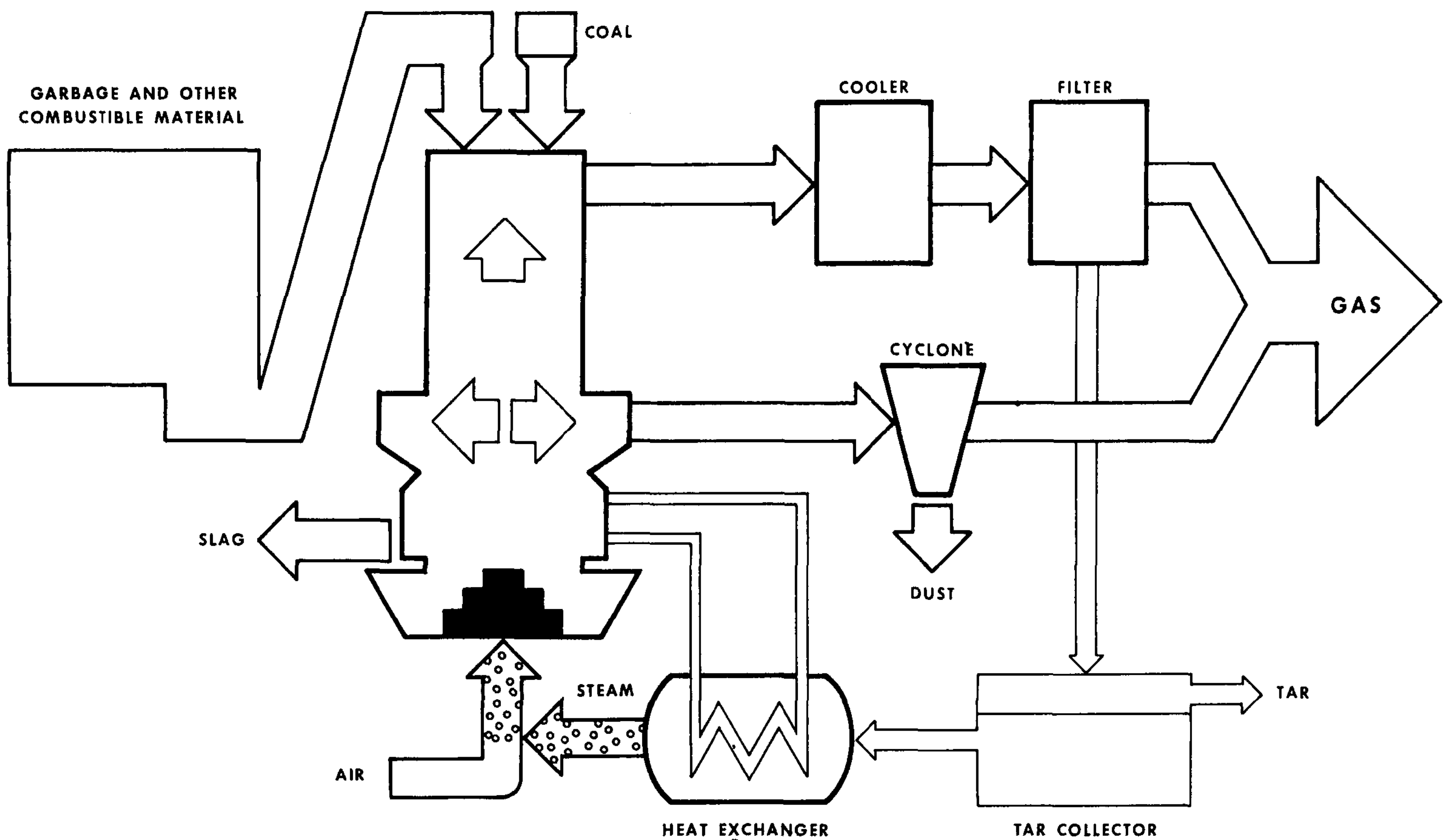


Figure 7. MOTALA PYROGAS.

If no coal is needed for the process, the capacity will be doubled.

The Gislaved plant will be owned by Gummifabriken Gislaved Aktiegolag (a rubber company). The National Board for Technical Development supported some of the early development, and the National Board for Environmental Protection is providing 50% of the costs of constructing the basic plant at Gislaved. Rubber waste will be included in the waste pyrolyzed, and the resulting gas will be burned in a furnace to provide heat for the factory.

SWITZERLAND

NATIONAL OVERVIEW

Although the Federal Agency for Environmental Protection supervises in a general way refuse disposal and has some influence over the choice of methods used, the local (or sometimes regional) authorities make their own decisions. The first priority has always been refuse disposal rather than energy/materials recovery (although this may be changing due to rising fuel costs).

Only the larger incinerators (say, over 200 tons/day) have heat recovery, providing electricity and/or district heating or industrial steam (the latter being preferred whenever possible as it is the easiest and most economical to operate). There are four incinerators with power generation alone (burning a total of 249,000 tons/year), eight with heat and power generation (561,000 tons/year), twenty nine with no recovery (371,000 tons/year), and twelve composting plants (86,000 tons/year). There are also both controlled and uncontrolled landfills. It is becoming increasingly difficult to find acceptable sites for incinerators within cities or on the outskirts, and it is even more difficult to obtain land for a landfill (especially because of the mountains).

Materials recovery is performed by private firms only (expect where separation is necessary to produce acceptable compost). Incinerator operators tend to oppose separate paper collections because of the reduction in the fuel value of the refuse. There is some separate glass and metals collection, although the glass industry is interested only in color-sorted glass. There is very little post-incineration ferrous metal separation since few steel mills will accept the product (due to impurities). Tests are being made on the use of incinerator ash for road-building (with promising results so far) which is particularly important since Switzerland faces a gravel shortage. There has been successful laboratory experimentation on the recovery of heavy metals (e.g., zinc and lead) from fly ash.

There is a trend toward re-usable bottles. Private initiative has led to the sale of certain beverages (including wines) in gauged bottles with ½ and/or 1 litre etched markings. All breweries are moving toward the use of the same bottles. Some large supermarkets are agreeing to use the same interchangeable screw-top bottles.

NOTABLE DEVELOPMENT

Incineration by Von Roll (headquarters in Zurich): A "typical" Van Roll plant has a capacity of around 600-900 tons/day (2 or 3 units of 300 tons/day), with no pre-treatment of the refuse, a heat recovery system producing power and/or district heating (plus some live steam, perhaps), a wet ash/residue system, and an electrostatic precipitator. The boiler is located after the main combustion chamber and is a suspended tube panel type, with cleaning by an automatic rapping/vibrating device. The combustion chamber temperature lies between 800-1000°C and the gases exit into the electrostatic precipitator at 220-280°C. There is not normally a gas scrubber, but one is going to be necessary in the future in both Germany and Japan (due to stringent air pollution regulations).

Von Roll does not recommend viewing a refuse incinerator as a power generator. Optimal steam conditions are different for the different purposes and a compromise has to be made. Boiler corrosion is now fairly well under control but unpredictable problems can arise. Nevertheless, it is considered well established that a large incinerator can break even on its operating costs/heat recovery, and possibly a slight profit can be made (if capital costs are not included).

The materials flow for a typical incinerator includes as little as ½ ton of input water (possibly clarified sewage water) per ton of refused burned. Each ton burned gives 350-450 kilos of solid residue (dry weight) with 15-20% water content, depending on the refuse composition. The flue gas contains a maximum of 2000 mg/nm^3 hydrogen chloride, 3000 mg/nm^3 sulphur dioxide, and traces of carbon monoxide. The carbon dioxide content is typically 5-11%. It is very difficult to measure heavy metals in the flue gases; it is known that most are removed at the beginning of the electrostatic precipitator.

In all new incinerators in Germany, as well as in new and certain old incinerators (over a specified size) in Japan, electrostatic precipitation is to be followed by full or partial scrubbing (depending on the size of plant, emissions allowed, etc.). The process may be wet or dry; the latter involves blowing an alkaline chemical such as dolomite into the combustion chamber (e.g. the Belgian Solvay process). The gases may or may not be reheated before emission to the atmosphere. Inevitably there are significantly increased costs, a greater risk of corrosion, and the possibility of water pollution.

Combined refuse/sewage sludge treatment is possible. At a 150 tons/year plant has been constructed in Dieppe, France, the heat from the combustion of refuse is used to de-water and dry the sludge (previously pre-thickened from 98% to 80% water); the dry sludge (40-45% water) can then be added to the refuse while maintaining self-sustained combustion. Two similar plants are planned for Brive and Deauville (also in France). However, the sludge drying unit is very expensive (it is a jacketed vertical column type heat exchanger with critical parts made of stainless steel), and the process is probably suitable only for smaller units.

In larger plants it is preferable to pre-heat pre-thickened sludge for about 20 minutes in a continuous operation, raising its temperature from 20 to 100°C (thermal conditioning). This changes the coagulation properties, making the sludge easier to settle. The thickened material from the bottom of the vessel is dewatered in a filter press to about 40-45% water; it is then a sterile, ordorless cake which is safe to deposit and can be used as a fuel (if ground to reduce its size) or as a soil improver, etc.

A major problem with combined refuse/sewage sludge disposal is that the authorities responsible for refuse and sludge are often separate; thus there are political rather than technical difficulties.

Von Roll considers that the burn-out in the supplementary fuel plant at St. Louis is poor. This is not a major problem where a landfill is available but it makes the use of the ash for road construction, etc., more difficult. Von Roll considers that if 10% refuse is burned, the fuel with the best burning characteristics (i.e. the normal fuel) will burn best, leaving the poorer fuel (i.e. the refuse) making up most of the unburned material in the ash. Possibly an after-burning grate might be needed.

WEST GERMANY

NATIONAL OVERVIEW

The government agencies principally concerned with energy/materials recovery from municipal solid waste are (i) Umweltbundesamt (UBA) (Federal Environmental Protection Agency) as well as federal Ministries such as Interior, Science and Technology, etc., and (ii) state agencies, e.g., Bayerisches Landesamt fur Umweltschutz (Bavarian State Agency for Environmental Protection).

With the help of experts from industry, the universities, other government departments, etc., the UBA has prepared a major solid waste program which was expected to be adopted by the government and issued toward the end of 1975. Solid waste management is currently covered by the Waste Disposal Law of June, 1972, which includes provisions for regional planning, control of solid waste facilities, limitations on the introduction of single-use packaging, etc.

Disposal in West Germany currently involves landfill, composting, and incineration. The government is studying pyrolysis, hydrolysis, and high-temperature incineration, and is developing a major project on energy/materials recovery (the "Reutlingen" project, see below). While it is thought that air pollution problems from pyrolysis plants might be less severe than those from incinerators, there are instead problems of water pollution and tars, which are being examined. Also being examined is the problem of removing chlorides from scrubber water (for the time being this water is lagooned or fed through a municipal sewage treatment plant). These and other research and demonstration projects will be supported in 1976 by the Ministry of the Interior (from a fund of 4-6 million D-Mark), with UBA providing administration and technical assistance. There may be additional funds from other ministries.

There are presently some 19 composting facilities in West Germany, and the percentage of waste disposed of by composting seems to be rising from about 2% to perhaps 5% (e.g. the plan for Stuttgart calls for an increase in the number of plants from the present 6 to a total of 19). There may be a trend away from using fully mechanized plants because of high costs: new plants are likely to involve shredding, mixing with other materials (e.g. sewage sludge) and placing in large windrows with mechanical mixing. However, mechanical mixing equipment for large plants is currently not very good, although development work is proceeding in East Germany and France. Markets are not strong in all areas, but there is a constant demand from vineyard owners.

There are currently 31 incineration plants, of which 27 recover energy. Several more plants are nearing completion. Some produce electricity but the problems of doing so (i.e., corrosion, difficulties of matching supply and demand, and questionable economics) have made the production of steam for other purposes (e.g. district heating, industrial uses, distilled water production, sludge drying) more attractive. A major new consideration is the need to meet very stringent air pollution standards, necessitating scrubbing of at least part of the gas steam in addition to electrostatic precipitation (five new plants are to have both types of cleaning). This significantly raises the costs (by about 25%). Nevertheless, incinerator technology is very advanced, and it is thought that large incinerators will continue to play a role in the disposal of very large quantities of refuse.

An interesting practice is the conversion of old coal-burning power or industrial furnaces into refuse incinerators, making use of the existing infrastructure. The refuse may be burned alone or in combination with pulverized coal or with sewage sludge. An additional advantage is the fact that new planning permission is not required.

NOTABLE DEVELOPMENTS

1. The "Reutlingen" recycling demonstration plant: Feasibility studies are presently being completed for the construction of a demonstration resource recovery plant probably to be located about 30 miles south of Stuttgart in a rural area, adjacent to a new composting plant, and serving about ½ million people. The process would initially involve shredding and air classification, with the light fraction providing paper recovery and the heavy fraction providing both aggregate material and composting feedstock. Market studies so far suggest that only paper is worth recovering, although it is anticipated that plastics might subsequently be recovered, followed by non-ferrous metals; glass recovery is not yet considered feasible. The purpose of the project is to test out the markets as well as the processes.

It is expected that there will be three lines each with a capacity of about 15 tons/hour; different processes will be tried out, leading ultimately to the choice of an optimum configuration. Wet processes will be avoided as far as possible in order to avoid water pollution problems.

The plant will probably be owned by an independent company formed by the federal government, the states, and private industry (both the manufacturers of disposal equipment and the users of the recovered products). It is anticipated that the federal government might provide up to 40-50% of the costs, the states about 10%, and industry the remainder. It should be noted that these estimates are tentative only.

2. Development at Krauss-Maffei (Munich): The Krauss-Maffei Company, which will be assisting in the "reutlingen" project, has developed a front-end separation process (System R80), currently at pilot-plant stage. The process includes primary magnetic extraction, shredding, secondary magnetic extraction, screening and air classification (Fig. 8). The air classifier separates the waste into three fractions, (i) the light fraction consisting of paper, plastic film, and light textiles, (ii) the middle fraction consist-

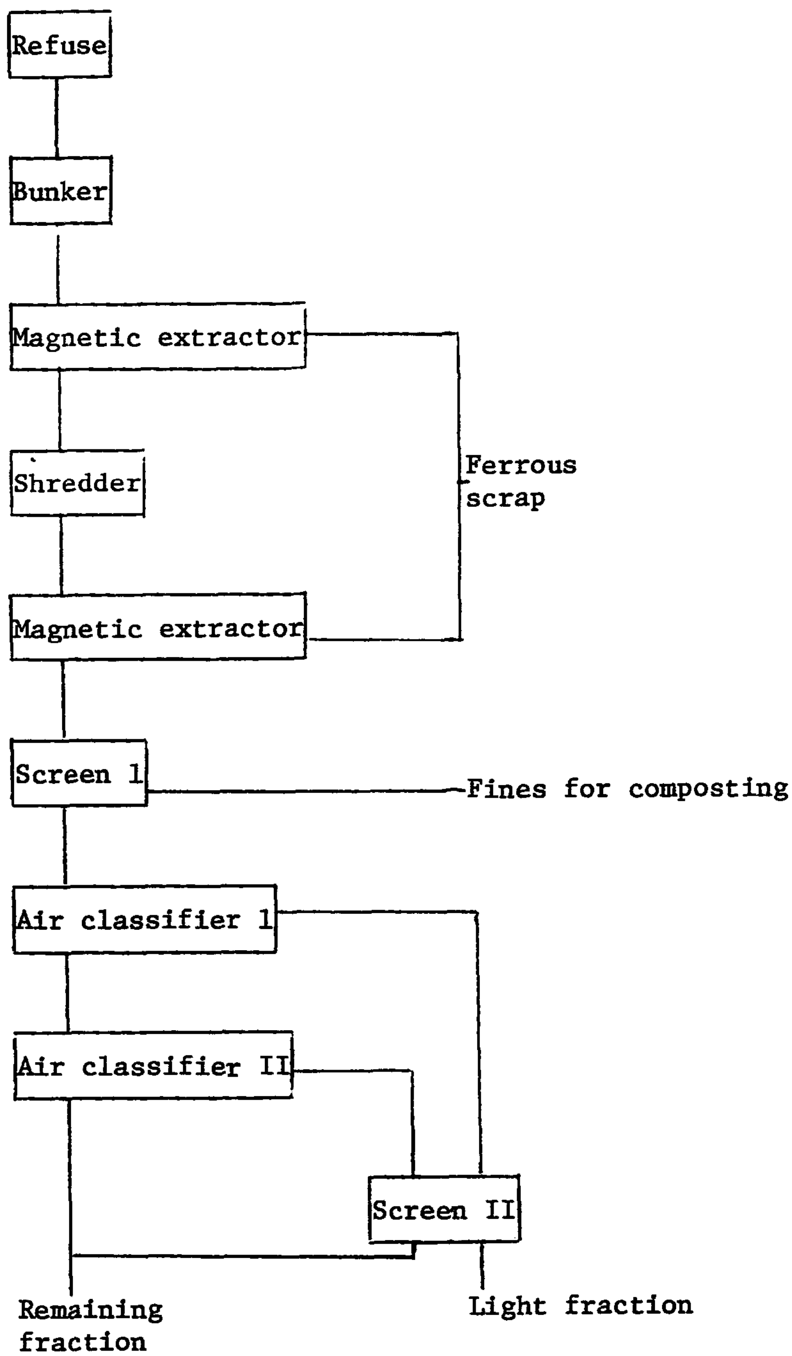


Figure 8. KRAUSS MAFFEI-SYSTEM (R80)

ing of cardboard, heavier plastics, leather wastes, etc., and (iii) the heavy fraction consisting of the heaviest plastics, non-ferrous metals, bones, wood, stones, etc.

Additional components can be added to the process depending on the particular conditions, the products required, etc. The products can include a composting feedstock, recovered papers and cartons (which can be re-processed to form new paper and cardboard), plastic granules, glass cullet, aggregate, and/or a combustible fuel (which can be incinerated or pyrolyzed).

3. Development at the University of Hamburg: Research on pyrolysis is reportedly being done at this university involving a bench scale fluidized bed system. No further information was obtained.

4. Development at Kiener, Goldshofe: A system has been developed which involves the gasification of coarsely shredded refuse in a rotary kiln. The gas produced is cracked in a gas generator and then burned in a gas engine to produce electric power. A pilot plant of capacity 40 kg/hour was originally constructed; however, this has now been shut down and a 100 kg/hour demonstration plant was started up in Goldshofe (August, 1975). The University of Stuttgart has been testing the system.

LIST OF ORGANIZATIONS AND INDIVIDUALS CONTACTED*

BELGIUM

Antwerp Waste Management Service
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* Does not include other organizations and individuals who were contacted but failed to provide substantive replies.

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FRANCE

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ITALY

Frangipane, E. de Fraja, and G. Bozzini, "Municipal Solid Waste Disposal by Recovery Plants in Rome", Translated by American Embassy, Rome, August 1975.

SWEDEN

Hovenius, G., "Composting Project at Laxå - Examination of Tenders of Mechanical Equipment", Statens Naturvårdsverk, 1975.

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Bahri, M., "Resources Recovery from Municipal Solid Waste-Full Scale Tests", Flakt (AB Svenska Flaktfabriken), December 1974.

"Regional Development Plan Serves Large Community", Solid Wastes Management, 17, December 1974.

National Swedish Environment Protection Board, "Solid Waste Management in Sweden", Prepared for ECE Seminar on the Collection, Disposal, Treatment and Recycling of Solid Wastes, Hamburg, September 1975.

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Schenkel, W., "Technological and Economic Feasibility, Research and Policy Principles Related to Collection, Transportation and Disposal of Solid Wastes", Prepared for ECE Seminar on the Collection, Disposal, Treatment and Recycling of Solid Wastes, Hamburg, September 1975.

Umweltbundesamt (Author: Klaus Stief), "National Information About the General Situation and Main Problem Areas in the Field of Solid Waste Management", Prepared for the ECE Seminar on the Collection, Disposal, Treatment and Recycling of Solid Wastes, Hamburg, September 1975.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

This is the report of a study which set out to determine whether priorities in Western Europe with respect to energy and materials recovery from municipal solid waste are the same as those in the United States, which include (a) the use of refuse as a supplementary fuel, (b) pyrolysis, and (c) resource recovery. The study also attempted to identify solid waste/energy processes in Europe (both existing and under development) that appear to offer potential advantages over processes currently employed in the United States.

Recovery activities in Belgium, Denmark, England, France, Italy, Luxembourg, Netherlands, Spain. Sweden, Switzerland, and West Germany are reported. For each country, a national overview is given, followed (where appropriate) by a description of particularly significant developments. Systems involving household sorting and separate collection, front-end materials/fuel separation, the burning of refuse-derived fuel in electricity generating plants and cement kilns, pyrolysis, incineration with heat recovery, and materials recovery from post-incinerator residues are discussed in the report. A summary of key findings is also included.

Most of the information was collected between July and September 1975. The report contains the names and addresses of all persons contacted in the study.

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