COMMISSION OF THE EUROPEAN COMMUNITIES
DG XII – RESEARCH, SCIENCE, EDUCATION

RAW MATERIALS

RESEARCH AND DEVELOPMENT

STUDIES ON SECONDARY RAW MATERIALS

I. HOUSEHOLD WASTE SORTING SYSTEMS

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PREFACE

This volume is part of a series of assessment studies on Secondary Raw Materials that have been prepared under the sponsorship of the "Commission of the European Communities" (Directorate-General for Research, Science and Education).

The decision to carry out those studies, as well as other work to be published under the general heading "Raw Materials Research and Development", results from current concern about prospects of supplying the European Community with raw materials in sufficient quantities and at acceptable costs in the mid- to long-term. An essential part in defining the purpose and scope of the work was played by a Sub-Committee of CREST (1), established to investigate on-going activities in the member states, both in the areas of primary and secondary raw materials, in order to determine what R & D actions, if any, should be undertaken by the Community to alleviate its supply problems.

The volume comprises 4 reports, each one of them prepared under contract with the European Economic Community:

1. Household waste sorting systems.

   Report from the WARREN SPRING LABORATORY, Stevenage (Contract No. 278-76-9 ECI-UK with the Secretary of State for Industry, London).

2. The disposal of urban waste in Italy.

   Report from COSTRUZIONI E IMPIANTE S.p.A., Fiat Engineering, Torino
   (Contract No. 279-76-9 ECI-I)

3. Household waste sorting systems in the Federal Republic of Germany.

   Report from UMWELTBUNDESAMT, Berlin
   (Contract No. 281-76-9 ECI-D)

4. Household waste sorting systems: costs and development in the French economic situation.

   Report from the BUREAU DE RECHERCHES GEOLOGIQUES ET MINIERES, Orléans
   (Contract No. 280-76-9 ECI-F)

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(1) Set up by the resolution of the Council of Ministers of the European Communities of 14 January 1974, the Scientific and Technical Research Committee (CREST) is responsible for assisting the Community Institutions in the field of scientific research and technology development.

COMMISSION OF THE EUROPEAN COMMUNITIES
(Directorate General XII - Research, Science, Education)

HOUSEHOLD WASTE SORTING SYSTEMS

A report
by

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November 1977

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HOUSEHOLD WASTE SORTING SYSTEMS

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SUMMARY

This final report of the CREST study of bulk consumer (household) waste mechanical sorting systems reviews the technology of waste sorting and describes how it is being applied in Europe and North America to the recovery of useful products from waste. Household waste statistics in the EEC are presented and potential markets for the products of waste sorting processes are surveyed. Comparisons are made of the estimated capital and operating costs of processes currently under development. It is concluded that differences in the calculated operating costs of the processes under consideration are probably not significant because of the different circumstances prevailing in the countries where they are being operated. It is suggested that more technical information is required on the performance of front-end shredding or sizing systems to enable data for the design of plants for different waste composition to be assembled. Particular attention should be paid to the recovery of paper fibre, and the need for more fundamental work on air classification is emphasised. Discussions have been held with the representatives of the co-pilot countries involved in the study to agree on recommendations for a Community R & D programme in this field. Joint recommendations for R & D are presented in this report.

This report was originally submitted as report CR 1399 (MR) from the Warren Spring Laboratory.

<u>CONTENTS</u>

1. INTRODUCTION

This is the final report in the CREST Study of Bulk Consumer (Household) Waste Mechanical Sorting Systems. Briefly, the terms of reference of the study were:

1. To study mechanical sorting systems that are in operation or under development for the recovery of usable commodities from bulk consumer wastes (household refuse) and to assess selected systems in technical and economic terms to identify which, if any, are suitable for beneficial use by members of the Community.

2. To report on these studies and make recommendations on the possible need for full scale proving trials of a preferred system, or systems, under conditions (waste composition, tonnage throughput, product markets etc) appropriate to the requirements of Community countries.

In this study Warren Spring Laboratory (WSL) acted on behalf of the United Kingdom as project pilots, with the assistance of Bureau de Recherches Géologiques et Minières (France), Umweltbundesamt (Germany) and Società Costruzione e Impianti s.p.a. - Fiat Engineering (Italy) as co-pilots. The study started in September 1976 with a series of visits by the WSL project team in the USA and Canada to assess the major North American developments in waste sorting. In November 1976 representatives of the pilot and co-pilot countries met in England to see the WSL pilot sorting plant and for discussions to formulate and coordinate the work for the study. A record of these discussions[1] and a detailed report of the American visits[2] were submitted as the first interim report to the Commission. Between January and June 1977 visits were arranged with the co-operation of the co-pilots to processes under development in France, Germany, Holland, Italy, Spain and Sweden. A detailed technical and economic appraisal of processes under development in the UK, Holland, Spain and Sweden, together with information on household waste statistics in the UK and an assessment of potential markets for the products of a waste sorting process formed the substance of a second interim report[3], submitted in July 1977. Coverage of French, German and Italian processes at this stage was the responsibility of the respective co-pilots.

The final period of the study has been devoted to consolidation of the information collected and discussions with the co-pilots to arrive at a consensus of opinion on recommendations for a Community research programme. Full agreement has been reached with the co-pilots and joint recommendations are presented in section 2.2. The conclusions in section 2.1, however, and any other opinions expressed in the later chapters of this report are those of the authors. There may be differences in emphasis between the final reports of the co-pilots, reflecting variations in national priorities.

In chapter 3 a brief review is given of the available information on household waste statistics and potential markets for the products of waste sorting plants in the EEC. Chapter 4 provides a summary of the technology of waste sorting in order to put the various flowsheets under development into perspective. Chapter 5 contains an interpretation in a European context of the information gathered in North America, with particular emphasis on the detailed technical and economic appraisals of the US Bureau of Mines and Black Clawson systems which are available. Chapter 6 reviews all the European systems which have been included in the study, although the process descriptions are given in less detail than in the previous interim report. The final chapter summarises estimates of the economics of waste sorting and details of the calculations of operating costs are given in an appendix.

2. CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

Solid waste sorting technology has reached an exciting stage in both Europe and North America, and appears to have good prospects of making an important contribution to solving some of the problems of household waste disposal and resource conservation within the next decade. Developments in Europe are, however, following a distinctly different path from those in the USA. This is due to differences in rates of waste production, compositions of the wastes and markets for the products. The per capita rate of production of waste is considerably higher in the USA than in Europe, and this enables benefits due to economies of scale to be realised. During the last year a number of very large plants (up to 2000 tonnes/day) have come on stream and several more are under construction. Waste in the USA is very rich in paper and, because of the widespread use of aluminium beverage cans, the aluminium content can be as high as 1 per cent. Extraction of these two components is therefore considered to be of greatest importance. There is, however, little interest in the recovery of paper for re-pulping, and there is much greater emphasis on the production of waste-derived fuel than in Europe. This is no doubt due to the availability of ample indigenous supplies of wood pulp and fears of inadequate supplies of energy.

There is a strong family resemblance between most of the various systems under development in the USA. With one exception they are dry sorting systems based on front-end shredding, ferrous metal extraction and air classification, followed in some cases by glass and aluminium recovery from the air classifier heavies. The influence of the pioneer work of the US Bureau of Mines is apparent, although there are differences in detail between the various flowsheets. There is much more information available on the separation efficiency of the USBM process than for any of the others but this is based on pilot plant experience. Detailed and reliable information on the quality of the products and economics of the processes will not be available until operational experience on the full scale plants has been gained. Preliminary reports indicate that teething troubles are being experienced but few operational data are available yet.

The exception to the general trend is the Black Clawson process, which uses wet pulping to separate a fibre product. The combustible rejects are dewatered and subsequently incinerated, or sold as a waste-derived fuel. The limited data available indicate that both the fibre and fuel products are of lower quality than products which can be separated in a dry processing system. It is difficult to see any advantage in adopting the Black Clawson approach of pulping the whole of the waste input, although pulping of a paper-rich product from a dry separation system holds promise as a method of fibre recovery.

The scale of developments in Europe is much smaller than in the USA, but there is a wider variety of flowsheets producing a greater range of products. The only full-scale commercial sorting systems in operation in Europe are the Sorain-Cecchini plants in Italy. The plants in Rome operate at a scale of 600 tonnes/day, and Cecchini state that the minimum capacity for economic viability is 400 tonnes/day. This process is, however, considerably more complicated and capital intensive than others under development in Europe, because the sorting plant is completely integrated with an incineration plant which raises steam for sterilisation of an animal feed product. There are processes at the pilot-scale in France, Germany, Holland, Italy, Spain, Sweden and the UK, and in several countries there are plans to construct plants with capacities in the range 200-300 tonnes/day.

Although a wide variety of flowsheets has been encountered in the processes under consideration in this study, all have one basic feature in common. The first stage, or "front-end", of the process is always to liberate the waste, if it is delivered in sacks, and then to improve its handling characteristics so that subsequent separation of its components according to their physical properties is facilitated. In general either primary shredding or sizing is used in the front-end of a sorting process. As mentioned above shredding is the preferred method in the United States and it has also been adopted in several processes under development in Europe. The alternative method of primary sizing is used by Sorain-Cecchini in Italy. It is also the basis of the system developed independently in England by Warren Spring Laboratory. A similar system is in use by Karl Fischer in Berlin, and it is understood that the BRGM pilot plant in France also incorporates separation by size rather than shredding. Air classification is limited to a smaller proportion of the input waste than in shredding plants because of the preliminary concentration of paper and plastics brought about by the sizing operation. The advantages of a degree of preliminary sizing are recognised by some organisations who nevertheless feel that shredding is essential. In one plant in the USA (National Center for Resource Recovery, New Orleans) and in the Aachen pilot plant in Germany fines are removed by screening before primary shredding, thus reducing the throughput and duty required of the shredder and minimising wear due to abrasive materials in the fines. As discussed in Section 4.1, the available evidence does not demonstrate unequivocally the superiority of either type of front-end process. The choice must depend upon the individual designer's assessment of the relative importance of the various advantages and disadvantages. Whether or not any of these points will prove to be of overriding importance will only be revealed as a result of long-term operating experience and further development work.

Having decided upon the type of front-end system he prefers, the designer of a waste sorting plant must choose the subsequent combination of unit processes which are most suitable for the extraction of saleable products from the waste. This choice is dictated to a large extent by the interplay between the composition of the waste and potential local markets for the products. As can be seen in Section 3.1, waste composition varies widely between different countries (and even between locations within a country). There is a clear tendency towards higher paper and lower organic contents in the more northerly countries and vice versa in southern Europe. Household waste in the UK is also characterised by a high content of inorganic fines in districts where coal is burned as a domestic fuel, and there is generally an inverse relationship between the proportions of paper and fines in the waste.

Most of the organisations visited in Europe regard paper fibre recovery as very important because there is a very strong incentive to reduce consumption of primary wood pulp by increasing the consumption of secondary fibre. In the UK waste-derived fuel is seen as an important alternative market for the paper in the waste. A high proportion of the country's energy requirements is provided by solid fuel, and it is hoped that the effect of cyclical variations in secondary material prices on sorting plant economics can be stabilised by having this alternative outlet. Not surprisingly, interest in making use of the organic materials in the waste is at its highest in Italy, where an animal feed product is being produced and sold. The market for compost is at best patchy in all countries, but in Holland finely divided organics have been found to be potentially valuable for use in brick manufacture. Ferrous metal is recovered everywhere because technology is well developed for extraction of a product which can be sold in existing markets. Interest in glass and plastics recovery is less uniformly distributed, but considerable development work is in progress.

All the processes under consideration have been developed to suit specific conditions relating to waste composition and product markets. This, of course, makes comparison of process efficiencies very difficult; a process which produces a high quality product in a specific location might perform very differently on waste of different composition in another country. For example, the Fläkt process, designed to use Stockholm waste as feedstock, is very unlikely to be suitable for use in Rome in its present form, and the converse is also true for the Sorain-Cecchini process. The need to adapt a process to suit local conditions is illustrated very forcibly by the almost complete re-design of US Bureau of Mines technology in Madrid, to a lesser degree by the modifications being made in the exploitation of WSL technology in different locations in England, and no doubt will be experienced by Fläkt in the design of a plant for use in Holland. Based on present evidence, there is no case for selecting one system rather than another except in relation to specific local circumstances.

The difficulties involved in comparing the economics of different processes are discussed in Chapter 7. It is concluded that differences in overall capital costs of less than 20% are not significant, but the average capital cost of a 20 tonne/hour sorting plant in the EEC recovering paper, fuel, ferrous metal and possibly glass should lie in the range 3-4 mua. Operating costs vary from country to country, but in general, although waste sorting is more expensive than direct landfill, it is an economically attractive alternative to landfill at a distant site involving the use of a transfer station. It is also cheaper than other waste disposal methods such as incineration and composting.

The main purpose of this study was to make recommendations for a Community programme of R & D into recovery of resources from household waste by physical sorting. In particular the project team was asked to consider the desirability of initiating a model investigation on a realistic scale to acquire engineering and economic data under conditions most relevant to the interests of member countries. The conclusion reached is that a sorting system must be designed to suit local conditions, particularly waste composition and product markets. The setting up of a single model plant to serve the Community is therefore not recommended. It is considered preferable to concentrate on investigations of unit processes aimed at improving separation efficiencies and the quality of recovered products. The following section presents recommendations for R & D which have been unanimously agreed between pilot and co-pilots. It is recognised that individual member countries may differ over the relative priorities of the recommended topics for research. The UK, for example, sees research into air classification systems, paper fibre recovery and the use of waste-derived fuel as being of particular importance.

2.2 Recommendations for R & D

Recommendations for Concerted Action

There are already several major research programmes in progress or planned within several member countries of the Community. The project team is very concerned to avoid recommending duplication of this research. It is felt, however, that there are certain areas where international discussion and co-ordination of this research would enhance its value, both to individual countries and to the Community as a whole. The spirit of international co-operation which has been experienced during the present study has been of great benefit and this could provide a foundation upon which further collaborative work could be built.

It is therefore recommended that a programme of concerted action should be established, provided that the support of national governments can be obtained. It is recognised that in some cases existing R & D is funded by commercial interests and could not be included in a concerted action programme. The programme should be organised to cover the following aspects of household waste sorting technology.

1) Work in progress or planned in member countries (e.g. the Doncaster prototype plant in the UK, the Bundesmodell Abfallverwertung in Germany) should be monitored, existing links between research groups should be maintained and new ones encouraged wherever possible. These links should be used to promote comparative investigations of different systems under consistent conditions, and studies of the effect of varying the composition of the feed. It is recognised that different project timescales might give rise to problems in making comparisons, but when the planned new generation of experimental plants working at a realistic scale is in operation co-ordination of research and parallel investigations in different locations could be very valuable.

2) Standard methods should be established for sampling and analysing household wastes, specifying the quality of waste-derived products, and reporting cost and related economic data. Comparison of processes in different locations is very difficult, but the value of such comparisons would be greatly enhanced if better standardisation of feed analysis, process parameters and product specification were achieved. The effect of statutory requirements applying to waste recovery in different member countries on the design and viability of waste sorting processes might also be considered.

3) Potential health hazards arising from the handling, treatment and storage of domestic waste and related products should be investigated. This is an area which would require considerable co-ordination of testwork and data collection.

The method envisaged for implementation of the concerted action programme is a series of meetings of technical experts from the member countries. Because of the wide range of topics for discussion it is suggested that these meetings should take the form of symposia lasting 2-3 days, with say, 20 invited delegates per symposium. The estimated cost of a four year programme of 3 symposia per year is 200,000 units of account.

This sum would not include any funds for specific projects arising from the concerted action programme.

Recommendations for Indirect Action

It is recommended that the major proportion of the financial resources allocated to R & D in waste sorting should be used in a programme of indirect action. Research is recommended into topics where it is felt that more fundamental studies or the development of new or improved separation techniques are required. The recommended topics for investigation come under three headings:

1) Separation Technology
2) Material Recovery
3) Energy Recovery

Separation Technology

The possibility of two to three projects in this area is envisaged. The highest priority is placed upon an investigation of air classification, but liberation and comminution of waste are also recommended for study.

Air Classification There are several air classification systems available, but there is a serious lack of the information necessary for scale-up of pilot installations and to enable the best choice for a particular situation to be made. It is therefore recommended that a fundamental investigation of the parameters affecting separation should be carried out prior to larger scale trials in association with the experiments on front-end systems. The main aims of this work should be:

a) To compare existing types of air classifier under consistent conditions.
b) To investigate the effect of changing design variables and composition of the feed.
c) To establish criteria for the design and scale-up of air classification systems to process household wastes.

Liberation/Comminution The choice of a front-end system for a sorting plant is still largely a subjective one. Information in the literature is of limited help because of the varying conditions under which the experiments are carried out. It is therefore, proposed that comparative investigations of shredding and sizing systems at a scale of at least 10 tonnes/h should be carried out under consistent conditions with a clearly defined feed. Particular attention should be paid to the following points:

a) The suitability of the processed waste for subsequent separation into products.
b) Elimination of gross oversize materials in sizing plants.
c) Maintenance and reliability.

The concerted action programme could be of assistance in promoting this research. The cost of purchasing new equipment could be minimised by co-ordination of studies in different research groups using existing equipment as far as possible.

Materials Recovery

The two most important topics for further research are paper fibre recovery and plastics recovery. Two projects in each of these topics are envisaged.

Paper Recovery In most locations paper is potentially the most valuable constituent of the waste so there is a strong incentive for its recovery. The importance of household waste as a source of secondary fibre has already been recognised by the CREST Working Party on Paper Recycling, and a number of research topics in this field have been included in a proposal for a research programme on paper and board recycling. It is felt that certain aspects of this earlier programme have been largely achieved in the present study. In particular most of the work recommended in Part A of the programme has been done in the present study, e.g. classification of urban wastes, the technical feasibility of separating paper fibre from household wastes and economics of processing to obtain a fibre product. Further effort should concentrate on the recommendations in Parts B and C which relate to the use of urban fibre by the paper industry and health problems which might arise from its use. In addition it is considered very important that support should be given for further R & D on paper separation technology, an aspect which was not included in the earlier recommendations by the Working Party:

a) Most existing paper fibre recovery systems are based in part on air classification to provide a paper-rich concentrate for further upgrading. There is a requirements for research into the design and operation of air classification systems to produce a better paper-rich product.

b) Further work is needed on methods of separating plastics film from paper which are less costly in terms of capital equipment and energy consumption than existing ones.

c) The development of other novel methods of paper recovery should be encouraged. These might be based, for example, on the selective detection and removal of specific contraries from a paper-rich concentrate.

d) As an alternative to dry separation of a paper fibre product, wet processing at the front-end of the paper mill should be investigated in co-operation with the paper industry.

Plastics Recovery Recovery of paper fibre will normally result in the production of a by-product which is rich in plastics film. In some member countries plastic bottles are a significant constituent of household wastes and these can also be separated as a product. Research is therefore recommended into the separation and cleaning of plastics concentrates, paying particular attention to the following aspects:

a) The indications are that the size and nature of the potential market for plastics products recovered from household wastes varies considerably between the member countries. In some locations it might be possible to sell a mixed plastic product, while in others segregation of polymer types will be necessary. Similarly, requirements for reclaimed polymer for use in moulding or film blowing applications will vary. A community-wide market study is therefore recommended to determine where R & D effort might be most profitably applied.

b) There are several processes available for the manufacture of products from mixed waste polymer. Although perhaps the main problem to be solved in this field is the creation of new markets for the products, there is scope for further work on the feedstock formulations required for specific end-products, and the effect of additives on product quality.

c) The potential for developing technology for separation and cleaning of mixed and contaminated polymer waste merits investigation. The nature and level of contaminants which inhibit the use of reclaimed polymer in standard moulding or film blowing equipment should be studied, taking into account the possibility of developing new chemical additives to counteract the degradation of secondary polymers during moulding.

Energy Recovery

The project team is aware that an EEC Energy Research Programme was adopted by the Council of Ministers in 1975. One of the main subject areas is Energy Conservation, and project proposals have already been received which relate to the use of the energy content of wastes. This is, therefore, another area where close co-ordination of projects by the Commission is essential. It is considered that further work is needed on the use of both shredded and densified waste-derived fuels, and the following project areas are suggested for consideration:

a) Community support should be given to encourage an investigation of the use of shredded waste-derived fuel (for example, in the generation of electricity). Shredding, handling and firing systems for suspension-fired boilers will need to be developed, but there is much relevant experience in the USA which can be drawn upon.

b) Experience in the UK suggests that for industrial use a densified fuel product is most likely to have adequate storage and handling characteristics. A great deal of work is required on the continuous production of fuel pellets or briquettes. Most work carried out to date has used machines designed for agricultural purposes and many problems have been encountered. Pilot-scale tests to measure specific power consumption, die wear and throughputs are needed to enable suitable equipment to be designed. Methods of handling densified waste-derived fuel are needed and extended firing trials are necessary to determine the effect of firing waste-derived fuel on corrosion, fouling of boiler tubes and atmospheric emissions. Possible additives to the fuel from the point of view of increasing its calorific value, prolonging its storage life, reducing its susceptibility to water and inhibiting biological activity should be examined.

Funding

In making suggestions for the allocation of funds to the three project areas the project team has taken into account the close inter-relationship between these areas and the fact that results of the work on separation technology will support and benefit research into materials and energy recovery. Nevertheless, materials recovery is regarded to be of primary importance and the largest share of the funding should be directed to this area. With these considerations in mind the following allocations of funds for indirect action over a period of 4 years are suggested:

Separation technology	(3 projects)	0.8 - 1.0 mua
Materials recovery	(4 projects)	1.9 - 3.0 mua
Energy recovery	(2-3 projects)	0.8 - 1.2 mua
	Total:	3.5 - 5.2 mua

It is expected that the indirect action programme would attract a 50% contribution from the Commission, i.e. a sum of 1.75 - 2.6 mua.

A total budget requirement of 3.7 - 5.4 million units of account over a period of 4 years is suggested for the combined concerted and indirect action programmes.

3. WASTE STATISTICS AND MARKETS FOR PRODUCTS

3.1 Household Waste Arisings in the European Community

Household waste statistics for the member countries have been obtained from the co-pilots, members of the CREST Consumer Wastes Working Group and a report on the post consumer waste stream in the EEC[4]. The statistics are summarised in Table 1. These are the most recent data available, but they do not all refer to the same year. Nevertheless they give an indication of the size of the waste disposal problem in the Community. The total municipal waste stream in the Community amounts to some 73 million tonnes/year, generated at a rate of just under 300 kg/capita/year. The rate of waste generation tends to increase as standards of living improve, and it is interesting to note that it is greater than 600 kg/capita/year in the USA.

Methods of disposal in Belgium, Germany, The Netherlands and England are shown in Table 2. Statistics for France and Italy are available in a slightly different form and are considered separately. In France 284 plants treat about 20,000 tonnes/day of wastes. This corresponds to about 50% of the total waste collected, the remainder presumably being disposed of by direct landfill. The types of treatment in France are as follows:

Incineration	126 plants	5800 tonnes/day
Incineration with Heat Recovery	20 plants	8100 " "
Composting with Incineration	40 plants	2400 " "
Composting	46 plants	1700 " "
Shredding and Landfill	52 plants	1600 " "

In Italy there are 190 plants in operation or under construction treating about 19000 tonnes/day of waste, or just under 50% of the total waste collected. Methods of treatment are:

Incineration	148 plants	1300 tonnes/day
Composting with Incineration	32 plants	3700 " "
Composting	6 plants	500 " "
Recycling	4 plants	2000 " "

TABLE 1. - EEC Household Waste Statistics

Member Country	Total Municipal Waste Stream m. tonnes	Average Rate of Waste Generation kg/capita/year
Belgium	3.0	309 (255 in Flanders)
Denmark	1.5	306
France	12.0	235
Germany	18.0	300
Ireland	0.6	200
Italy	14.5	261
Luxembourg	0.1	333
Netherlands	3.5	300
United Kingdom*	19.4	346
Total	72.6	287

* Figures extrapolated from data collected by Waste Disposal Authorities in England. Commercial waste and bulky waste delivered to Local Authority sites by the public are included

TABLE 2. - Methods of Waste Disposal

Member Country	Disposal as % of Total Waste Stream		
	Landfill*	Incineration	Composting
Belgium (Flanders only)	62	29	9
Germany	72	25	3
Netherlands	50	30	20
UK (England only)	91	9	<1

*Includes shredding followed by landfill

Landfill is the most widely used disposal method, accounting for at least 50% of the waste collected in all member countries. Incineration is more popular on the continent, where it is the treatment method for 20-30% of the waste in several countries, than in the UK, where it is no longer favoured by the Department of the Environment. Composting is also quite popular on the continent, despite the fact that the market for the product is very variable.

It is difficult to compare analyses of household wastes in different countries because of variations in the methods of analysis and the variety of ways in which the results are expressed. National average waste compositions, although interesting for the indication they give of the total loss of resources in household wastes are of limited value to the recovery plant designer because of the wide variations in composition between different locations, as well as seasonal variations in a specific location. The variation in waste composition is illustrated in Table 3, which shows analyses of the waste in a number of European towns and cities. There is a clear tendency towards higher paper and lower organic contents in the more northerly countries and vice versa in southern Europe. Stockholm waste is very similar in composition to waste in the USA, where it is usual for the paper and board content to be higher than 50% and the proportion of vegetable and putrescible materials tends to be low. Household waste in the UK is also characterised by a high content of fines in districts where coal is burned as a domestic fuel, and there is generally an inverse relationship between the proportions of paper and fines in the waste.

TABLE 3. - Waste Composition in Different Locations

Constituent	Increasing Paper ← Composition, Weight % Sweden Stockholm	France Paris	UK Stevenage	Germany Aachen	Increasing Organics → Holland Amsterdam	Spain Madrid	Italy Rome
Paper and Board	40-50	34	33	31	26	19	18
Vegetable and Putrescible	10-20	15	16	16	46	50	50
Metals	6- 7	4	7	7	3	6	3
Glass	8-10	9	9	13	14	3	4
Plastics	6- 8	4	3	4	6	8	4
Textiles	} 15-20 (Textiles, Fines, Unclassified)	3	3	2	2	2	} 21 (Textiles, Fines, Unclassified)
Fines		22	25	22	} 3 (Fines, Unclassified)	} 12 (Fines, Unclassified)	
Unclassified		9	4	5			

3.2 Markets for the Products of Waste Sorting Plants

An attempt was made in the second interim report[3] to describe the potential markets in the UK for products extracted from domestic waste. It was pointed out that although prices for established grades of scrap may be published, it will not be possible to establish a clear relationship between the value of the products of a sorting plant and existing primary or secondary material prices until commercial-scale plants have been in operation long enough for product consistency and quality to be evaluated. An additional complication is the effect of the severe fluctuations in secondary material prices which have been caused by the supply and demand cycle in recent years. For the present the best that can be done is to base the product value on the price of the nearest comparable material, allowing a reasonable financial incentive for the prospective user to purchase a waste-derived feedstock. It was concluded that there are good prospects in the UK for finding markets for recovered paper fibre, waste-derived fuel, ferrous metal and glass, but that the prospects for selling plastics, compost and animal feed are not very good, at least in the short term.

In considering the Community as a whole it has only been possible to obtain a very limited amount of information about potential product markets. Italy is the only member country in which experience of the operation of commercial-scale plants has been built up over a period of several years. The indications are that the markets for recovered products in Italy are considerably more buoyant than seems likely to be the case in any other member country, with a wider range of products being saleable at considerably higher prices than elsewhere in the Community. This is illustrated in Table 4, which shows the best current estimates of the values of household waste-derived products in the member countries, expressed in units of account per tonne of material. Where it is known that there are strong reservations about the marketability of a particular product this is indicated by ascribing nil value to the product; a question mark indicates that marketing prospects and values are uncertain.

The Community is heavily dependent on imported wood pulp and it is generally agreed that increased recycling of paper fibre should be encouraged. Household waste is potentially a major source of additional fibre for recycling. Active work on the recovery of a paper product from a sorting plant is under way in France, Germany, Italy, The Netherlands and the UK. This work has demonstrated that it is possible to produce paper-rich products containing not more than 5% contraries, and that such products can be used in the manufacture of the middle ply in multi-ply board. While further development work and product evaluation is needed, in most countries the value of a paper-rich product is expected to be of the order of 20-30 ua/tonne.

TABLE 4. - Values of Waste-Derived Products in the Community

Product	Estimated Price units of account/tonne						
	Belgium	France	Germany	Ireland	Italy	Netherlands	UK
Paper	?	23	11-23	18-22	65-80	36	18-31
Fuel	?	10	?	?	?	?	8-11
Ferrous Metal	?	18	13-26	18	60-70	?	18
Plastics	?	53	42-76	nil	600	71	nil
Organics:							
Compost	3	?	2-4	nil	4	?	nil
Brickmaking	?	?	?	?	?	4-5	?
Animal Feed	?	?	nil	nil	55-70	?	nil
Glass	9*	22	8-10	21*	?	?	12-15

*These prices apply to colour-sorted glass

Interest in the production and use of waste-derived fuel is probably greater in the UK than in the rest of the Community, but there is also active research in progress in France, Germany and Italy. The product seems most likely to find a market as a supplementary industrial fuel in factories where there is existing equipment for burning solid fuel. Because there are quite severe limitations on the amounts of contaminants, particularly plastic film, which are acceptable to paper mills, a proportion of paper will always have to be recycled from a sorting process together with other combustible materials. It therefore makes sense to have a second outlet available in the form of waste-derived fuel. A further advantage of having an alternative outlet is that it provides some scope to adjust the operation of the plant to allow for variations in the demand for specific products. A great deal of further work is required to demonstrate the acceptability of waste-derived fuel, but promising results have been obtained. A value of around 10 ua/tonne seems reasonable.

There is an established market for ferrous scrap, although the acceptability of ferrous metal extracted from household waste has not been demonstrated in some member countries. Ireland, for example, has no experience and in France it appears to be necessary to export such scrap to Italy to find a market. The value of the scrap is very much higher in Italy than elsewhere, probably because of a thriving market in the manufacture of reinforcing bars for concrete. In the UK the only current market is in refined iron-making, where the tin content is beneficial for the manufacture of certain grades of cast iron, but there is room for considerable expansion of this market. In the future detinning could provide an additional outlet if an economic method could be found to reduce the tin content of detinned used cans to 0.02-0.03%, at which level they could be used in high-grade steel manufacture.

The very high value for recovered plastics in Italy was quoted by Sorain-Cecchini at their Rome plant. A new plant to produce a plastics concentrate for film making and subsequent manufacture of refuse sacks was under construction. There is strong interest in several other countries, but estimates of the value of the recovered material are considerably lower than in Italy. There is unlikely to be a market in the UK or Ireland in the short term because existing plastics reclamation activities are insufficient to exhaust supplies of waste plastics from industrial sources.

The market for compost is very variable. Provided the quality of the product is high, i.e. undesirable constituents such as glass and metals are removed, it appears to be a saleable commodity in several countries. Even in the UK, where composting is not normally considered to be a viable method for waste disposal, experience at one plant in Leicestershire has shown that with energetic marketing the product can be sold. Its value is very low, however, and it should be remembered that the organic fraction of raw waste would need further treatment at extra cost to realise even this low value. An alternative outlet for the organic fraction in brickmaking, which is being investigated in Holland, has the advantage that the organics can realise the same value as compost without additional treatment. Production of animal feed provides a method of making a high value product from part of the organic content of the waste. Italy is the only country where such a market exists at present, but there is also strong interest in France. On the other hand, in Germany, Ireland and the UK, there are strong reservations about the production of animal feed. Contamination of the product with toxic substances such as metals, discarded medicines, insecticides and weedkillers would be of great concern. In addition, the success of the Italian process is closely associated with daily collection and delivery of waste in vehicles which cause the minimum compaction of its constituents.

There is a market for colour-sorted glass cullet in several member countries, but the manufacture of green container glass from mixed cullet has only been investigated in the UK. Recovery of glass for use in container manufacture is unlikely to be economically attractive in areas remote from a glassworks. There has been some research into the use of waste glass as fillers for paints, plastics, etc and in the production of floortiles. It is too early to predict the size of the market which might become available for these kinds of product.

4. THE TECHNOLOGY OF SORTING

In order to sort one material from another, some difference in properties must be exploited. The property might be physical or chemical, or in some cases a combination of the two. Binary mixtures of materials with widely differing properties, for example, iron and glass, present few problems in their separation but when considering the sorting of household waste into its various components, the complexity of the mixture introduces many obstacles. The dominant charateristic of household waste is its heterogeneous nature; its components possess a wide variety of sizes and shapes, and physical and chemical properties. Separations are usually achieved by the identification and use of a particular component property and many different principles have been tested. These include size, shape, mass, colour, density, friction, elasticity, brittleness, magnetic properties, electrical conductivity, etc. In many cases the equipment used to exploit these properties has been developed from primary mineral processing technology and in fact much of the research and development work in the sorting field is being conducted by experts in mineral processing technology. In many respects household waste can be considered as an 'ore' often being 'high grade' in the case of paper and 'low grade' in the case of non-ferrous metals.

In practice, although similar properties are exploited for separation, designs of equipment are variable as is the order in which components are removed from the bulk waste stream. The complete sorting processes encountered during the course of the current study are described later whilst this section is confined to the principles and types of equipment for unit separations.

Waste for sorting normally arrives at the separation plant in collection vehicles but differences in these vehicles can influence the form of the separation circuit. For example, some vehicles merely compress the waste creating minimal cross contamination problems whilst others employ screw compacting units, which tend to grind and further mix the materials. In the first case, dustbin lining bags may be intact (and require subsequent facilities for opening to discharge the contents) whilst in the second case the bags are often split open. Hence a choice must be made of a "front-end" system to best cope with the incoming waste and produce material in the correct form for subsequent separation.

Front-end treatment is normally confined to size separation or size reduction, i.e. screening or milling. There are advocates of both methods and the reasons for their choice will be evident from the plant descriptions given later.

4.1 Front-End Processing - Size Separation and Reduction

Size separation is achieved by screening and there are various types and designs of screen. The preferred equipment appears to be the trommel screen, a rotating drum (either inclined or fitted with internal scrolls to promote the waste flow) equipped with holes, the size of which depend on the requirements of the subsequent processing steps. Holes can be round or rectangular and perforated in plate or made up of chain-linked material. There appears to be no fixed design principle on hole configuration with the exception that a given screening area is provided for a given throughput. Even this latter point has few fixed guidelines and experiments are continuing in several laboratories to establish scale-up data. Similarly trommels may or may not be equipped with internal lifters to agitate the contents during their passage. The decision to install lifters still appears to be subjective and insufficient information is available to prove their worth.

The major problem which seems to be common to the users of trommels is screen blinding. Waste tends to hang over or otherwise block the holes in the screen, thus reducing its effective working area. Devices have been developed to overcome this blinding effect (see WSL, Fläkt and Enadimsa)[3] and successful continuous cleaning has been reported. In spite of these problems there is no doubt that the trommel screen can form a very effective first stage separation system to provide sized streams for further classification.

The alternatives to trommels, which are used less frequently, are standard vibratory screens and roll grizzlies. Again, the design of screen deck is variable, ranging from wire grids through perforated plate to simple longitudinal grate bars. Vibrating screens to not appear to have the performance potential when used as a primary screen, of the trommel system. For example, splitting or emptying of bags does not occur to the same extent and much more oversize material is produced than in a trommel.

Insufficient data exist on the use of roll grizzly equipment to comment on its applicability save to say that very bulky items can be readily separated from the main waste stream.

Size reduction, as a preliminary treatment for incoming waste, probably presents more of an equipment selection problem than size separation. Many different varieties of milling machines are available including high speed hammer mills (both horizontal and vertical) having fixed or swinging hammers, flail mills, low speed knife and disc mills, and wet pulping units. On the whole wet pulping systems have not proved to be popular, although the Black Clawson Hydrasposal unit in the USA is well known, and a semi-wet selective pulverising system has been developed in Japan[5]. A review of refuse pulverisation in the UK has been published[6], but the data quoted refer to pulverisation as a pre-treatment for landfill. Some information is available on size distributions of shredded waste in the USA[7] and comments on the use of primary shredding were made in the second interim report of the current study[3].

On the basis of the information and quantitative experimental results available it is not possible to state a clear preference for either size separation or size reduction for the front-end of a sorting system. Each has its apparent advantages and disadvantages and these are summarised in Table 5.

Further work is required to determine whether any of these points is of overriding importance in increasing subsequent separation efficiencies.

The selection of subsequent separation procedures is dictated by a combination of local market potential for the recovered products and the composition of the waste material. It can be noted at this stage that these two factors are so variable as to make the selection of a single optimum sorting system, applicable to every situation, quite impossible.

It is at this secondary stage where use is made of the properties specific to the required materials to effect their separation and the machinery used can best be described by considering the products which are sought.

TABLE 5. - Comparison of Size Reduction and Size Separation

	Advantages	Disadvantages
Size Reduction	Reduces the paper content to a more suitable size range for subsequent air classification	More difficult to avoid cross contamination of constituents.
	Plant can accept a wide range of gross oversize and difficult materials	High capital, operating and maintenance costs may be involved.
	Recovery of paper content from books, telephone directories, etc is facilitated.	Possible hazards arising from explosive materials in the waste.
	High throughput capability	More energy intensive
Size Separation	Constituents are concentrated into streams for further processing	Removal of gross oversize or difficult materials is required.
	Reduces cross-contamination	
	Possible lower maintenance costs	Heavier paper and board may be lost.
	Less energy intensive	Restricted throughput capability

4.2 Air Classification

All the systems included in this study recover either paper or waste-derived fuel as a major product. In most cases an essential stage in the process is the separation of a light fraction by exploiting density and aerodynamic properties in an air classifier. The air classification principle is a simple one in which solid particles are classified according to their terminal free fall velocities in air. Separation is based on the different trajectories of the particles which are subjected to the drag forces of an air stream and gravitational attraction. The basic simplicity of the system is however severely complicated by the diverse nature of the waste material to be separated because the terminal free fall velocity of the waste components is dependent on the "apparent" specific gravity of each particle. This latter factor is in turn dependent on the size, shape, composition and moisture content of each particle. A simple example to illustrate that separation into clean components is not straightforward would be the effect of a common air stream on a sheet of dry paper compared to a crumpled ball of moist paper. Thus, precise separation of mixed household wastes by air classification alone is impossible but the production of light and heavy classified products is relatively easy. The procedure is normally as follows: waste, in one form or another depending on the foregoing treatment (sizing, shredding, etc), is presented into an air stream; the lighter particles are carried along with the air to some suitable collection point (normally a plenum chamber or cyclone equipped with a product removal system) whilst the heavier particles either do not join the air stream or rapidly fall out of it. Although simple in principle, the designs of air classifiers are numerous. There have been attempts to provide a theoretical basis for their design (based on terminal falling velocities, drag coefficients, shape factors, etc)[8-10] but these have been of limited use due to the diversity of the waste and this has resulted in a semi-empirical approach based on experience with other materials.

The simplest form of air classifier involves blowing material off a conveyor belt (WSL) and this can prove very effective with a sized feed material, particularly in the recovery of large sheets of newsprint. Aspiration of air above a conveyor was first demonstrated by the US Bureau of Mines to give an effective separation and the Enadimsa system shown in Fig. 1 is a development of the USBM design. In operation the Enadimsa air classifier provides for separation by both aspiration and air scrubbing (downstream of the aspiration point). The air knife effect generated at the conveyor discharge ensures minimal masking of the light material by heavier particles in the waste feed.

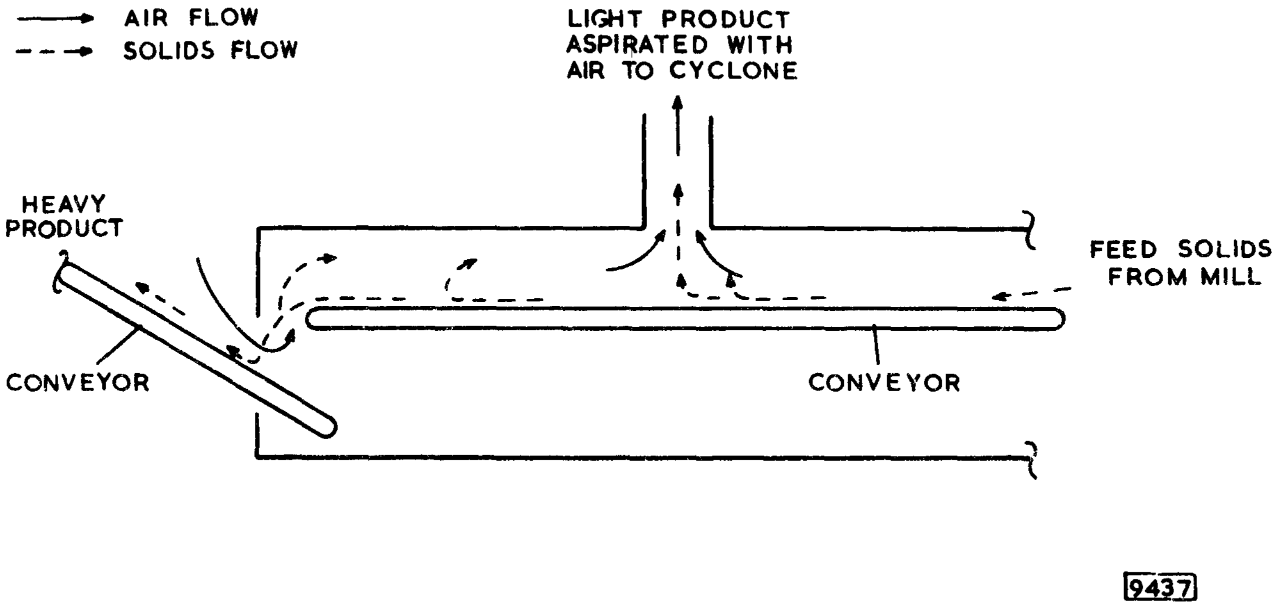

FIG.1 ENADIMSA HORIZONTAL AIR CLASSIFIER

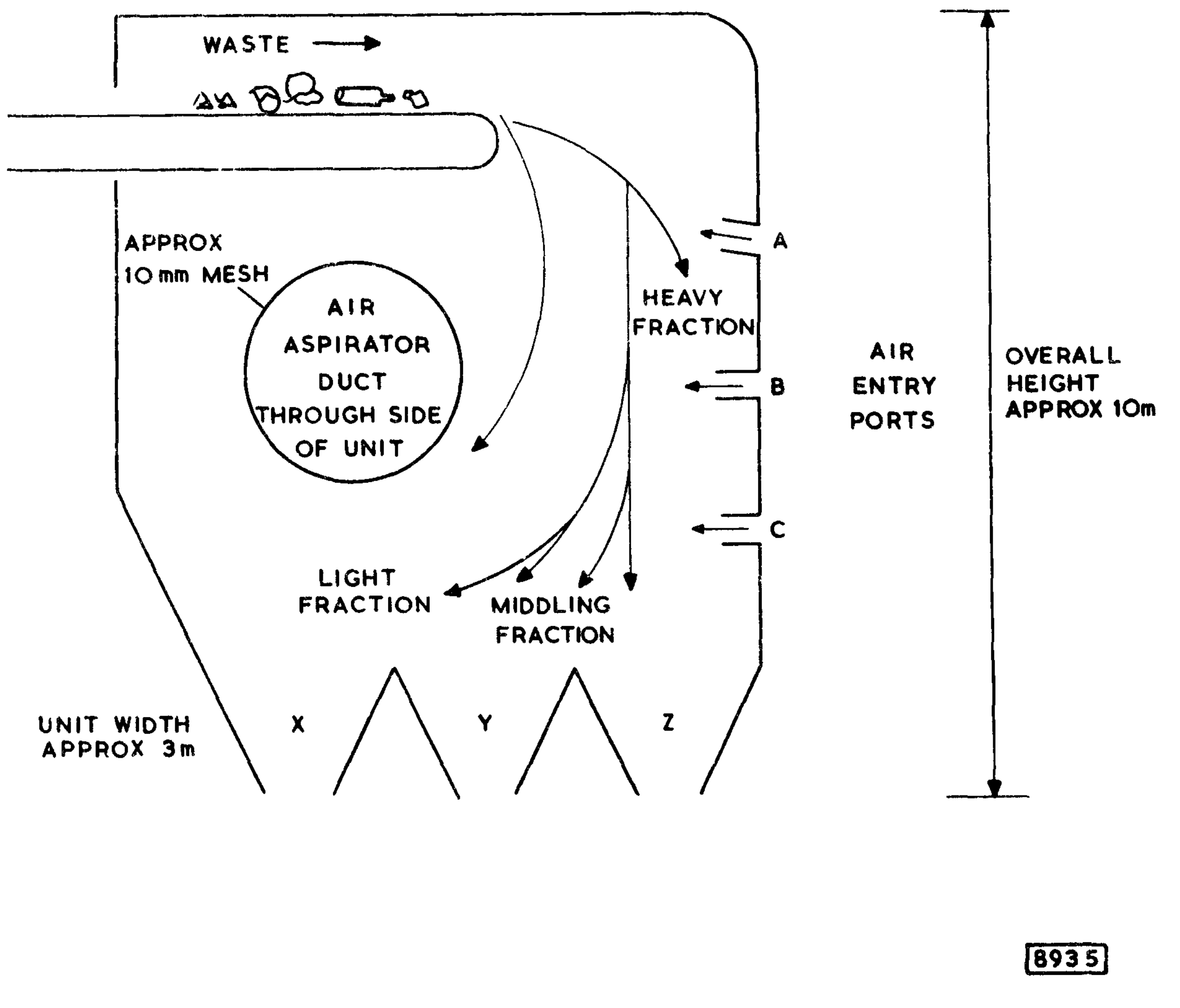

FIG 2 KARL FISCHER AIR CLASSIFIER

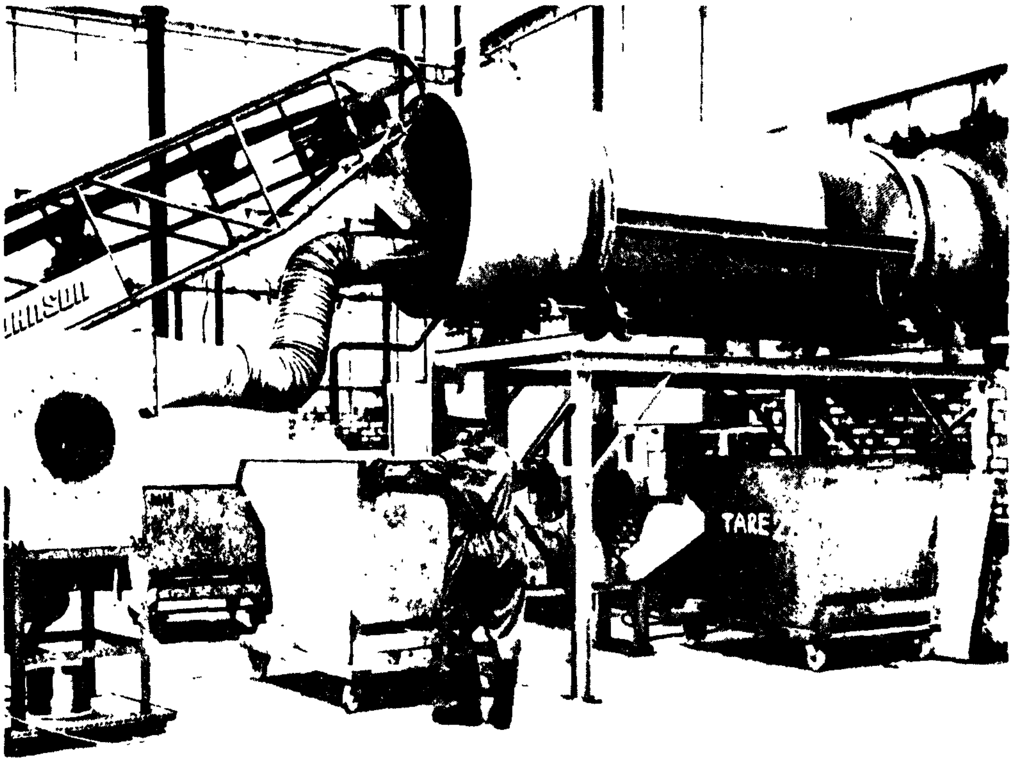

FIG. 3 WSL HORIZONTAL ROTARY AIR CLASSIFIER

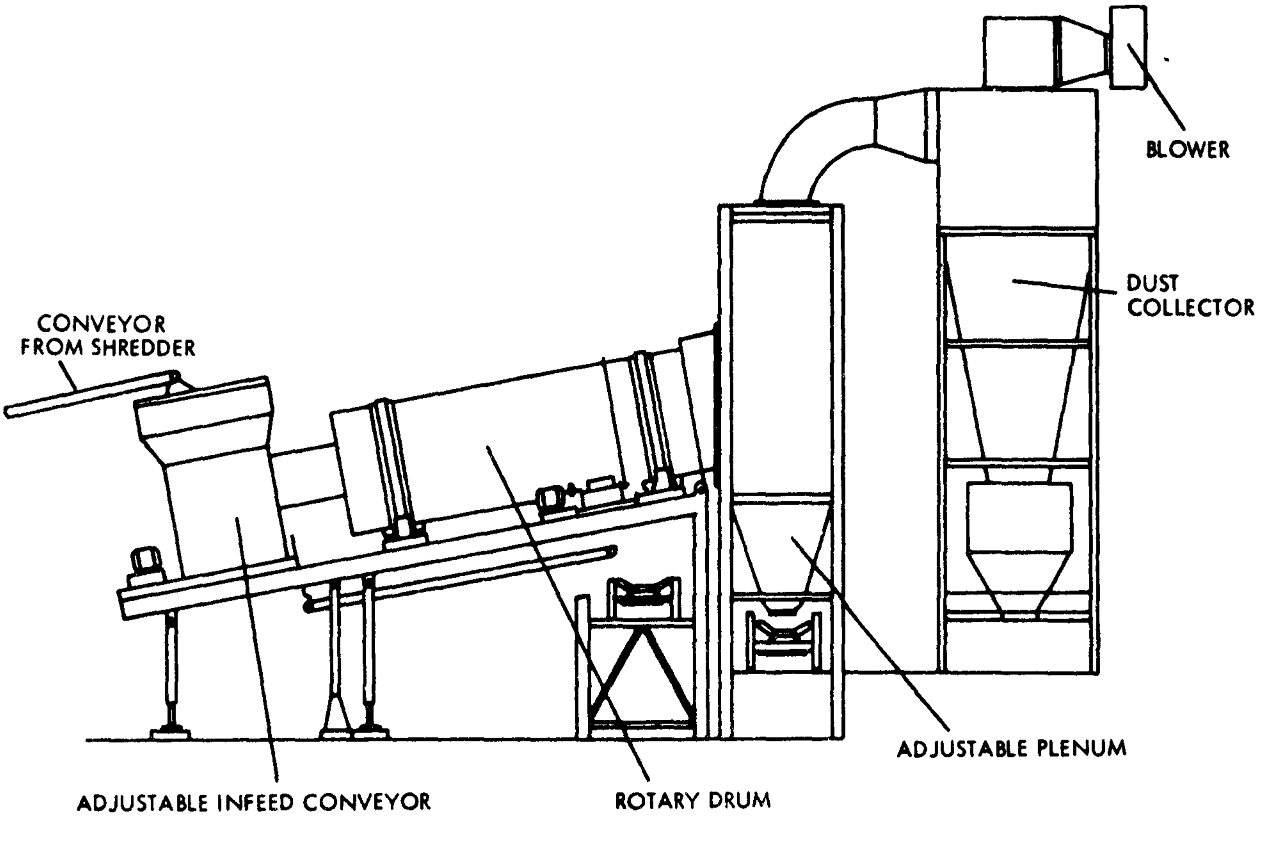

FIG. 4 RAYTHEON ROTARY AIR CLASSIFIER

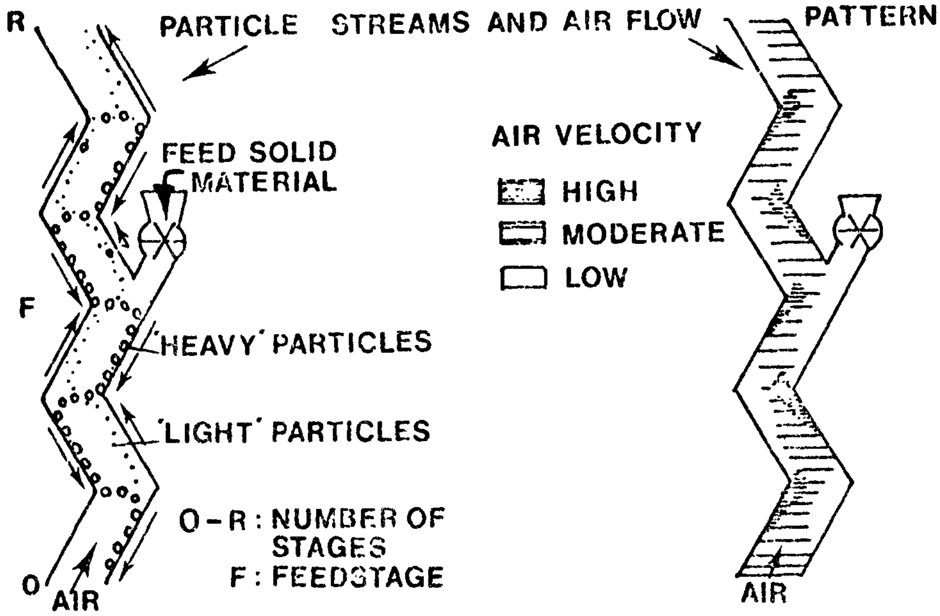

FIG. 5 ZIG-ZAG AIR CLASSIFIER

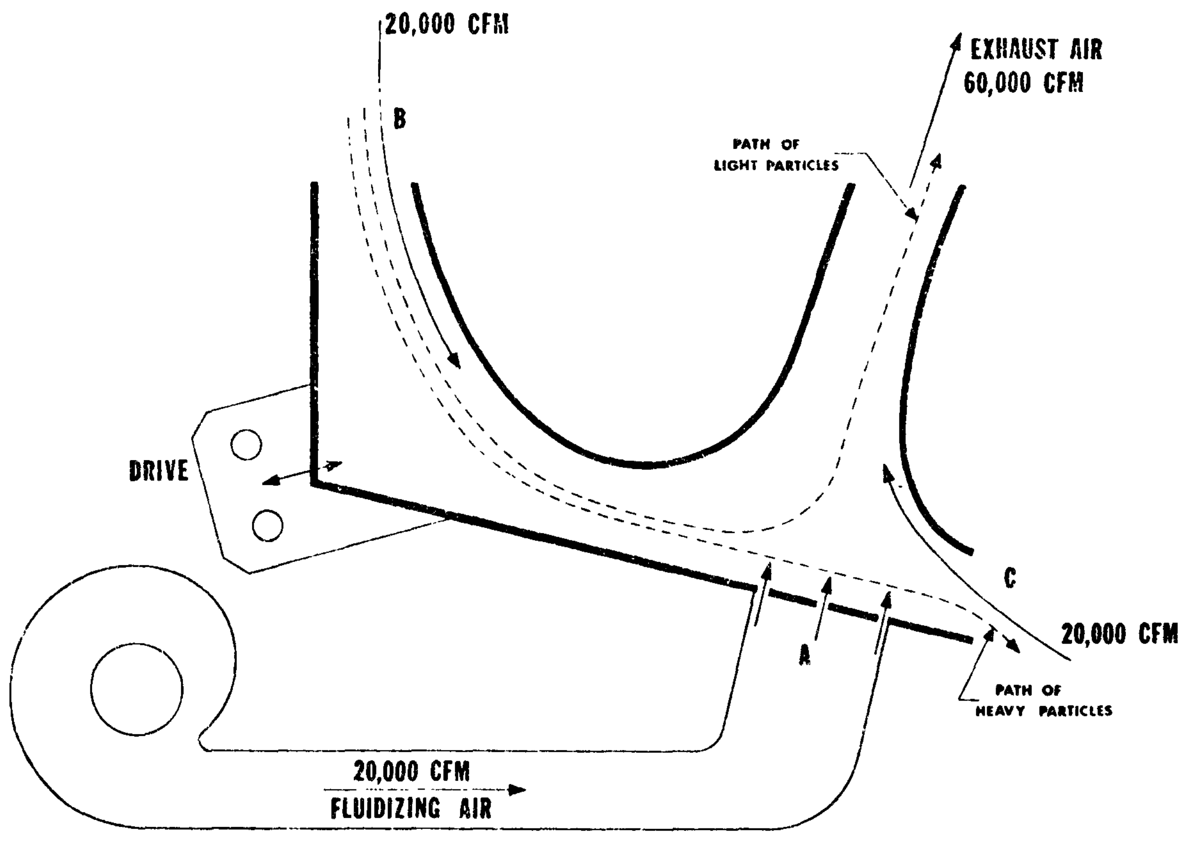

FIG. 6 TRIPLE S 'VIBROLUTRIATOR' AIR CLASSIFIER

The masking effect caused by heavier particles resting on lighter material is avoided when waste is allowed to fall into an air stream, either by gravity or "force-fed" by conveyor, and several different units employing this principle have been tested. The simplest type is the vertical column air classifier in which the waste falls into an upward flowing air stream. This type has been used in the USA in the first generation of waste-derived fuel plants. Although good separation of a combustible fraction has been achieved, problems have been experienced due to the carry-over of fines into the light fraction. A number of more sophisticated designs have been developed using ballistic effects, rotation or multiple stages of air classification to obtain a cleaner light product.

A ballistic effect is used in the air classifier designed by the Karl Fischer company of Berlin, in which waste is projected into a large chamber and air jets blow the light materials to the back of the classifier (Fig. 2). Separation of the heavy fraction is assisted in this type of unit by the ballistic effect created by the feed conveyor.

Cleaning effects are promoted in both the WSL horizontal (Fig. 3) and the Raytheon inclined drum classifiers (Fig. 4) by means of the drum rotation. In the former however air is blown into the drum whilst in the latter the air is drawn into the unit by aspiration from the plenum chamber, The Raytheon machine is provided with lifters so as to promote multiple stages of classification. The relative merits of the two systems remain to be established but both provide very effective separation of light and heavy fractions, the proportions of which can be readily varied by adjusting the air flow. (It may be noted that the guideline air requirement for classification in use by most investigators is of the order of 30 m^3/min per tonne of waste treated per hour.

Multiple stages of classification also arise in the zig-zag air classifier (Fig. 5), as used by Fläkt, TNO and several other organisations. This type consists of a number of rectangular sections connected to each other at a fixed angle of 120° in order to create a folded channel. This creates the flow pattern shown in Fig. 5, which produces two separate streams of particles: a "light" stream carried upwards by the air and a "heavy" stream flowing down along the walls. At each junction of two sections the two streams of particles are subjected to a repeated classification process. The separation efficiency of the unit can be adjusted by changing the number of zig-zag elements.

Another type of air classifier has been studied in the USA by the National Center for Resource Recovery and is in use in the Chicago waste-derived fuel plant. The Triple S classifier makes use of vibrational motion of the equipment to promote the cleaning action and this is assisted by air entering the unit in the three different directions shown in Fig. 6 (from A, B and C). The total air input of 60,000 cfm (1700 m^3/min) relates to a feed input rate of 73 tonnes/hour. Triple S claim that the separation in this system is much less sensitive to particle size variation than in more conventional classifiers, but no evidence is available to substantiate this claim.

4.3 Paper Recovery

As noted previously air classification produces a light and a heavy product. Alone, it is not sufficient to produce a paper product acceptable to the paper industry, due in the main to the plastics content. It is generally necessary to modify the properties of either the paper or the plastics components so that they can be subsequently separated. Three general methods have been used to do this and descriptions of the equipment used are given in Chapter 6.

The three methods are summarised below:

1. Moistening (TNO): to increase the density of the paper so that it can be separated from plastics in a second air classification stage - the plastics then become the light product.

2. Semi-pulping (Enadimsa in association with SOCEA): to break down the paper structure so that it can be screened from the plastics. It is understood that Cecchini use a similar method, although no details of the equipment are available.

3. Heating (Fläkt and US Forest Products Laboratory)[12]: to shrink the plastics, which may be removed as a heavy product in a second stage of air classification.

Systems which produce a wet fibre product at the sorting plant appear to be disadvantageous due to storage problems. In most situations the pulped product must be dried at an energy cost. The technical and economic feasibility of paper/plastic separation at the paper mill, rather than the sorting plant, is worthy of close investigation.

4.4 Waste-Derived Fuel

There is a close relationship between the extraction of waste-derived fuel and paper fibre from waste because air classification generally forms the basis for separation of a preliminary concentrate. The principles involved in the design of air classification systems apply equally to the separation of either type of product. In the case of fuel, however, removal of plastics is unnecessary unless a very high PVC content is present, which would result in undesirably high levels of chlorine in the fuel. Although care is needed in air classifier design for fuel production, the problems are recognised and are less severe than the problems of fibre recovery.

The biggest problems arise in the conversion of the light combustible fraction from an air classifier into a marketable fuel product. Such a product must be capable of use in existing boiler installations with minimum modification of existing plant, minimum adverse effect in terms of boiler corrosion and atmospheric emissions, and maximum energy conversion efficiency. Most probably the product will be aimed at industrial consumers for use as a supplementary fuel in association with coal.

An area of particular concern to the fuel user would be the slagging or clinkering potential of the ash. Because the composition of solid waste varies so much, an examination of some basic characteristics of the constituents can be useful. Table 6 shows the fusion temperatures of the residues and non-combustible constituents commonly found in ash from incinerated solid wastes[13]. With the exception of the glass fraction, the remaining components have ash fusion values within the range commonly encountered with most coals.

TABLE 6. - Ash Fusion Temperatures

Constituent	Initial Deformation °C	Softening °C	Fluid °C
Clear Glass	805	918	1005
Brown Glass	882	949	1138
Green Glass	893	982	1138
Ash from:			
mixed waste	1105	1172	1205
cardboard	1127	1183	1227
paper	1183	1261	1361
textiles	1116	1194	1227
plastics, rubber, leather	1150	1216	1261
bones and shells	1539	1539	1539
coal	1140	1200	1330

Clearly it is important that the fuel should not be contaminated by glass. Early experience in the USA showed that hammer milling of the incoming waste tended to produce fine glass particles, which were subsequently carried over into the air classifier lights. The problem has not arisen in fuel produced by the WSL pilot plant, and it seems that pre-treatment of the waste before air classification is of significant importance. Problems are likely to be less severe in plants incorporating front-end sizing, and might be overcome when size reduction is carried out by using a course shred followed by screening.

Other differences between waste-derived fuel and coal which might give rise to problems are shown in Table 7, which compares the properties of fuel prepared at WSL[14] and St Louis[15] with coal. Differences between the two waste-derived fuel samples can be explained, largely by differences between the processes although the composition of the input waste must also be an important factor.

TABLE 7. - Analyses of Waste-Derived Fuels Compared with Coal

	WSL[14]	St Louis[15]	Coal[14]
Proximate Analysis (% as analysed)			
Moisture	12.5	23.1	6.1
Ash	10.2	19.2	6.5
Volatile Matter	65.4	47.1	34.0
Fixed Carbon	11.9	10.6	53.4
Calorific Value (MJ/kg as analysed	16.9	12.0	30.1
Ultimate Analysis (% as analysed)			
Moisture	12.5	23.1	6.1
Ash	10.2	19.2	6.5
Carbon	49.8	28.5	76.8
Hydrogen	6.1	6.9	5.1
Sulphur	0.2	0.17	1.65
Chlorine	0.24	-	0.22
Carbon Dioxide	0.22	-	0.08

The very high ash content of the St Louis sample must be due to the presence of glass in the fuel, and it is significant that the presence of abrasions has also been observed to cause severe wear in pipes used for pneumatic conveying of the fuel[5]. The higher moisture and lower volatile matter contents of the St Louis fuel are no doubt due to the presence of vegetable matter, which is selectively removed before air classification in the WSL process.

Both waste-derived fuels differ significantly from coal, and it follows that optimum combustion efficiency will not be achieved in equipment designed to burn coal. There is, therefore, a need for studies of the combustion data for the design of suitable combustion equipment or the modification of existing industrial burners. A Community-sponsored project along these lines for suspension firing of waste-derived fuel has started recently at WSL. For ease of transport, storage and handling a densified fuel product may be preferred by industrial users, but many problems remain to be solved in the production and use of pelletised or briquetted waste-derived fuel. These aspects are currently receiving attention in several countries, but much more R & D effort is required to isolate and solve the problems.

4.5 Ferrous Metal Recovery

The use of magnetic separators for extracting the ferrous content from household waste has been common for many years. The recovery efficiency of such systems has generally been low, often no higher than 25% from raw waste and 50% from pulverised waste. Shredding or sizing, as carried out in a waste sorting plant, enables a uniform feed with low depth of burden to be presented to the magnetic separator. Several effective magnetic extraction systems have been developed, and 80-90% recovery of ferrous metal should be attainable.

The most popular type of separator is the Overband, which consists of a stationary electro-magnet around which a moving belt is fitted. Magnetic pulleys and drums are also used in some systems, but normally as a second stage to remove small quantities of ferrous material from other concentrates, or to increase the overall efficiency of ferrous metal recovery. Overband separators are capable of producing effective magnetic field intensities across operating gaps as great as 1000mm, but it is desirable to minimise the belt-to-belt distance because of the cost in relation to weight and power requirements[16] (Table 8).

TABLE 8. - Specification for Overband Magnetic Separators[16]

Operating Gap mm	Weight tonnes	Magnet Power kW	Motor HP	Price (1975) £
300	4.3	4.1	5.5	5000
375	4.5	6.5	5.5	6200
450	6.2	9.2	7.5	8500
525	8.4	11.7	7.5	10900
600	10.0	14.0	7.5	12900
675	12.7	17.1	7.5	15300
750	17.7	21.2	7.5	20400
900	25.4	27.6	7.5	26600

One method of limiting the operating gap is to combine the ballistic effect of a high speed feed conveyor with an in-line magnetic separator. This is illustrated by the Fläkt system in which material is projected towards a small, 1 kW, overband separator. In this way belt-to-belt lifting is eliminated, and additionally the ballistic effect provides a partial cleaning action by allowing some of the contraries to fall away from the tin-cans in mid air.

As mentioned in Section 3.2 markets for recovered ferrous metal from household waste are restricted by contaminants associated with used tin-cans. The problems involved in recovering tin and high grade steel scrap from used cans have been described by Linley[17]. The input to a continuous detinning plant must meet the following specification:

Seam opening >90% of the seam linear dimension
Dirt content <1%
Aluminium content <0.2%
All tinplate surfaces to be exposed to liquor attack
Particle size +2.5cm - 15cm
Bulk density >400 kg/m^3.

There are several approaches to achieving these specifications, but so far none has been proved to be wholly successful. Shredding will achieve size reduction and some seam opening. Cleaning can be achieved by water washing, air classification of shredded material, attrition (with or without added abrasive) or burning. In the latter case the temperature must be kept below about 300°C to minimise diffusion of the tin into the iron lattice. Cryogenic fragmentation has been tried, to improve size reduction, increase seam opening and facilitate the separation of dirt and aluminium from the tin-plate but with limited success.

Further work is required on the preparation of used cans for detinning and in particular on methods of opening the seams. Fortunately modern can-making technology is moving into the manufacture of two-piece cans, which have only one seam and the preparation task will therefore be less demanding in the future.

4.6 Glass Recovery

Although glass cannot be considered to be a major product from the sorting of household waste, a great deal of effort has been devoted to developing technology for its recovery. In general, two methods have been used to produce a glass product which is acceptable to the glass industry from glass-rich concentrates produced in a primary sorting circuit. These are:

a) Froth flotation, giving a concentrate of finely divided glass (1mm and less) which is a mixture of coloured and flint.

b) Optical sorting, giving a product in the size range +6-50mm. Transparency sorting yields a mixture of coloured and flint glass, but by adding a colour sorting stage the product can be separated into flint, green and amber fractions.

The nature of the feed to the glass recovery plant depends upon both the composition of the household waste being treated and the type of primary sorting circuit employed. The size range of the material is particularly important in determining the choice of glass recovery method to be adopted. By way of example, the application of the WSL sorting process to UK waste may be considered. A typical composition of the feedstock to the glass recovery plant would be:

	Dry Weight, %
Glass	60
Plastics	2
Ferrous metal	1
Non-Ferrous metal	2
Putrescible	2
Ceramics, brick, stone, etc	32
Combustible	1
	100

The size range of this material is +20 -70mm and tests have shown that it is possible to use either froth flotation or optical sorting to extract a high-grade glass product.

The situation is more difficult in a sorting plant employing front-end shredding. The glass will undoubtedly be pulversied in a hammer-mill type of shredder, its particle size range depending on such factors as the characteristics of the mill used and the cushioning effect of other constituents of the waste. Fig. 7 gives typical information

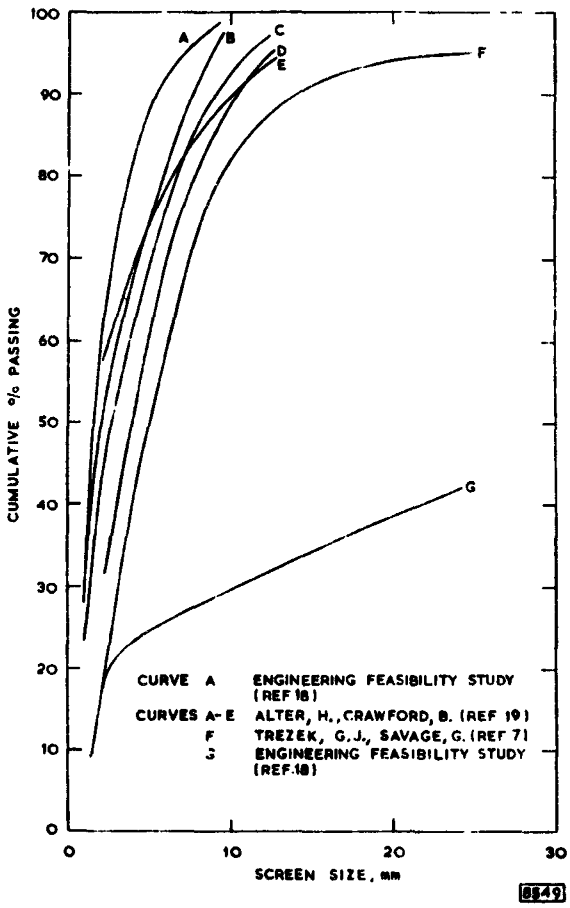

FIG 7 GLASS SIZE DISTRIBUTION IN SHREDDED REFUSE

found in the literature on the particle size distribution of glass leaving the shredder. The important point to note is that in all cases except curve G some 50 to 85% of the glass passes 5mm, and would be too small for recovery by an optical sorting process. Curge G in Fig. 7 shows the particle size distribution of glass from a twin-rotor flail mill. In this case about 70% of the glass after shredding would be in a size suitable for recovery by optical sorting. There are, however, no known examples of pilot-scale sorting circuits employing a flail-mill which use optical sorting for glass recovery.

4.6.1 Froth Flotation

Four glass recovery circuits incorporating froth flotation were included in the study. These flowsheets were developed by USBM[2], NCRR[2] and Occidental Research Corporation[20] in the USA, and WSL in the UK. Generally speaking, the feedstock for glass recovery consists of a sized, heavy fraction from which the majority of the ferrous, paper, plastic and putrescible materials have been removed. Glass recovery is carried out by a combination of froth flotation and either jigging (USBM and NCRR) or selective comminution and screening (Occidental and WSL). The flowsheets are similar in many respects, and only the WSL circuit will be described as an example.

The optimum size for the flotation process is plus 0.15 minus 1.0mm, so the first step is comminution in a rod mill, which was chosen because it caused the minimum production of fines while making possible the subsequent removal of metals and other non-brittle constituents. The rod-milled product is screened at 13mm to remove a non-ferrous metal-rich fraction and then at 1mm on a vibrating screen. On a full scale plant fines and fibrous material would be removed from the minus 1mm material in a hydrocyclone. At this stage in the process the material is made up of:

a) Glass, which can be recovered by flotation using a water soluble diacetate salt of an aliphatic amine as a collector and a liquid detergent as a frother.

b) Ceramic, pottery, stone, brick, bone and cinders which are not collector coated by the flotation reagent.

c) Naturally flotable materials such as coal, ash and wood fibre, which can be removed by using a frothing agent alone.

The first stage of froth flotation is therefore carried out using a frothing agent alone to remove coal and ash particles. Complete removal is not essential as small quantities of coal in the final glass concentrate can be tolerated in glass manufacture. This is followed by two stages of flotation in the presence of the collector. In water it forms a powerful cation which attaches itself to the glass surface, forming a strongly bonded hydrophobic film and thereby permitting flotation of the glass. Recovery of glass in the flotation circuit is about 60%, corresponding to an overall recovery of 50% of the glass in the waste. Recovery efficiencies of 65-70% have been quoted for the American processes, but it remains to be seen what can be achieved in continuous operation on a full-scale plant.

Samples of the glass product from the WSL pilot plant were made available to the UK Glass Manufacturers Federation and to the British Glass Industries Research Association. The latter organisation found that at least 98.8% of the material was glass with a particle size range between 0.125 and 1.0mm. Concentrations of iron, chromium and carbon were higher than normally expected in glass, but it was not considered that this would be a problem in the manufacture of green glass. Production trials indicated that green container glass containing 20% cullet from domestic waste could be melted successfully on a commercial scale.

4.6.2 Optical Sorting

Optical sorting for glass recovery from household waste was first used in the Black Clawson plant in Franklin, Ohio, where glass, non-ferrous metals and other inorganics are separated from the rest of the waste by wet pulping. Experiments have also been carried out by Sorain-Cecchini in Rome and at the Techniche Hochschule in Aachen. A flowsheet for recovery of glass by transparency sorting is also under development at WSL, because it is thought that it might offer advantages over froth flotation in terms of processing costs and improved recovery. Also the coarser particle size required for optical sorting might produce a product which is more attractive to the glass industry.

Equipment for optical sorting is manufactured by Gunson's Sortex Ltd, who offer two machines which separate by sensing transparency and colour respectively[21,22]. The first stage in a recovery process must be to prepare the feed for presentation to the machine in a clean, dry condition and in convenient size fractions. Suitable ranges are 6-20mm and 20-40mm. A feed of the composition shown on page 21 would need to be washed to remove any opaque coating from the glass. The next stage would be drying, and this should be done as simply as possible because conventional driers could add considerably to the capital and operating costs. After drying, screening with recycle of the oversize via a crusher would produce a suitable feed for transparency sorting. A final colour sorting stage could be added if desired.

The recovery of glass in the transparency sorter depends upon the proportion of opaques in the feed[22]. The published data relates to a feed containing 94% glass. For a glass content as low as 60% the manufacturers recommend a pre-sorting stage to bring the glass concentration up to about 95%, and they are developing suitable equipment. In these circumstances the glass recovery in the transparency sorter should be of the order of 90% at a throughput of 1 tonne/hour, with about 0.5% opaques in the recovered glass. The corresponding overall glass recovery efficiency would be around 63%.

4.7 Non-Ferrous Metals Recovery

Preliminary sorting of the waste involving removal of paper, organics and ferrous metals generally produces a heavy concentrate containing non-magnetic metals such as aluminium (usually the major constituent), copper and its alloys, stainless steel, die cast materials and very low concentrations of precious metals. Most of the work on extracting individual non-ferrous metals has concentrated on aluminium. The greatest degree of interest has been shown in the USA because of the high concentration of aluminium beverage cans in the waste in many locations.

An excellent review of the technology available for aluminium recovery from household wastes has been given by Alter[23]. This section is therefore confined to a very brief description of the techniques which have been used.

Separation techniques currently being tested make use of either the density or the conductivity of the non-ferrous metals compared with that of the contaminant namely glass, stones, organics, rubber, leather, etc. The simplest system technically makes use of the density differences in a standard mineral jig. Non-ferrous concentrate is fed into a pulsed wet jig, in which the various materials stratify into separate layers. Appropriately placed splitters float off organics, remove glass and aluminium foil and the heaviest fraction, consisting of the non-ferrous metals, collects at the base of the jig. Water is continuously recycled but make up water is required to replace that lost with the products. The system is being tested by USBM and Enadimsa but at a relatively small scale. Enadimsa have indicated that they expect some scale-up problems to obtain higher throughput machines and these may preclude their use at large scale.

Other wet systems which have been investigated and could be applied to heavy non-ferrous separation are rising current, heavy media and magnetic fluid systems. The rising current principle employs the differences in falling velocity of particles in a liquid, usually water, in which an effective density greater than that of still water is created. The sink fraction consists of metals and glass which would have to be further processed for complete separation.

Heavy media separation relies on a sink-float separation in a suspension of a finely ground mineral (e.g. ferrosilicon, magnetite) in water. The density of the liquid suspension is controlled by the amount of mineral present. Heavy media processing may follow a rising current separator and multiple passes at different densities can be used to separate out a desired product. Magnetic fluid separation is a similar technique but in this case the fluid is a colloidal suspension of magnetic material usually magnetite, in water or kerosene. The apparent density of the fluid is adjusted by control of a magnetic field, and this permits a very wide range of densities (up to 20 g/cm^3) to be obtained. Both methods have given rise to problems in content of the fluid densities and subsequent product cleaning, and of course the separated products are wet, which may reduce their value or necessitate a drying stage.

In general, dry methods of separation based upon the electrical properties of the metals, have proved to be more popular than wet methods. Eddy current separators have attracted the most attention, particularly in the USA[2]. The waste stream containing non-magnetic metals passes through a magnetic field on a conveyor. This causes eddy currents to be generated in the metal particles. By making the magneti field vary as a function of time, the eddy currents interact with it to product a force which levitates the metal particles and carries them along the direction of the magnetic wave. The effect can be used to deflect the metals from the conveyor and suitably placed splitters can then provide a concentrate of the desired product. Systems of this type have been developed in the USA by Occidental Research Corporation and Combustion Power Company[24-26]. Raytheon have developed an eddy current separator which was permanent magnets[27]. Fig. 8 shows a schematic diagram of the separator in frontal view (left) and side view (right). The essential component is a long ramp down which the waste stream is allowed to slide. Permanent magnet strips of alternating polarity are inclined at an angle of approximately 45° to the ramp axis. Under the influence of the eddy current-induced force, the metallic particles are deflected in the manner shown in Fig. 8. This equipment has been tested by USBM, who have concluded that its separation efficiency is limited, but that it is a useful pre-concentration stage before an electrostatic separator. A rotary-drum separator designed along similar principles has also been investigated by Ratheon[28].

In parallel to the testing of the Raytheon ramp separator, USBM have also tested the Carpco two-stage electrostatic separator (Fig. 9). This unit was used for separating aluminium foil from organics, the input mixture being their heavy product from the secondary air classification system (Section 5.1.3). The drawback in this system is that the feed to the separator must be dried. As the feed materials enter the unit the particles are charged in a high voltage electrostatic field. Conducting materials (metallics), however, immediately lose their charge to the electrically earthed drum while the non-conductors retain a surface charge and are electrostatically attracted to the drum. These particles are swept off once they have passed the splitter point.

At this stage it is felt that the concentration of non-ferrous metals in European waste is probably not high enough to merit further investigations in this area but a watching brief should be maintained on the developing American technology and its economics.

4.8 Plastics Recovery

As discussed earlier in Section 4.3 a plastics concentrate is an inevitable by-product of paper fibre recovery from an air classifier light fraction.

Several techniques have been developed in Europe, Japan and the USA to use mixed plastics waste directly for the production of finished articles. In general, polyolefins are preferred for these processes but proportions of other thermoplastics are acceptable and some thermosets and contrary materials are permissible. In some cases materials such as paper wastes and sawdust are intentionally added to the plastics to improve properties. The materials produced by such methods are in most respects inferior to virgin plastics in their physical properties and the properties of products from any one process, or even any one machine, will vary as the nature of the wastes used varies. For this reason they are suitable only for non-critical applications and applications where the relative weakness of the material can be compensated for by the use of thick sections.

An alternative approach is to separate mixed plastics into individual polymers and clean them so that they can be re-used in conventional moulding or film-blowing applications. Processes which have been devised include the following:

1) The US Bureau of Mines has developed a sink/float process for separation of polymer mixtures[29].

2) In the UK Professor M Bevis of Brunel University has developed a washing and polymer separation process. This is subject to a patent application and details are not yet available, but basically it is a sink/float technique using water and a specially designed system of rotors and baffles to effect the separation. No chemical additives are used.

3) The Mesco Separator (Mitsui Mining and Smelting Co, Japan) is based on a flotation process using reagents which preferentially change the surface properties of individual polymers from hydrophobis to hydrophilic. Separation efficiencies of almost

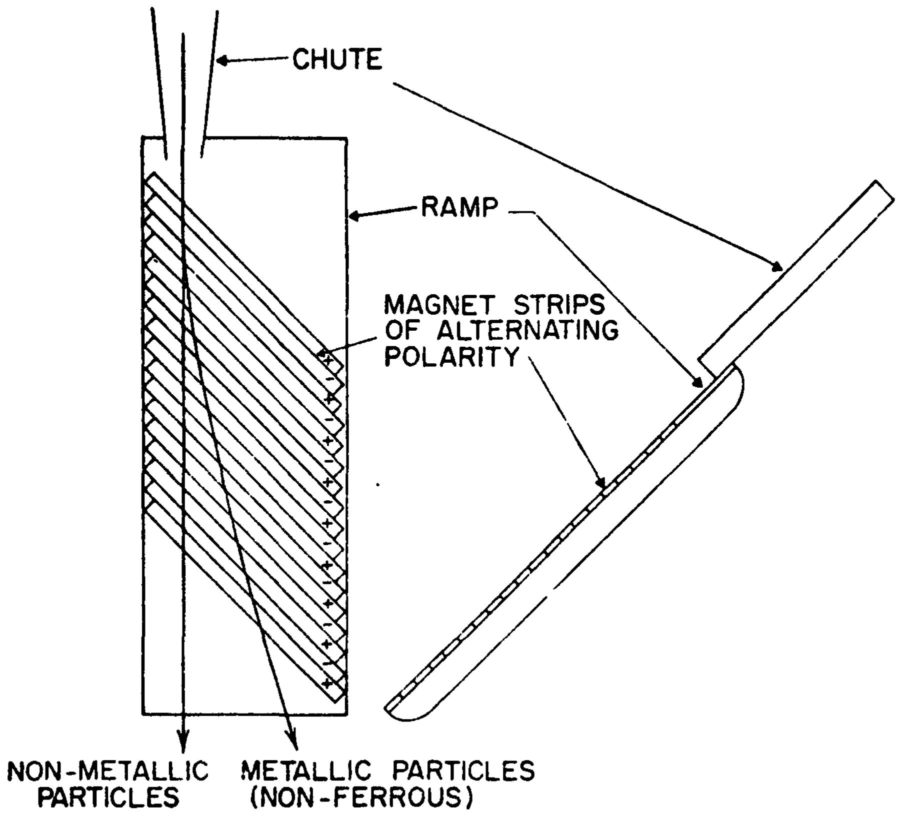

FIG.8 THE RAYTHEON ALUMINIUM SEPARATOR

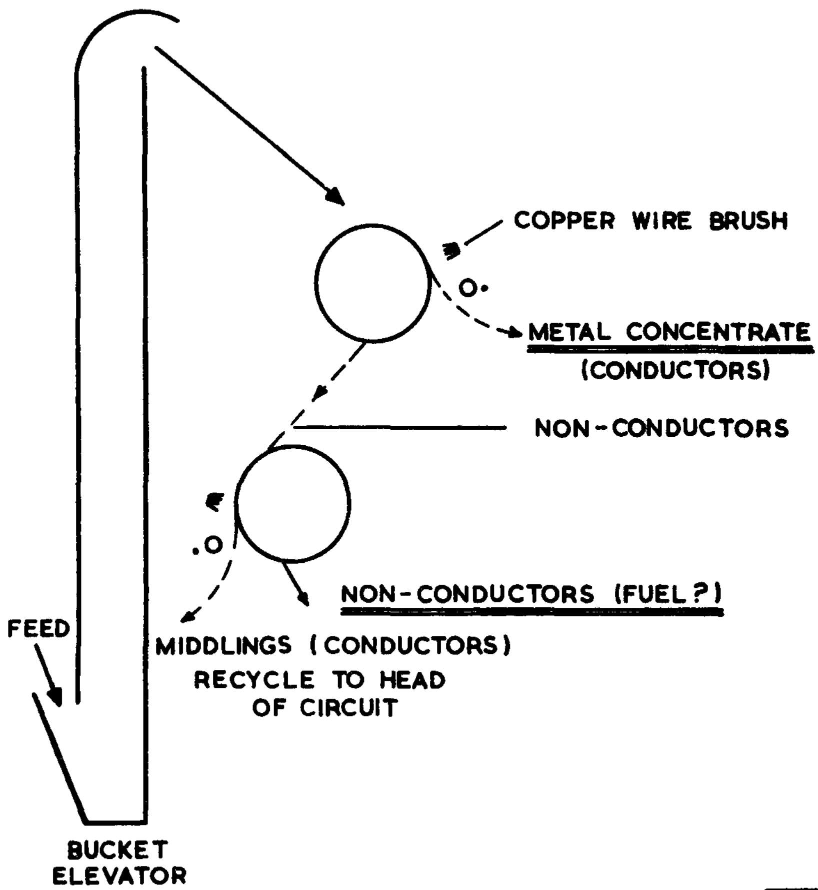

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FIG.9 CARPCO HIGH TENSION SEPARATOR

100% are claimed for many polymer pairs. A description of this process has recently been published[30]

It is not known whether such techniques could be applied to the plastics fraction of household wastes to recover polymer of sufficiently high quality to be acceptable to the plastics conversion industry.

4.9 Organic Fraction

The organic portion of the waste generally becomes concentrated as other more valuable constituents are extracted. The main outlets for an organic residue (neglecting landfilling) are animal feed production, either by direct sterilisation of the organic materials or by production of single cell protein, composting, or methane generation by anaerobic digestion. The technology involved is beyond the scope of this study but it is included in the concurrent CREST fermentation and hydrolysis study. The problems of marketing products made from the organic fraction were discussed in Section 3.2.

5. WASTE SORTING PROCESSES IN NORTH AMERICA

The study included a series of visits in the USA and Canada so that the applicability of recent American developments in sorting technology to wastes in the European Community could be assessed. The following organisations were visited:

Ratheon Service Company	Burlington, Massachusetts
Black Clawson	Franklin, Ohio
Teledyne National	Baltimore County, Maryland
US Bureau of Mines (USBM)	Washington DC
National Center for Resource Recovery	Toronto
City of Ames Solid Waste Recovery System	Ames, Iowa
Ralph M Parsons Company	Chicago, Illinois
Browning-Ferris Industries (to see Raytheon Air Classifier)	Houston, Texas
National Center for Resource Recovery (NCRR)	New Orleans, Louisiana
Occidental Research Corporation (formerly Garrett Research and Development)	La Verne and El Cajon (San Diego), California

Full reports of these visits were given previously[2]. The present report concentrates on a detailed appraisal of the USBM and Black Clawson processes, followed by a brief review of the main features of other American developments using published information as well as data collected during the visits. The reasons for selecting two processes for special consideration are as follows:

1) The USBM process was the first raw household waste sorting circuit to be demonstrated at pilot-scale, and a considerable amount of information about its performance is available[11,31-34]. Its influence on subsequent developments by other organisations can be clearly seen.

2) A detailed economic evaluation of the USBM process has recently been published[34].

3) The collaboration between USBM and Enadimsa in Spain has provided an excellent example of how American technology has had to be adapted to accommodate waste of very different composition in Europe (see Section 6.6).

4) The Black Clawson process is unique in using wet pulping as the basis of the separation system.

5.1 The US Bureau of Mines Process

The USBM has been involved in waste processing since 1966, and a pilot plant for sorting raw household waste has been in operation since 1973 at College Park, Maryland. This pilot plant was designed to process 5 tons/hour* of waste to recover refuse-derived fuel (RDF), ferrous metal, glass and non-ferrous metals. The following process description is based upon the recently published economic evaluation[34]. The proposed process flowsheet, reproduced in Fig. 10 is different in some details from previously published flowsheets. Fig. 11 is a simplified version, showing the main features of the flowsheet, to facilitate comparison with other processes discussed in this report. The numbers in Fig. 10 indicate the materials balance for a throughput of 1000 tons/day of US household waste and are based on average data collected at the pilot plant from a number of waste samples.

Incoming waste is dumped into a receiving pit, from where it is conveyed into the primary bulk separation section. This section has three parallel processing lines, one being present as a standby in case of breakdown.

The input waste is fed into the primary shredder which is a double-opposed flail mill, where it is coarsely shredded, liberating materials to be reclaimed, but only denting or slicing tin cans. The shredder discharge conveyor is covered by a hood referred to as the light air-classifier, in which very light paper and plastic is aspirated from the moving bed of shredded waste. Airflow through the hood is induced by a fan located downstream of a cyclone and baghouse dust collector. This section of the plant is isolated from the rest of the equipment by reinforced concrete walls as a precaution in case of an explosion in the shredder.

Ferrous metal is removed from the air classifier heavies by an overband magnetic separator and conveyed to the ferrous metal cleaning section. The non-magnetic material is fed into one end of a horizontal air classifier where it falls into a stream of air injected by a blower. Three product streams are collected from this unit: a heavy fraction which is conveyed over a magnetic head pulley for separation into massive ferrous and non-ferrous metal products; a middling fraction containing the bulk of the glass, ceramics, the lighter non-ferrous metals, heavy organics and other heavy combustibles; and a light fraction which is aspirated via a cyclone for collection and forms a second paper/plastic product for fuel production.

The middlings from the horizontal air classifier are screened at 19mm in a trommel, and the oversize is shredded to -50mm in a knife mill prior to air classification in a three stage aspirator. Induced draught through the shredder and the bottom and side of the aspirator entrains the light combustible material, while a heavier, aluminium-rich fraction falls through and is conveyed to the non-ferrous metal recovery section. The undersize from the trommel (-19mm) is conveyed to the glass recovery section.

5.1.1 Glass Recovery

The glass recovery section was a combined jigging and froth flotation operation to recover glass as clean cullet. This section and the remaining sections use one process line operating 8 hours per day, and sufficient surge capacity is provided to ensure a constant feed to the sections.

The undersize from the trommel screen (comprising about 25% of the input waste) is fed to a bank of 10 mineral jigs. The jigs produce four product streams: organic waste for dewatering and use as fuel; heavy non-ferrous metals for collection and sale; fine glass, and a glass/aluminium mixture. The latter two streams are combined, the larger aluminium particles removed by selective comminution and screening of 0.8mm, and glass is recovered by froth flotation.

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*1 US short ton = 2000 lb = 0.907 tonnes

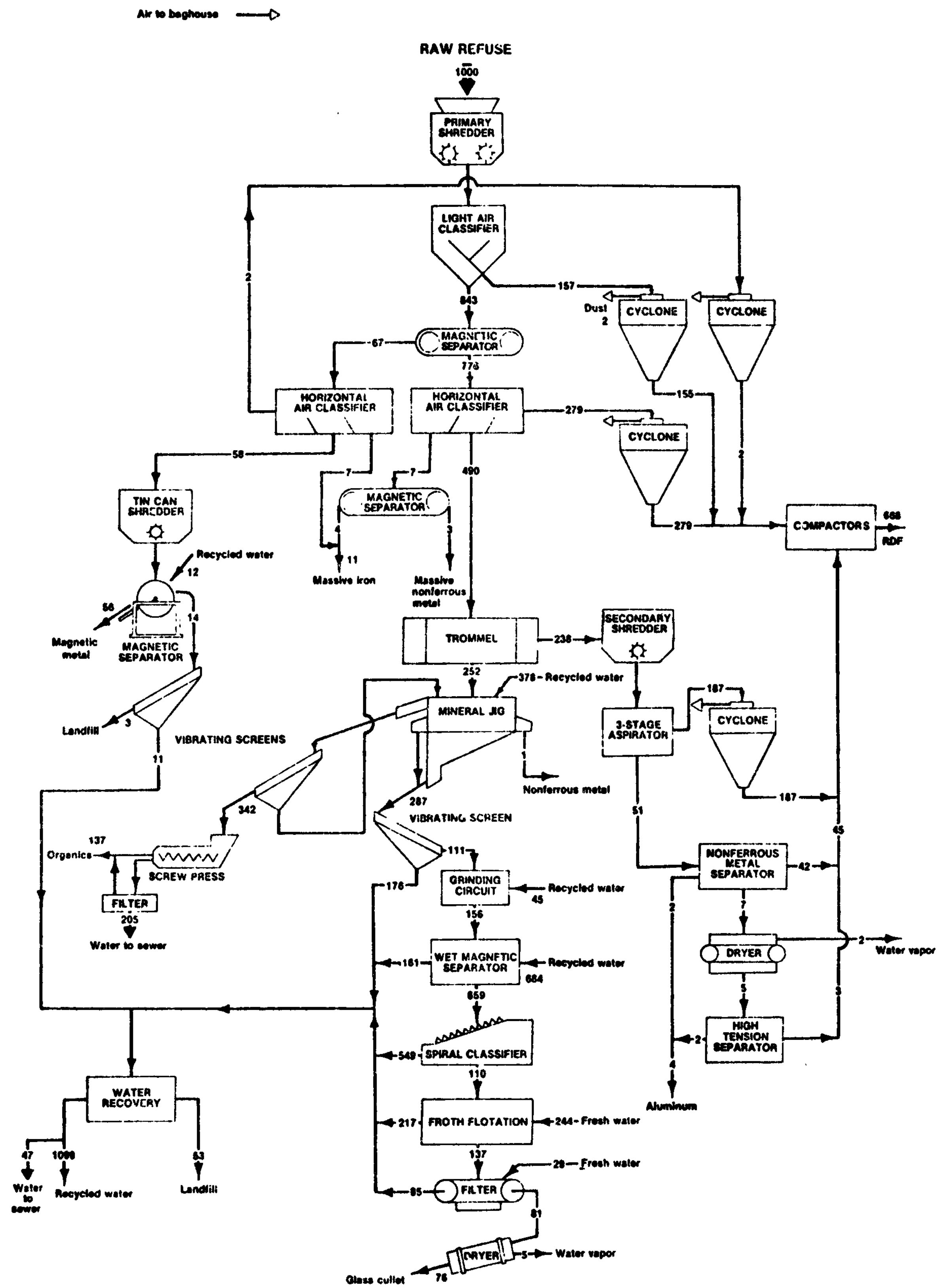

FIG.10 USBM FLOWSHEET

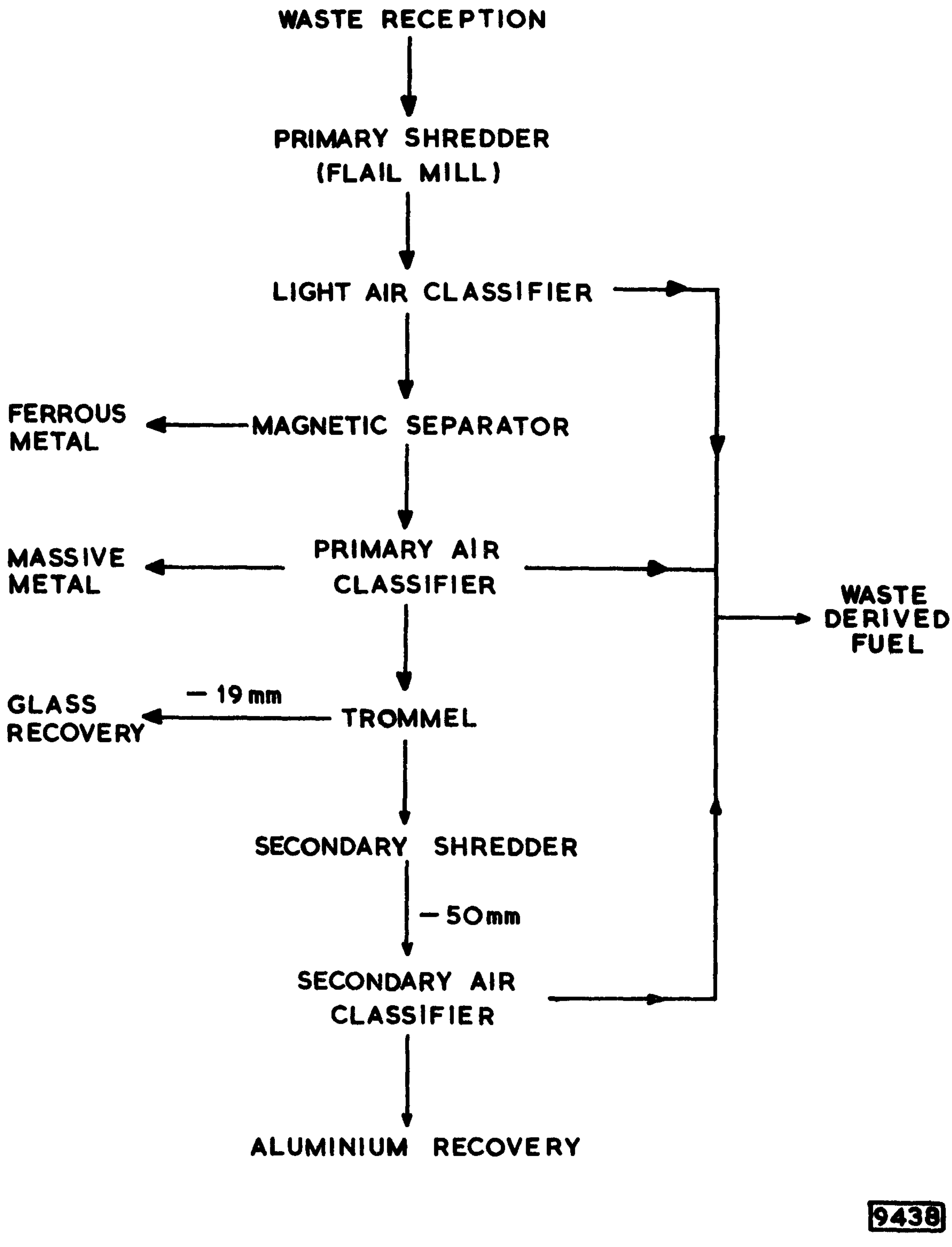

FIG.11 USBM SIMPLIFIED FLOWSHEET

5.1.2 Ferrous Metal Cleaning

The ferrous metal fraction from the primary bulk separation section is fed to a horizontal air classifier similar to the units described previously. Ten per cent of the feed to this unit is collected as massive metal and conveyed to the massive ferrous metal collection bin. Another 2.4% is entrained in the airstream and collected in a cyclone. The remaining material is fed to a tin can shredder and reduced in size to minus 50mm. After shredding the ferrous metal is fed to a drum-type magnetic separator where food particles, paper and other non-magnetics are removed by water sprays.

5.1.3 Non-Ferrous Metal Recovery

The heavy material from the three-stage aspirator is fed to a non-ferrous metal separator. This unit consists of multiple inclined stacks of the device developed by the Raytheon Service Company, and described in Section 4.7. The feed is separated by this unit into three fractions: a 95% metal product, a 40% metal concentrate, and a heavy combustible fraction containing less than 4% metal.

The 40% metal concentrate is then dried in a moving belt dryer and fed to a high-tension separator. This unit recovers a 95% metal product, which is combined with the 95% metal product from the non-ferrous metal separator and conveyed to a storage bin. The non-metallic product from the unit is combined with the heavy combustibles from the non-ferrous metal separator and conveyed to the fuel handling section.

5.1.4 Fuel Handling

Combustibles, collected in the three cyclones in the primary bulk separation section and the cyclone in the ferrous metal recovery section, are combined with the heavy combustibles from the non-ferrous recovery section and conveyed to a 9.1m high storage bin. The bin discharges directly into four compactors, which load the fuel into containers for shipment. The final density of the compacted product is about 320 kg/m^3.

Dust, contained in the airstream from the cyclones, is collected in baghouses and mixed with the dewatered organics from the mineral jigs. This wet product, heavy organic fuel, is not compacted but loaded directly into separate containers for shipment.

5.1.5 Water Recovery

Water requirements for this process are minimised by recycling the waste water. All the items of equipment which require water can use recycled water except for the froth flotation unit and the following filter which require pure water to maintain the purity of the glass cullet. Impurity buildup in the recycled water is limited by discarding to a sewer the water from the screw press in the glass recovery section after it has been filtered to remove suspended solids.

Waste water streams from the glass recovery and ferrous metal recovery sections are pumped to a thickener. Overflow from the thickener is filtered to remove suspended solids and is then recycled. Thickener underflow is pumped to a rotary vacuum filter and dewatered. The filtrate is recycled to the thickener. Filter cakes from the two filters are conveyed to a collection bin for landfill.

5.1.6 Products

The products of the USBM process, as envisaged from its operation in the USA, are waste-derived fuel, a heavy organic fuel, mixed-colour glass cullet, light-gauge iron, massive iron, aluminium and mixed non-ferrous metals. The quality of the products was discussed in a previous report[2], but it is necessary here to add some comments on the fuel products and on the products which might be expected to be recoverable from European wastes.

In an earlier publication[33] it was stated that the light products from the first two air classifiers contained a considerable amount of fine glass, grit and dirt as would be expected from a process with front-end shredding. It was suggested that to prepare these products for use as fuel they should join the feed to the trommel and thus be subjected to a further shredding and air classification treatment. This method of processing is not included in the flowsheet shown in Fig. 10, for which economic data are available, and the fuel product from this flowsheet might therefore be expected to have a high ash content. The average calorific value of the fuel is expected to be about 15 MJ/kg. The heavy organic fuel product, after dewatering to 50% solids, has a calorific value of around 9 MJ/kg.

As noted in Section 3.1 the composition of household waste in the member countries of the Community differs significantly from that in the USA. This makes prediction of the recoveries achievable with an American process difficult. If the processes were operated in the UK, the virtual absence of aluminium cans from the waste in most locations would undoubtedly make the recovery efficiency for aluminium very much lower than in the USA. In attempting to make an economic analysis it is therefore assumed that the non-ferrous metal recovery section of the process would be omitted. For the remaining materials it is assumed that the same recovery efficiencies could be achieved in the UK. This is a reasonable assumption for ferrous metal and glass, but it is open to doubt for fuel in view of the lower paper and higher moisture contents of the waste. This doubt is reinforced by the experience of Enadimsa in Madrid, who found that it was necessary to eliminate the horizontal air classifier from the flowsheet to enable them to process waste with a high content of vegetable and putrescible material. In the more northerly countries of Europe the waste is near to American waste in composition but some modification of the flowsheet shown in Fig. 10 would probably be required.

5.2 The Black Clawson "Hydrasposal/Fibreclaim" Process

This wet separation system was originally designed to relaim paper fibre and ferrous metals from household waste, and to provide for the disposal of the residue. A 150 short ton/day plant was constructed in Franklin, Ohio, with financial assistance from the Environmental Protection Agency, and began operation in 1971. A glass and non-ferrous metal recovery system was added in 1973. The plant is currently operated only for one 6 hour shift per day, and treats about 54 tons/day of waste.

A simplified flowsheet of the Franklin plant is shown in Fig. 12. Incoming waste is tipped in a covered reception area. Bulky items, such as household appliances, tyres, mattresses, etc are removed, and the remaining material is loaded onto an apron conveyor. The waste is transported into the hydrapulper at the base of which is a rotor to agitate the material. Water, from a recycle loop, is added to form a slurry. The waste is broken up in the pulper until it is small enough to pass a 25mm screen underneath the rotor. Massive metals are ejected from the pulper and magnetically separated to recover the ferrous metal. The non-ferrous materials are returned to the pulper, where they are eventually reduced to less than 25mm in size and pass through the screen. The slurry containing minus 25mm materials passes into a liquid cyclone where the glass, ceramics, non-ferrous metals and other heavy inorganic materials are removed for further treatment, or disposal.

Pulp for fibre recovery at 3% solids is sized at 1.6mm in the "selectifier screen". This is a high volume rotary pressure screen. The oversize is rejected to the dewatering and incineration system. The screen undersize enters centrifugal cleaners for removal of grit, glass and other fine solids. The cyclone overflow continues via a screw dewatering system (to 18% solids), to a cone press (to 50% solids) and finally to a stock dilution tank, from which it is pumped to a neighbouring factory for use in the production of roofing felt.

The input to the dewatering and incineration system consists of the rejected material from the fibre recovery system, or the whole of the pulp from the liquid cyclone if the fibre recovery system is not in operation. The pulp is dewatered to 45% solids in a similar system to the one used in the fibre recovery circuit. Sewage sludge can be added between the screw and cone processes, ostensibly without detriment to the process, although in practice it appears that only very limited quantities are added. The dewatered solids are fed to a fluidised bed combustor, the extracted water being recycled to the primary pulping unit.

The process is also offered as a waste-derived fuel process. In this case the dewatered pulp is conveyed to a fluffer, or light duty hammer-mill, which disintegrates the cake for pneumatic transport to storage hoppers.

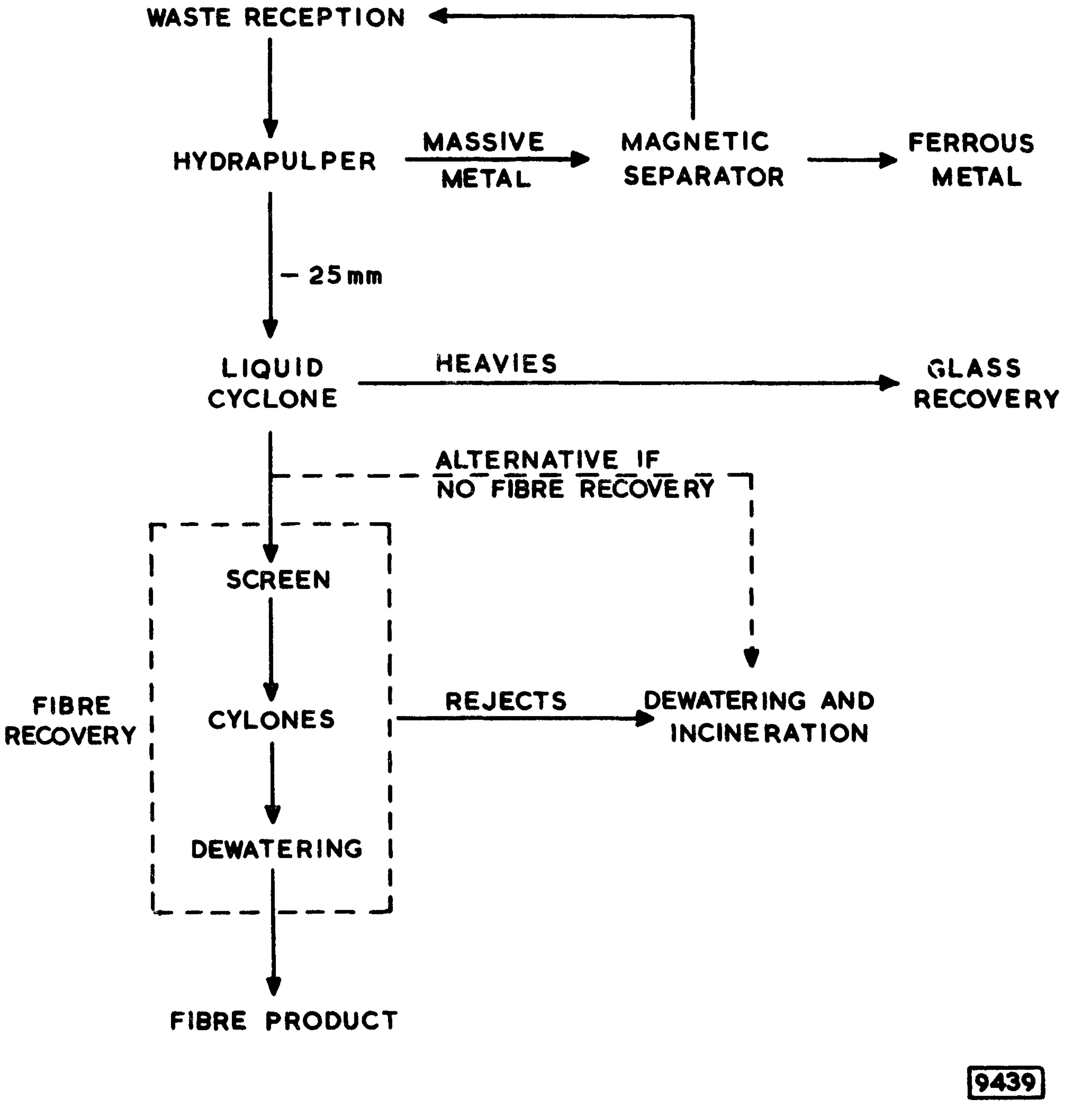

FIG. 12 BLACK CLAWSON SIMPLIFIED FLOWSHEET

The glass and non-ferrous metal recovery plant was described in a previous report[2], and a recently published paper provides information on the economics of this part of the plant[35]

Materials Balance and Products.

The Franklin plant has been the subject of a thorough technical evaluation on behalf of the Environment Protection Agency[36], and detailed materials balances have been published.

The composition of the waste input to the Franklin plant is as follows:

Paper	40%
Non-fibrous organics	37%
Ferrous metal	9.8%
Non-ferrous metal	1.3%
Glass	8.5%
Inerts	3.4%
	100.0%

In addition bulky unprocessable objects amounting to 7.5% of the input are received.

The process recovers 49% of the paper in the fibrous product and 94% of the ferrous metal. Approximately 50% of the input waste is burned in the incinerator and 20% is rejected to landfill if the glass recovery plant is not operated.

5.2.1 Paper Fibre Product

In Franklin this is sold for the manufacture of roofing felt and there appears to be no experience in the USA of its use in papermaking. In England PIRA[37], the Research Association for the Paper and Board, Printing and Packaging Industries, has examined samples of the fibre product from Franklin and from the US Forest Products Research Laboratory in Madison, Wisconsin, (the latter sample was prepared by a dry separation technique, see Section 4.3). It was found that the two samples had considerably different fibre length distributions: 60% of the fibres in the Madison sample were "long" compared with only 35% in the Franklin sample. Considering the severity of the treatment in the Black Clawson process this is perhaps not surprising. The overall conclusion, however, was that both samples were similar in properties to a hardwood bisulphate pulp and could be used in the manufacture of low-grade board products. There was no contamination, either by chemicals or bacteria, which would inhibit their use by the paper industry.

5.2.2 Fuel Product

The fuel products has a calorific value of about 3 MJ/kg at a moisture content of 55%. The ash content is high at 24.5%, but this might be partly due to the additional grit from the sewage sludge. A much lower ash content of 5% is claimed for the fuel product when sewage sludge is not added[38]. It is, however, difficult to see any advantage in using a wet processing system to recover waste-derived fuel.

5.3 Other North American Developments

5.3.1 Raytheon Service Company

The process developed by Raytheon is based on work performed under a co-operative agreement with the US Bureau of Mines. Raytheon was awarded a contract to design a resource recovery system for Monroe County, New York. Contracts to build a 140 short ton/day plant at a cost of $28.4 million were signed in September 1976. Details of this project have been published[39].

The process flowsheet is shown in Fig. 13, and the relationship with the USBM process is obvious. The main differences are in the primary shredding and air classification system. Raytheon use a hammer mill rather than a flail mill, but coarse shredding is used to reduce the amount of fine glass produced and minimise the maintenance cost of shredding. The primary air classifier is a rotating drum inclined at

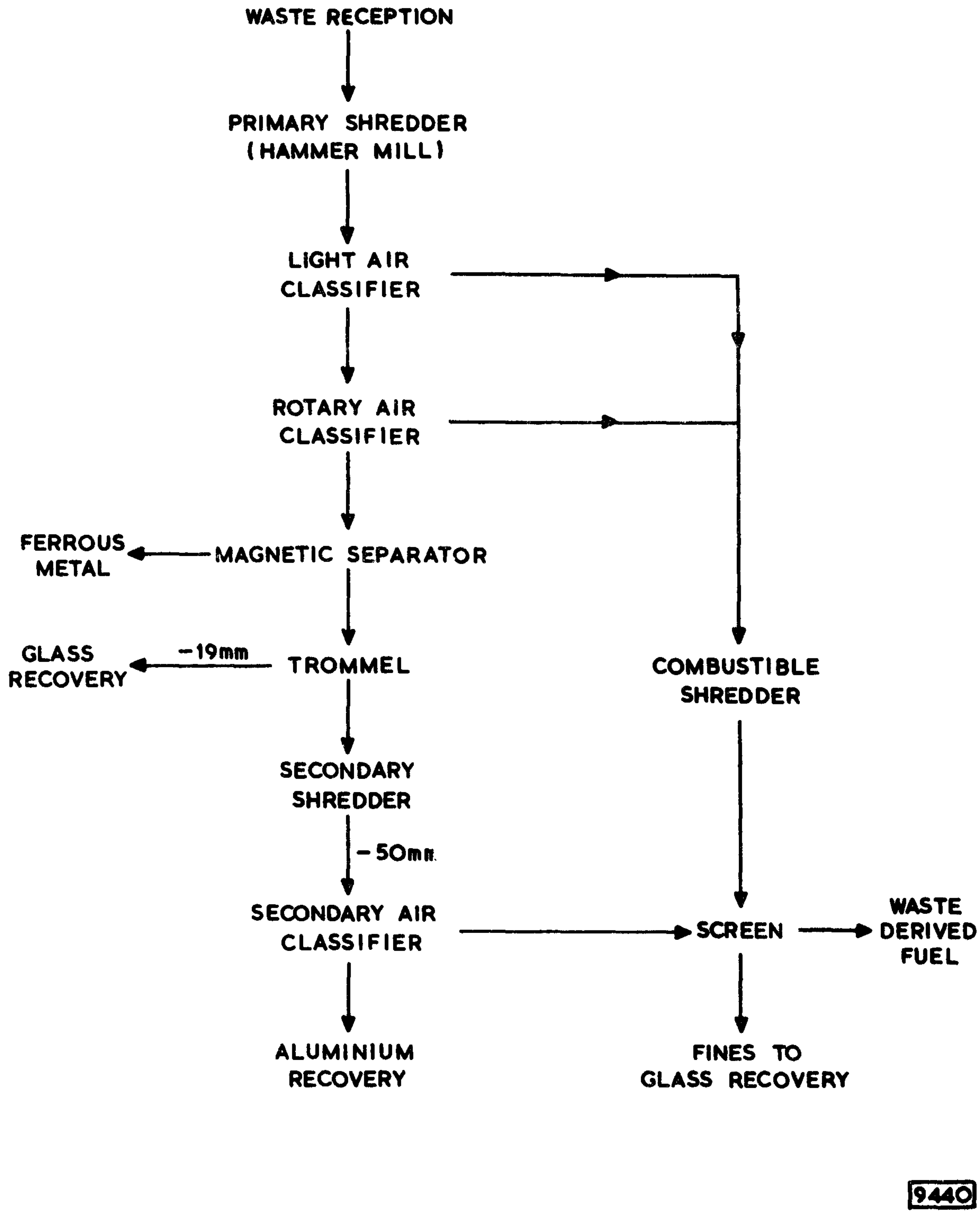

FIG. 13 RAYTHEON SIMPLIFIED FLOWSHEET

at a small angle to the horizontal with a low velocity axial air stream[9] (see Section 4.2). The secondary air classifier is a three stage aspirator, similar to the one designed by USBM, and the lights from the various air classifiers are shredded to -25mm for sale as waste-derived fuel. Glass recovery is by froth flotation, and non-ferrous metal recovery is still under development, but various novel methods are being investigated[27,28] (Section 4.7).

5.3.2 National Center for Resource Recovery

The National Center for Resource Recovery (NCRR) is a non-profit-making body which started as a public information group, but in 1972 moved into R & D with the aim of providing information necessary for assessments of the efficiency of operation of solid waste sorting systems. The first projects carried out were on the particle size distribution of shredded waste and the design of a mobile air classifier[40]. In 1973 a location for a laboratory was found in Washington D.C. A shredder was already on-site, and equipment has been added to develop this into a 20 short ton/hour pilot plant.

The flowsheet of the Washington pilot plant is shown in Fig. 14. This plant has been used to study the recovery of aluminium using an eddy current separator[25], and more recently to prepare over 200 tonnes of pelletised waste-derived fuel for combustion trials as a supplementary fuel in combination with coal[41]. Incidentally, the Triple S air classifier has now been replaced by a zig-zag air classifier designed by NCRR[41].

In 1973 the City of New Orleans signed a contract with NCRR to act as technical consultant in the design, construction and operation of a resource recovery plant. Construction started in November 1974, but at the time of the visit in September 1976 only the waste reception system was operating. The flowsheet, shown in Fig. 15, is similar in principle to the Washington pilot plant. A curious feature of the system is that there is no market for solid fuel in New Orleans, and the air classifier lights will be used to fill a swamp. The heavies are treated for recovery of non-ferrous metals and glass.

A particularly interesting feature of the New Orleans flowsheet is the use of a trommel preceding the primary shredder. This is done to remove abrasive materials prior to shredding, so as to reduce maintenance on the shredder and avoid the production of fine particles of glass. Pilot-scale tests indicated that approximately half of the input waste could be removed as minus 100mm material, and that this fraction contained approximately 70% of the metals and 95% of the glass in the feed[42].

5.3.3 Occidental Research Corporation

Occidental have developed a "Flash Pyrolysis" process which uses a waste sorting system as a front-end to produce an organic concentrate suitable for feeding to the pyrolysis reactor. Construction of a 230 short tons/day demonstration plant was nearing completion in September 1976.

The process flowsheet is shown in Fig. 16. Several aspects of this process are essential in preparing the feed for pyrolysis but could be omitted if the process were used to make a solid waste-derived fuel. For example, after removal of ferrous metal the shredded waste is conveyed to a storage building which provides buffer capacity so that the pyrolysis plant can be run continuously when waste is not being delivered. Also, after drying and screening, the air classifier lights are shredded to produce a pyrolysis feed which is 80% smaller than 1.2mm, and this step must be operated under a pressurised nitrogen atmosphere to prevent fires. Other aspects are more conventional, such as glass recovery by froth flotation and aluminium recovery using an eddy current separator, although Occidental have developed their own technology for these systems[20,24].

In 1974 there were plans to construct a waste sorting plant based on Occidental's technology for the Connecticut Resource Recovery Authority. Problems in the financing of this project led to a joint venture being undertaken with another company, Combustion Equipment Associates (CEA), for the construction of a plant in Bridgeport, Connecticut. This plant will use Occidental's technology for recovery of glass and non-ferrous metals combined with CEA's process for preparing a fine powdered supplementary fuel, ECO-Fuel II, which has handling and combustion properties similar to pulverised coal. The ECO-Fuel process uses shredding in a flail mill and air classification to produce a combustible

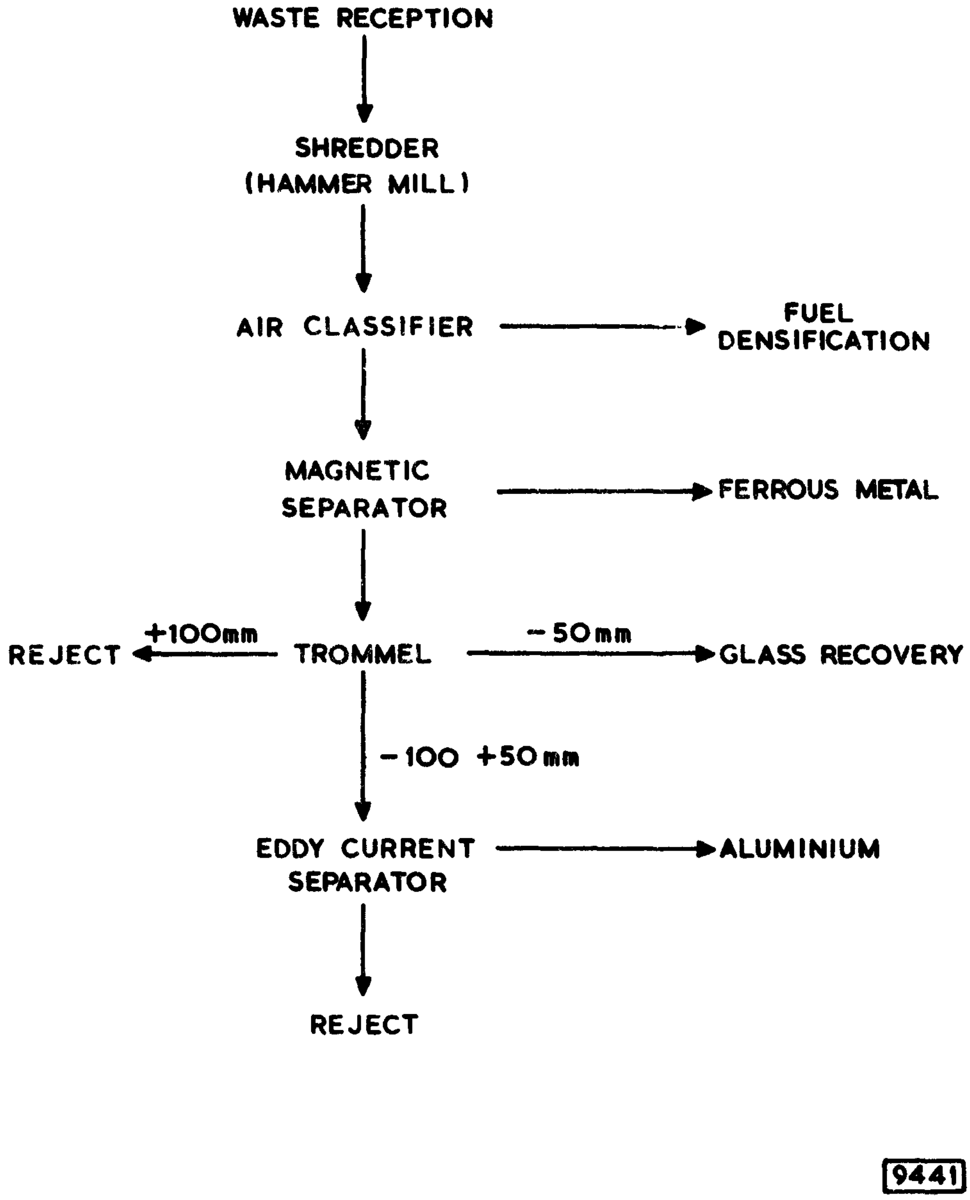

FIG. 14 NCRR WASHINGTON PILOT PLANT

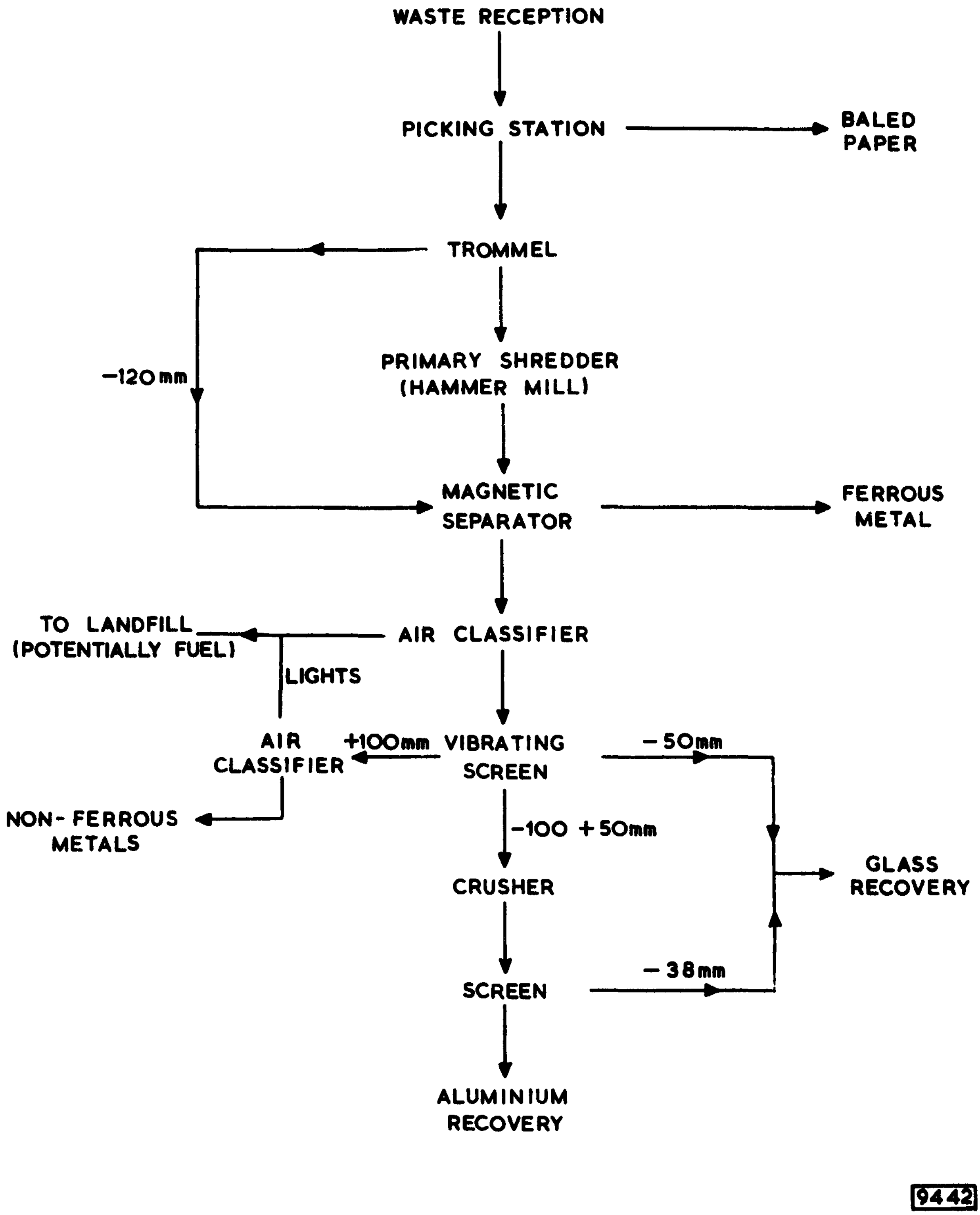

FIG. 15 NCRR NEW ORLEANS SIMPLIFIED FLOWSHEET

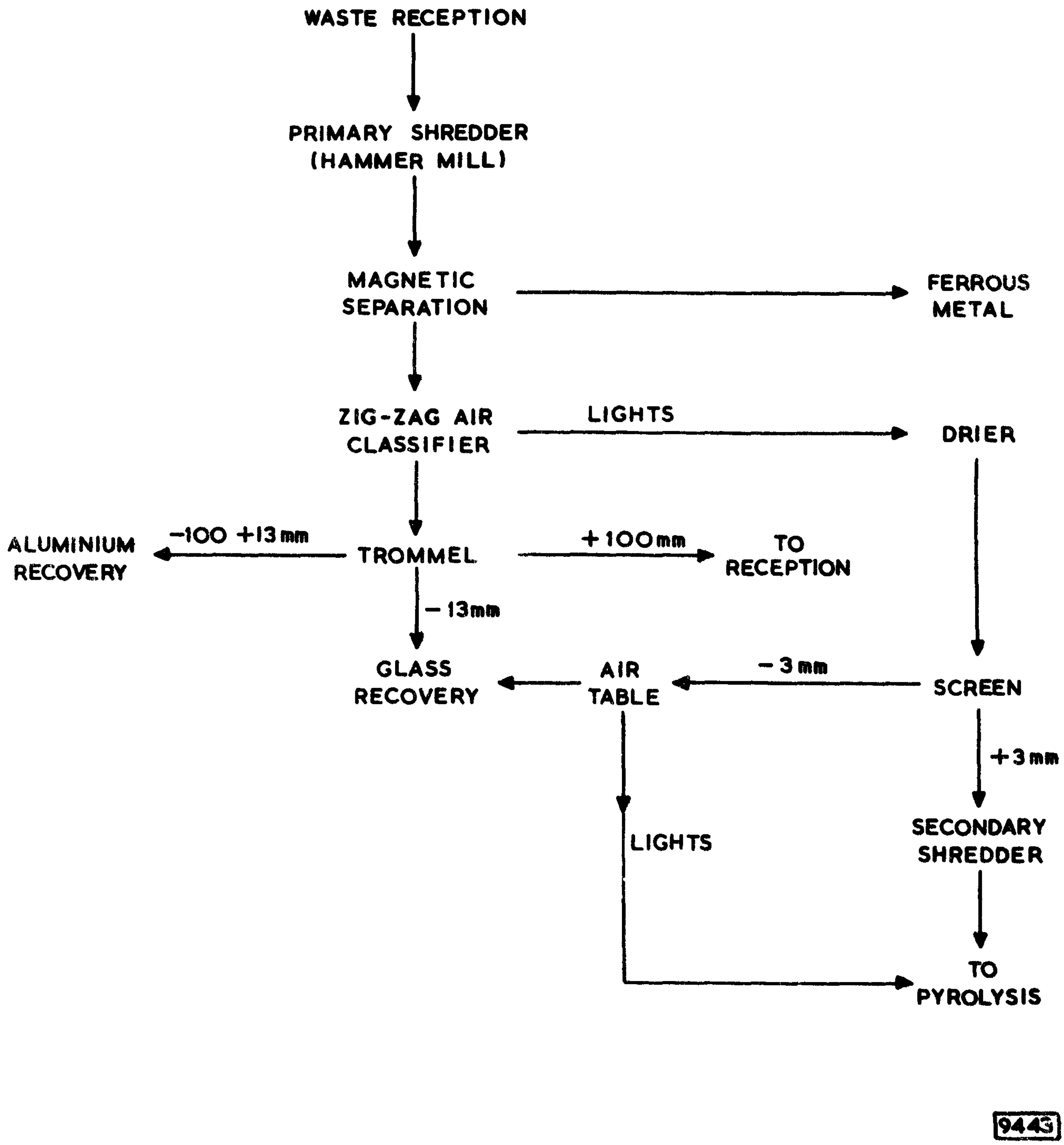

FIG. 16 OCCIDENTAL SIMPLIFIED FLOWSHEET

rich fraction, which is screened to remove glass and other inorganics before further size reduction by hot ball milling in the presence of a proprietary embrittling agent[43]. It has not been possible to obtain up-to-date information about the state of development of the Bridgeport project.

5.3.4 Teledyne National

This project is a joint venture between Teledyne, Baltimore County and the State of Maryland. In September 1976 the throughput of the plant was 800 short tons/day, but the design capacity if 1500 tons/day and it will operate at this level when construction of a transfer station is completed.

The process flowsheet, shown in Fig. 17, is fairly conventional. The two stage vertical cylinder air classification system is used to produce two products. The lighter one is a clean cellulosic fraction which is considered suitable for use in suspension-type boilers, while the denser one is intended for use in chain grate stokers.

At the time of the visit the system was still under development and many aspects had not been tested. Work on optimisation of the fuel products still had to be done, and the secondary circuit for glass and aluminium recovery was not in operation. An interesting feature is that no attempt is being made to process the glass product so that it can be used by glass manufacturers. Instead a range of foamed glass products such as aggregates of controlled density, pipes and panels are being investigated[2].

5.3.5 Ontario Centre for Resource Recovery

This organisation is a branch of the Ontario Ministry of the Environment. An experimental plant has been designed to process 800 short tons/day of domestic and commercial waste. The principal objectives of the plant are:

- to develop and evaluate processes and equipment for resource recovery
- to develop criteria for estimating capital and operating costs of a range of plant sizes and process combinations, and
- to provide a regular supply of recovered products of controlled quality for market development.

Construction of the plant was well advanced in September 1976 and was expected to be completed during 1977.

A simplified flowsheet is shown in Fig. 18. Manual extraction of paper and non-ferrous metals are included to enable the economic feasibility of recovery to be evaluated. Provision has been made to add automatic separation equipment at a later date if warranted. In order to investigate the use of solid waste as an energy source, an incinerator unit with a heat recovery system is included to provide part of the plant heating requirements. The air classification system is of novel design, and the plant was the only one visited in North America which included composting. At present, little of the equipment has been tested at the scale envisaged for this operation, so operating data from this experimental plant should be very interesting when they become available.

5.3.6 Waste Derived Fuel Systems

Several systems have been developed in the USA with the major objective of extracting a shredded combustible fraction from household waste for use as a supplementary fuel in power generation. The earliest, and best known of these schemes was the St Louis-Union Electric project. With a subsidy from the Environmental Protection Agency (EPA), a 35 tonne/hour demonstration plant was built to investigate the separation of a supplementary fuel from solid waste and its combustion together with coal in a pulverised fuel boiler. The plant consisted basically of a hammer mill, a vertical column air classifier and an overband magnetic separator. Detailed technical evaluations of the system were carried out by the Midwest Research Institute on behalf of the EPA and reports have been published[5]. This project was widely regarded as very successful, but it was shut down in 1976 because government funds for its operation had been exhausted, and its scale was considered too small for economical operation in St Louis.

Before the plant shut down, Union Electric announced a second and much more ambitious project based on the results of the first. It was intended to process 8000

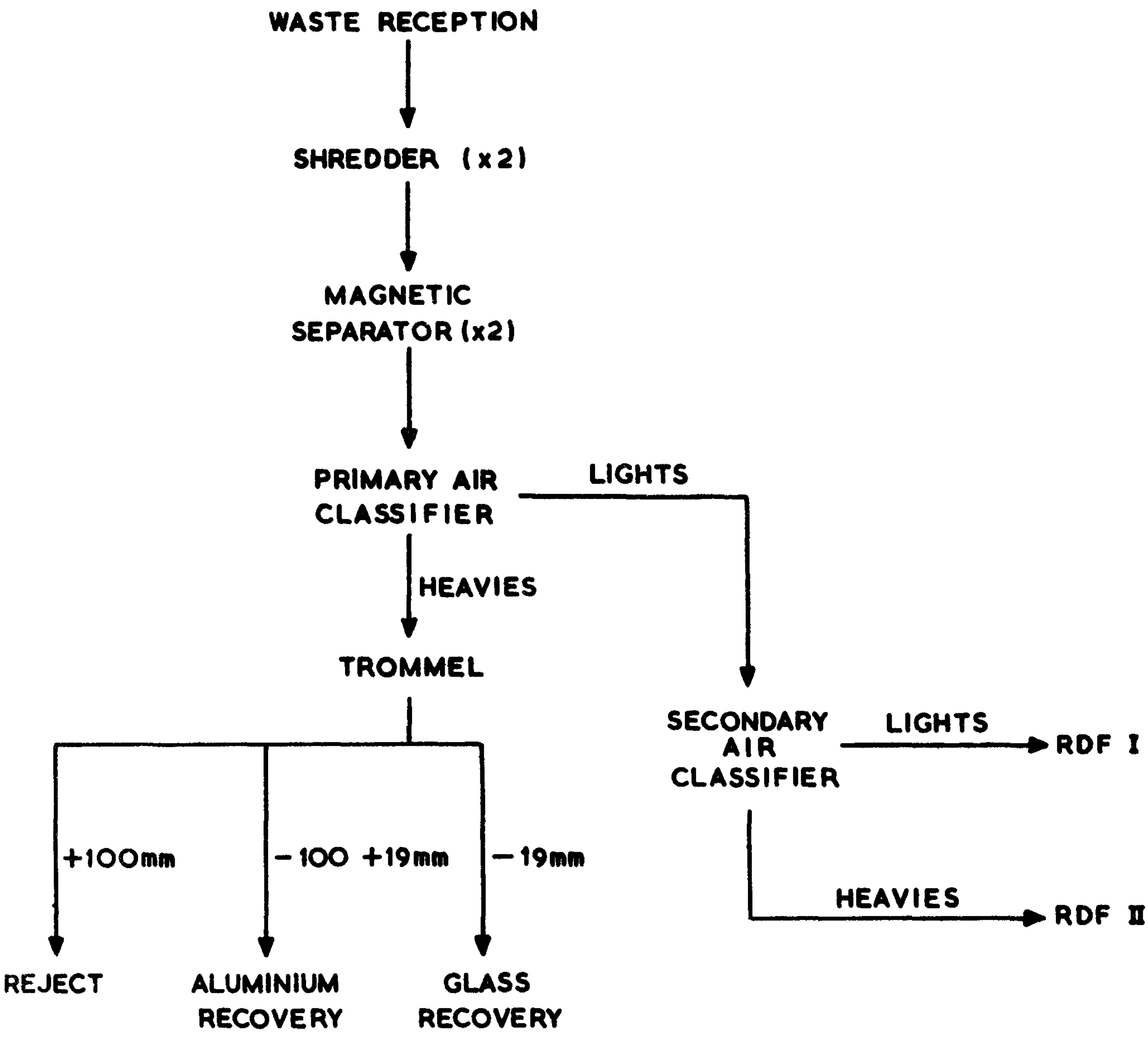

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FIG. 17 TELEDYNE SIMPLIFIED FLOWSHEET

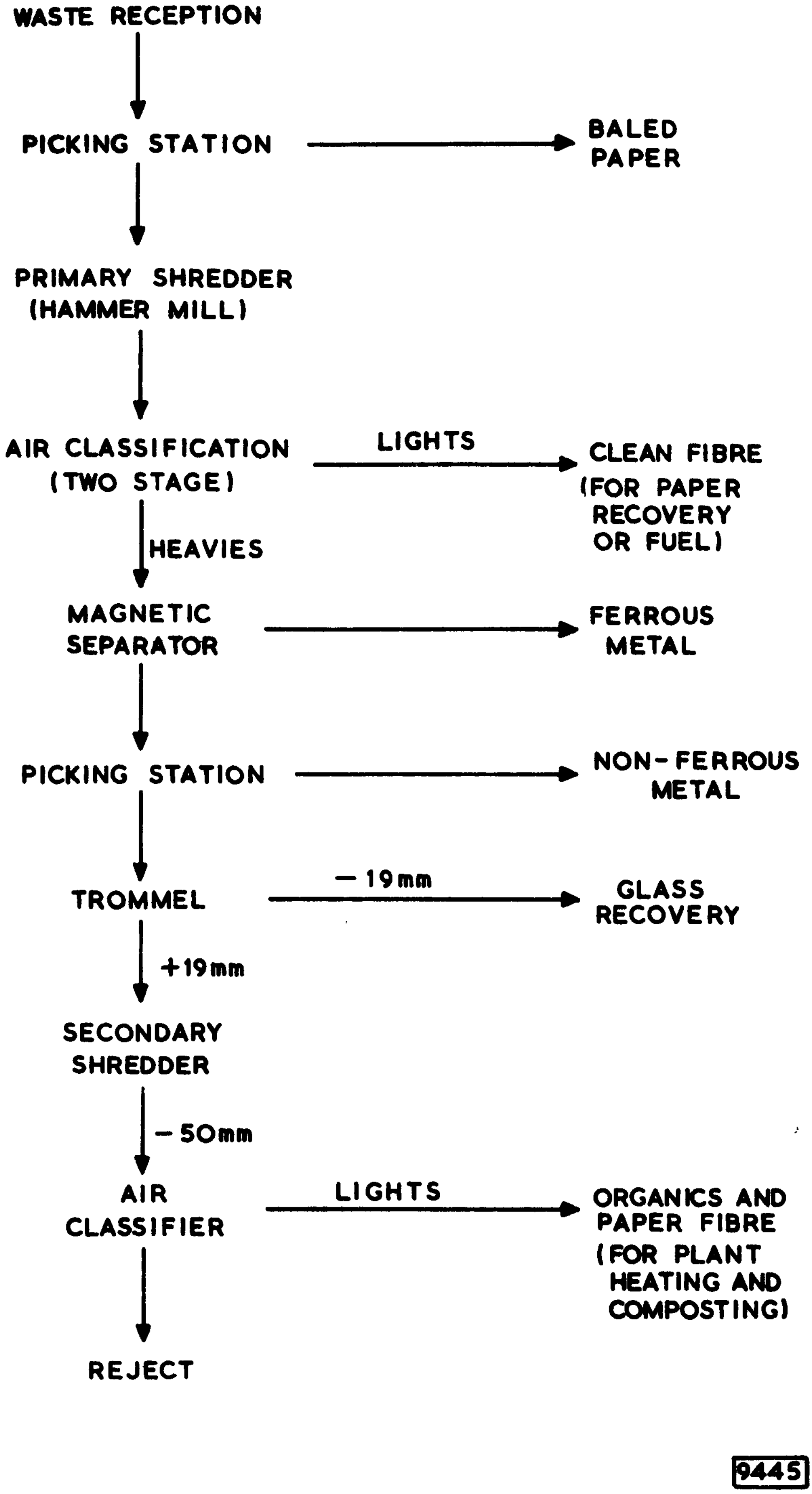

FIG. 18 ONTARIO CENTRE FOR RESOURCE RECOVERY FLOWSHEET

short tons/day from a large surrounding area and thus to provide fuel for two power plants. The initial phase of this project involved construction of a 6000 ton/day plant to supply the power plant used in the EPA demonstrations. Unfortunately problems have arisen in the funding of this project and the large plant has been delayed indefinitely. It is emphasised that the reasons for the cancellation are financial, not technical, and it is hoped and believed in the USA that the project will eventually be restarted.

A very similar process has been operated for over a year in Ames, Iowa. This plant is designed to process 300 short tons of waste per 6 hour day. Very few details of the operation of this process are available, and it has not yet been possible to obtain a copy of a promised EPA report*.

Two other processes have recently come on-stream. In Chicago, the plant designed by the Ralph M. Parsons company differs from the St Louis and Ames processes mainly in the type of air classifier used, which is a Triple S. It is reported that fuel from this plant was burned in the Spring of 1977[41]. In Milwaukee, the Americology Division of American Can have constructed a 1200 short ton/day plant. A zig-zag air classifier is used in this process, and there are also facilities for aluminium recovery. Eight hundred tons of fuel from this plant were recently burned by the Wisconsin Electric Power Company[41].

6. WASTE SORTING PROCESSES IN EUROPE

During the course of the study, with the assistance of the co-pilot representatives, information has been gathered on all the major developments in waste sorting technology within the Community. Italy is the only member country with experience of full-scale commercial operation of waste sorting, but pilot scale work is at an advanced stage in France, Germany, Holland and the UK and there are plans for the construction of larger plants. In Belgium a project has started at the Polytechnic of Mons but no results are yet available. Outside the Community interesting information on work in progress in Spain and Sweden has also been included. Detailed descriptions of most of the processes under development were given previously[3]. These processes are now briefly reviewed, taking into account further information which has become available.

6.1 France

Visits to three organisations in France were included in the study. In Orleans the Bureau de Recherches Géologiques et Minières (BRGM) has been studying waste sorting since 1975. A 1.5-2 tonne/hour pilot plant has been constructed, but because of the involvement of private enterprise in the funding of the project, BRGM were not at liberty to divulge details of the process. It is understood that shredding is not involved, and that the products of the process include cardboard boxes, newspaper and magazines, soiled paper, glass and plastic containers (including separation of polyethylene and PVC) ferrous metal and organic materials. The SOCEA company is developing a process in association with Enadimsa in Madrid, and a 15 tonne/hour prototype plant is under construction at Tournan-on-Brie. It was not possible to visit this plant, but the type of equipment used was seen in Madrid and is discussed in Section 6.6. The waste-derived fuel plant in Laval, constructed by Société d'Études et d'Ingénierie (SOCETING) was seen in operation and a description of the process now follows.

6.1.1 The COMBOR Process

The process is known by the name which has been given to the pelletised fuel product, COMBOR (Combustibles d'ordures ménagères). The flowsheet is shown in Fig. 19. The capacity of the plant at Laval is 8 tonnes/hour. It has been built on the site of a shredding and composting station and uses the existing Tollemache vertical hammer mill to reduce the waste to 50% minus 50mm. Ferrous metal is removed by a magnetic head pulley and the non-magnetics are screened at 20mm on a vibrating screen. The minus 20mm fines consisting of ashes, sand, glass and some paper and organics, amount to about 25% of the

*Since writing this report the EPA assessment of the Ames process has been received, but unfortunately too late for consideration here.

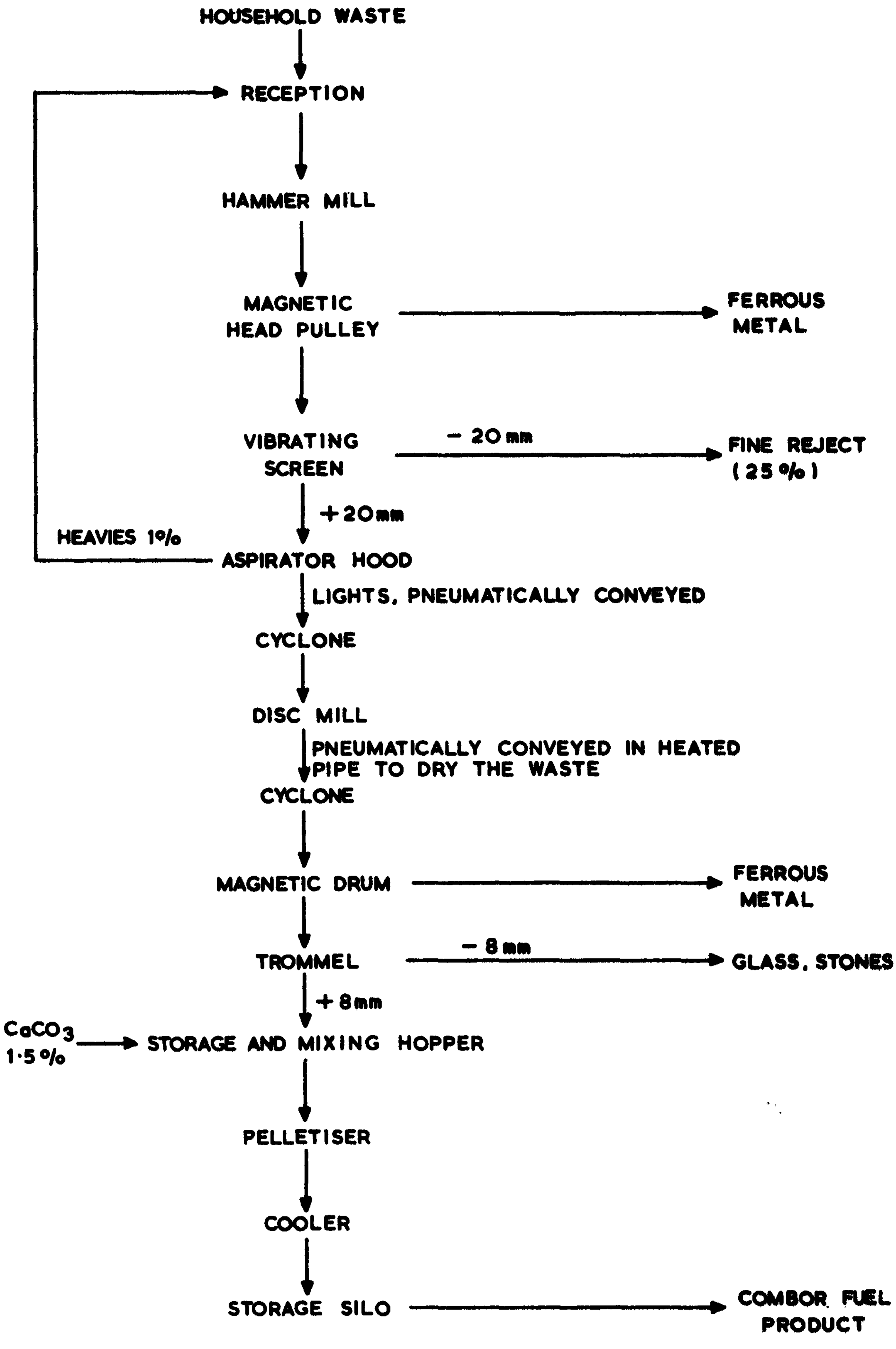

FIG.19 FLOWSHEET OF THE COMBOR PROCESS

input waste.

Light materials in the oversize are aspirated by a hood (approximately 1.5m x 0.5m) situated at the lower end of the vibrating screen. The simple air classifier uses 24000m^3/hour of air for a thorough, but not very selective, removal of lights. This ensures that losses of combustible materials are minimised; large pieces of textile, for example are aspirated, but so also are items such as cable which contain inorganics which might be expected to increase wear and maintenance requirements in subsequent parts of the plant. They may also give rise to undesirable characteristics in the fuel product. The heavies, amounting to only about 1% of the feed, are returned to the reception pit.

The remainder of the process consists of secondary shredding, removal of ferrous metal, glass and stones and pelletising of the fuel product. Before pelletising, calcium carbonate equivalent to 1.5% of the input to the mixer is added, ostensibly to neutralise chlorine released as hydrogen chloride during combustion. The company has not yet carried out any combustion trials, and has no information on the composition of the gases released, but all members of the CREST team were sceptical about the effectiveness of the presence of calcium carbonate in controlling the release of hydrogen chloride.

The fuel product is pelletised in two 75 HP presses, which are operated alternately. The pellet mills are fitted with stationary cylindrical dies made up of two semi-circular sections, with the axis of the cylinder vertical. The pellets are 16mm in diameter and approximately 25mm long. It was stated that the dies would require replacement after processing 3000 tonnes of fuel, but as the plant has only been in operation for 3 months this estimate cannot yet be firmly established.

Another aspect of the plant which will require regular maintenance is the pneumatic conveying system, and it was estimated that the life of the pipe bends would be 6 months.

The pelletised product is discharged at 70°C, cooled and then stored in a silo with a capacity of 3000 tonnes, or 4 months output. This is essential in Laval, where the product is to be used as fuel for a district heating system and demand will be seasonal. Production of COMBOR in Laval is expected to be 10,500 tonnes/year which is only 63% of capacity when the plant is operated on one 8 hour shift per day.

The COMBOR product represents 70% by weight of the waste input to the plant, but 10-12% moisture is evaporated during processing. The specifications of COMBOR which have been measured are:

Density	500 kg/m^3
Moisture content	12-14%
Calorific Value	3200-3800 kcal/kg (13.4-15.9 MJ/kg)
Ash fusion temperature	∿850°C

The glass content was claimed to be zero and the ash content 3-5%, but these low values are difficult to reconcile with the very low ash fusion temperature. It is expected that slagging problems might be experienced when the fuel is burned.

6.2 Germany

Pilot-scale sorting plants have been developed by the Technische Hochschule in Aachen, and by Kraus Maffei AG in Munich. In addition the production and combustion of waste-derived fuel is being investigated by the Karl Fischer company in Berlin. The Aachen project started in 1972 with funds from the Bundesministerium des Innern but the rights for its commercial development have been purchased by Siebtechnik GmbH. The Krauss Maffei R80 system was introduced in 1974 with financial support from the Bayerischen Staatsministerium für Landesentwicklung und Umweltfragen. The Aachen and Karl Fischer plants were visited by the project team, but the Krauss Maffei plant was only visited by the German co-pilots.

The published process flowsheet of the Aachen plant[44] is shown in Fig. 20. This represents the process as it is envisaged on a commercial scale rather than the pilot plant. There are several differences in detail, and the wet part of the process and glass recovery system are not on-line in Aachen. The scale of the pilot plant is 1-1.5 tonnes/hour. Primary shredding is carried out in a disc mill, but this is preceded by screening

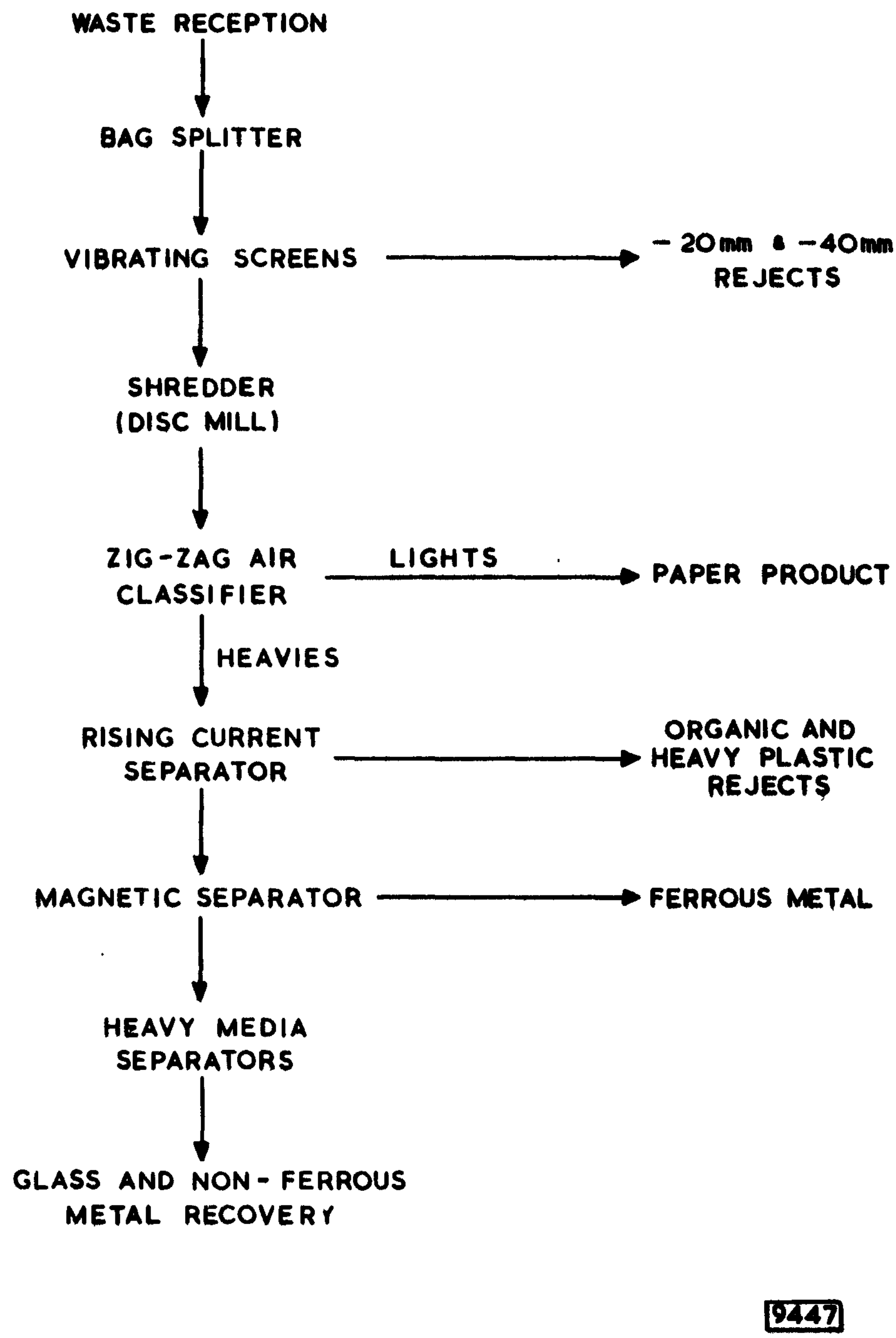

FIG. 20 AACHEN PROCESS SIMPLIFIED FLOWSHEET

to remove fines and a large proportion of the organic materials to minimise contamination and wetting of the paper content of the waste during size reduction. A paper-rich product is separated in a zig-zag air classifier.

The heavies from the air classifier are treated in a separate circuit for further separation of ferrous metal and glass concentrates.

The first step is the separation of organics and heavy plastics from metals and glass in a rising current separator. The advantage claimed for this method is that the cans are cleaned in the separator and their organic content is very low. In practice the rising current separator appeared to be much less efficient than claimed; a high proportion of ferrous metal was observed to report with the overflow, and the ferrous product was contaminated with paper and plastics.

After draining, ferrous metal is removed from the rising current separator heavies. Some off-line tests have been carried out on the recovery of non-ferrous metals by heavy media separation using ferro-silicon slurries and subsequent colour sorting of the remaining glass concentrates in a Sortex machine.

Several interesting ideas are being investigated in this pilot plant but it is apparent that many problems remain to be solved before a complete flowsheet can be commercially implemented.

A description of the Krauss Maffei R80 system is given in the Second Interim Report of the German co-pilots and only a very brief summary is given here. The process flowsheet is shown in Fig. 21. The incoming waste is coarsely shredded after magnetic separation to remove ferrous metal. The shredded material has a maximum size of 300mm and an average size of 120mm. After a second magnetic separation the non-magnetic fraction is screened at 60mm to remove compostable organic material. The oversize passes into a horizontal air classifier. The air classifier lights are screened at 100mm to remove an oversize product consisting of plastic film and paper sheets. Further paper is separated from the screen undersize on a zig-zag air classifier, and the paper fractions are combined. As the plant has not been seen by the authors it is not possible to comment on the efficiency of the process or the quality of the products.

The Karl Fischer pilot plant in Berlin has been designed to produce waste-derived fuel and in principle it is very simple. Household waste is conveyed into a bag splitter at a rate of 15 tonnes/hour. The firm has experienced problems with the bag splitter and hopes to eliminate this step and use the subsequent trommel for liberation. In consequence the waste will be fed directly into the trommel which has two screening sections; 20mm holes cut in a plate, and 200mm rings welded together in close packed arrangement (60° centres). The minus 20mm fraction is discarded to landfill and the plus 200mm fraction is retained as a final product. Surprisingly no further separation is made of the oversize product. It was stated that the product was almost 100% combustible and further treatment, other than shredding for fuel preparation, wasnot worthwhile.

The plus 20 minus 200mm fraction is conveyed to the air classifier, which was described in Section 4.2. The air classifier lights and the plus 200mm trommel oversize are combined and shredded in a slow speed knife shredder. The shredded product, nominally less than 50mm, is dried in a rotary drier and then stored in a silo. The company has designed a combustion unit and carried out combustion tests, but no detailed results are available.

6.3 Holland

The Centraal Technische Instituut TNO began work in the waste recovery area in 1971-72. Their studies concentrated initially on the use of a zig-zag air classifier with the aim of producing a recyclable paper product. The results of these experiments attracted the interest of the Dutch paper industry and financial support from the Estel group of companies for further development. With this support it has been possible to install a 15 tonne/hour plant at a shredding station in Haarlem. This large unit, which is a prototype rather than a pilot plant, has been in operation for two years to permit evaluation of the products to proceed on a continuous basis.

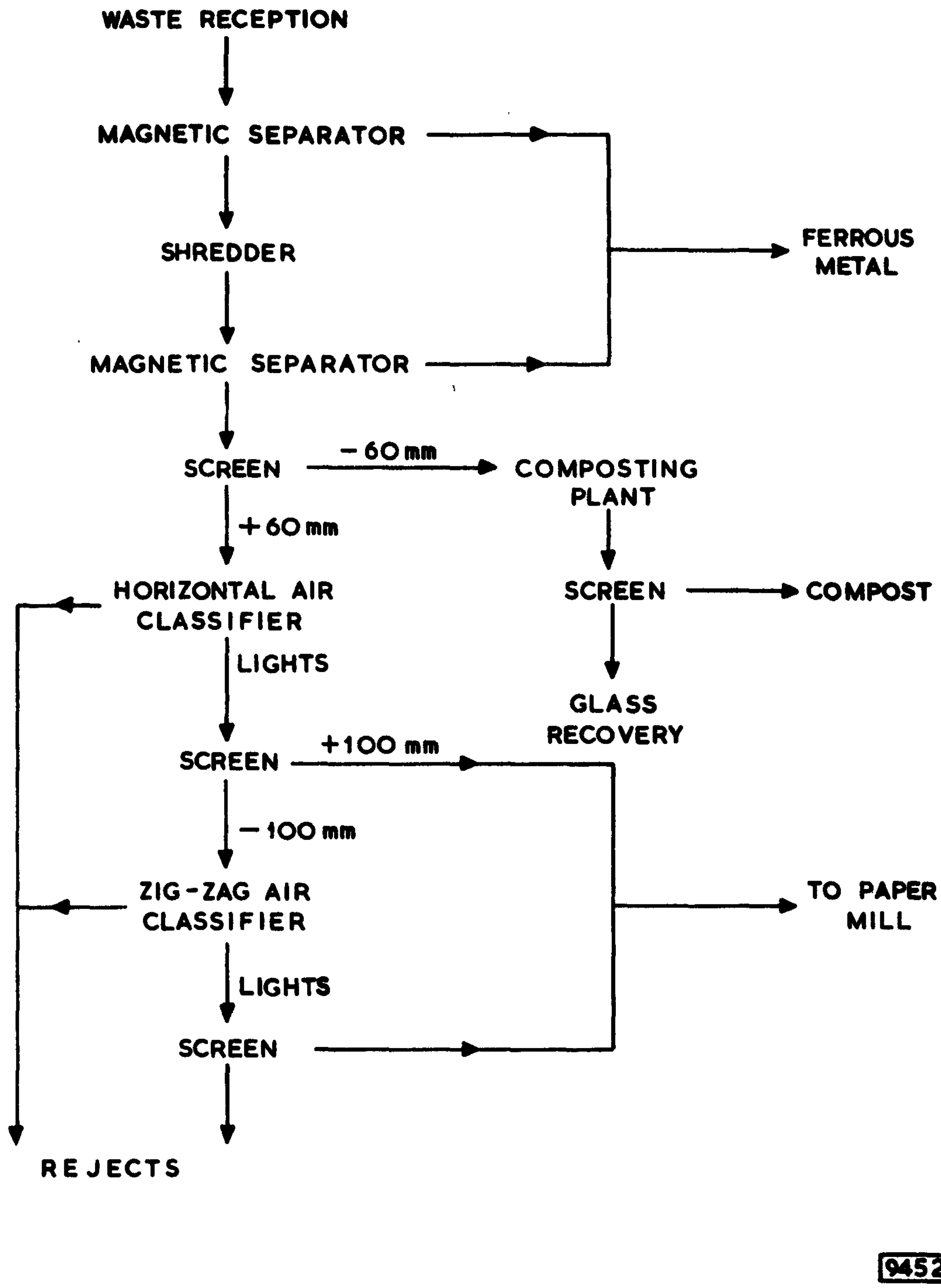

FIG. 21 FLOWSHEET OF THE KRAUSS MAFFEI R80 SYSTEM

The process flowsheet is shown in Fig. 22. The essential stages of the process are primary shredding and air classification in a zig-zag air classifier, screening of the light fraction in a specially modified cylindrical screen with internal rotating vanes, wetting of the screen oversize and subsequent separation of the wet paper from plastics in a second zig-zag air classifier. Energy consumption for paper recovery is high because the wet product must be dried for storage and transport, although the use of a filter press allows a 15% reduction in the fuel required for drying the paper. The paper product is suitable for manufacture of a good quality corrugated board. A fine product, containing a high proportion of organics, has found an interesting application in the manufacture of bricks. It could also be used for compost production, but it contains 20% inorganic materials such as glass.

During the visit the plant was operating well at full capacity, it was clean and there was very little dust in the atmosphere, although conveyors were not enclosed. Modifications to contain dust would probably be necessary for operation on wastes with a high content of dry inorganic fines.

6.4 Italy

Italy has the only full-scale commercial sorting plants in operation in Europe at the present time. In Rome, Sorain-Cecchini operate three 600 tonne/day plants, one in the west of the city and two in the east. In Perugia the Cecchini company has built a smaller plant, originally 100 tonnes/day but now increased to 220 tonnes/day. It is understood that the design of all these plants is essentially the same.

A simplified flowsheet of the Perugia plant is shown in Fig. 23. The basic separation process consists of a number of sizing operations in rotary or vibrating screens. The larger organic materials are sterilised and used to produce a pelletised animal feed product. Fine organics are used to produce compost. A two stage air classification system produces a paper-rich fraction, which is processed in a wet separation unit to yield a paper fibre product and washed plastics, which are sold for re-use. Ferrous metal is extracted magnetically and heated at 800°C to remove organics before baling for sale. The ferrous product is used in the manufacture of reinforcing bars for concrete. Large items such as wooden crates, tyres, etc, are removed in the initial screening step at 200mm and conveyed to an incinerator, where they are joined by rejects from several other points in the process. The sorting process is completely integrated with the incineration plant, which raises steam for sterilisation of the animal feed product.

There are two major features of the process which might limit its application in other countries. Firstly, daily collection of waste from households by vehicles which do not compact the waste is essential. Without thus, animal feed processing is impossible because the incoming waste organic materials degenerate so quickly. Secondly, an incineration unit for steam raising must be associated with the plant. The first of these factors would create problems in many locations due to the necessary increase in collection costs. In the absence of a market for compost and animal feed (the latter would almost certainly apply in some countries because of agricultural foodstuff restrictions which would be rigorously applied until extended trials had been completed) it would not be possible to have an integrated plant and there would be no justification for incorporating an incinerator. The front-end sorting system and the paper/plastic separation would be more widely applicable, although the Cecchini company is unwilling to release details of their operation.

Details of a 10 tonne/hour household waste sorting plant built by the De Bartolomeis company, and a shredding and air classification plant designed to treat waste from the Fiat factories are given in the Italian Second Interim Report.

6.5 United Kingdom

In order to assess the economic viability of waste sorting the Department of the Environment is providing financial assistance to two Waste Disposal Authorities, South Yorkshire and Tyne and Wear, for the construction of a reclamation plant in each county.

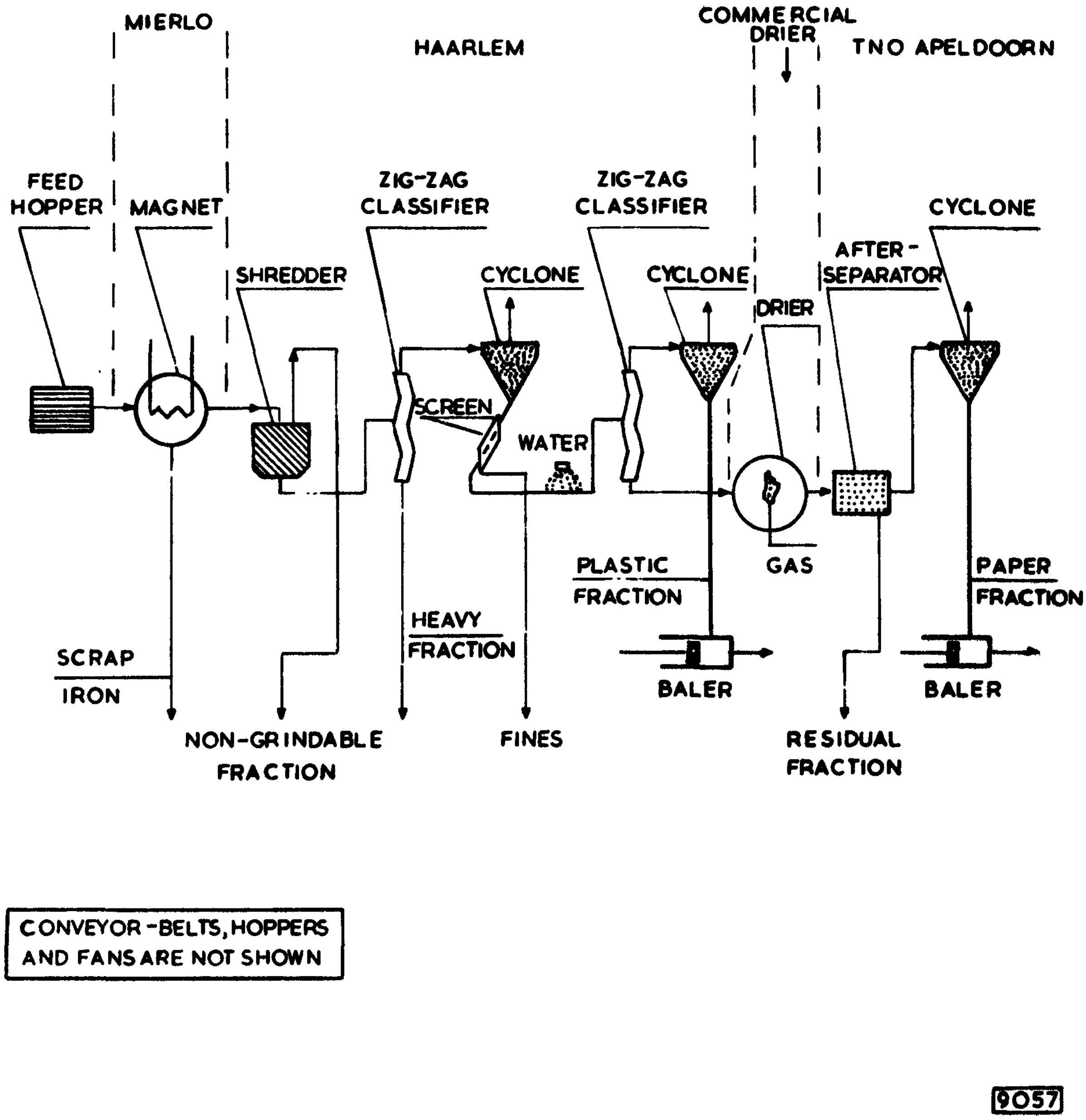

FIG.22 TNO SEPARATION SYSTEM

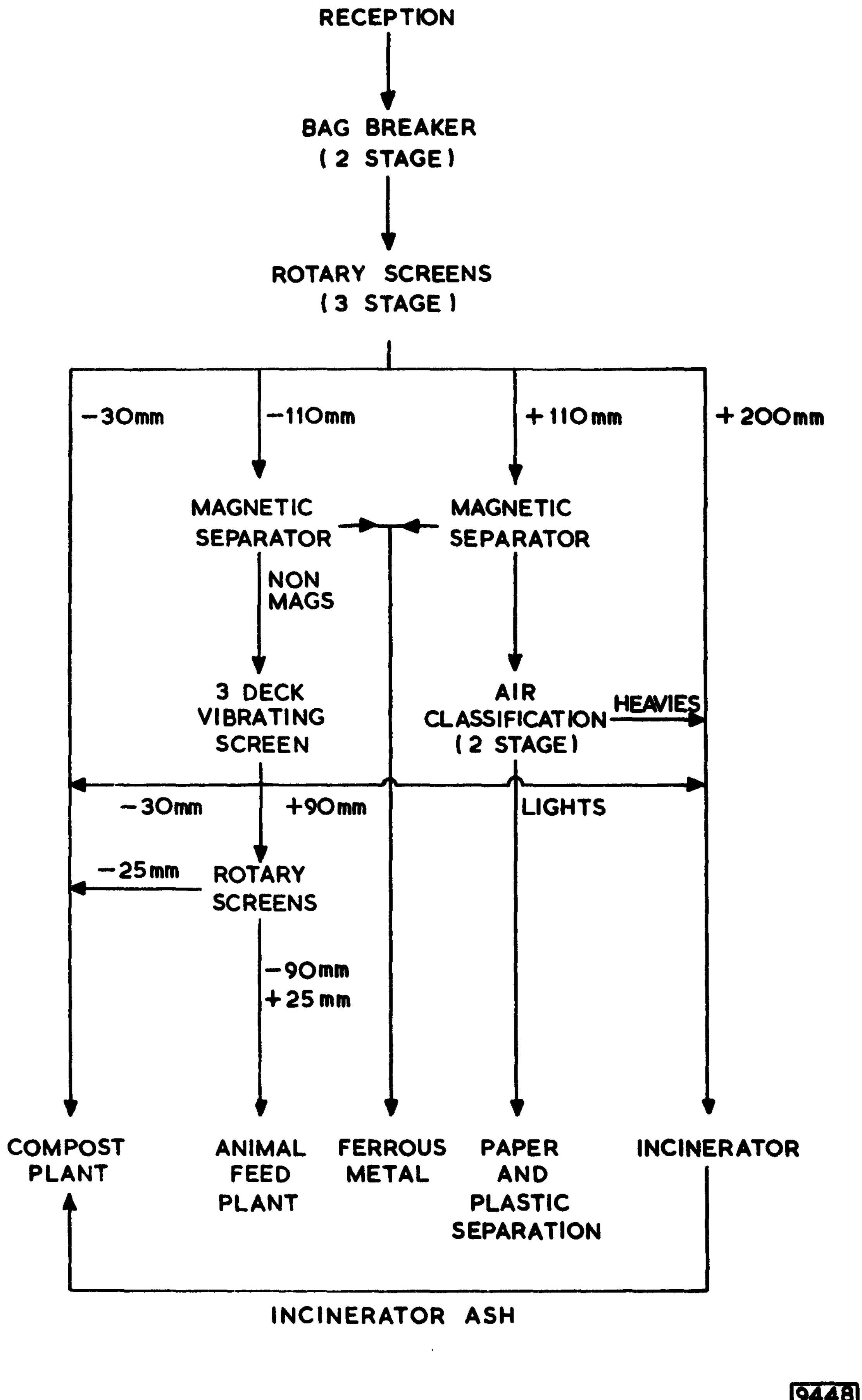

FIG. 23 FLOWSHEET OF THE CECCHINI PROCESS IN PERUGIA

6.5.1 The Doncaster Plant

Doncaster has been chosen for the plant in South Yorkshire. Its design is based on the results of R & D carried out at Warren Spring Laboratory in Stevenage. A two-stream plant is planned with a capacity of 10 tonnes/hour per stream operating 16 hours daily on a five-day week. It is intended that construction should start in late 1977.

In designing the Doncaster plant, experiments using Doncaster waste in the Stevenage pilot plant have been carried out to determine how the circuit must be modified to treat waste of rather different composition from Stevenage waste used in most of the earlier testwork[45]. The proposed flowsheet of the plant is shown in Fig. 24. The basis of the system is preliminary sorting according to size followed by secondary processing to yield marketable products from the sized streams. Initially the products of the process will be waste-derived fuel, ferrous metal and glass. Facilities will be incorporated to produce the fuel in either baled or densified forms. Shredding and densification is an expensive process, but it will make the product more attractive as a supplementary fuel by improving its handling and storage characteristics. The recovery of paper fibre from this paper-rich product, rather than using it as fuel, is still under investigation. So also is recovery of cardboard and paper from the primary trommel over-size by controlled air blowing.

The experimental nature of this plant is emphasised and it is expected that modifications to the circuit will be made in the light of operating experience.

6.5.2 The Tyne and Wear Plant

The Tyne and Wear plant will be located at Byker, Newcastle-upon-Tyne. This is a single-stream plant which will initially process 300 tonnes/day over two shifts on a 5-day week. The equipment is, however, designed for a maximum throughput of 30 tonnes/hour. Commissioning of this plant is scheduled for late 1978 or early 1979.

The process was designed by a team of engineers and solid waste experts drawn from the Department of the Environment, Tyne and Wear County Council, Heenan Environmental Systems Ltd (main mechanical and electrical contractor), and Warren Spring Laboratory, who after many considerations decided on the flowsheet shown in Fig. 25.

The plant is designed to process household and commercial waste, and selected industrial waste. Because of the wide variations in the size of the input waste a primary shredder was incorporated at the front-end. The plant is designed to produce a waste-derived fuel in a number of forms including pellets, and to extract ferrous metals. However, it is anticipated that testwork will be carried out on the light fraction from the air classifier to determine its suitability for fibre recovery.

The prototype air classifier has been developed by Newell Dunford Engineering Ltd. This is basically a rotating cone with its axis at a low angle to the horizontal. The feed enters the cone at its wide end and falls into an induced flow of high velocity air which has spiralled up from the narrow end of the cone. The light materials are carried out of the cone in the turbulent air stream and collected in a plenum chamber. The heavy materials such as cans and glass are cleaned as they tumble through the air and leave the cone at its narrow end. Trials have been carried out with a 2.3 x 4.7m cone at feed rates up to 7 tonnes/h.

The activities of some UK companies in the use of domestic waste as a supplementary fuel and the recovery of ferrous metal from raw waste, were described previously[3].

6.6 Spain

Studies into the recovery of re-usable materials from Spanish household waste have been undertaken by the Empresa Nacional Adaro de Investigaciones Mineras S.A. (Enadimsa). This group began to collaborate closely with the United Stated Bureau of Mines in 1973 and this led to the installation of a copy of the USBM pilot plant. Preliminary tests indicated the inadequacy of the system due to the high organic content of waste in Madrid. The system was therefore modified to take into account differences in waste composition between the United States and Spain.

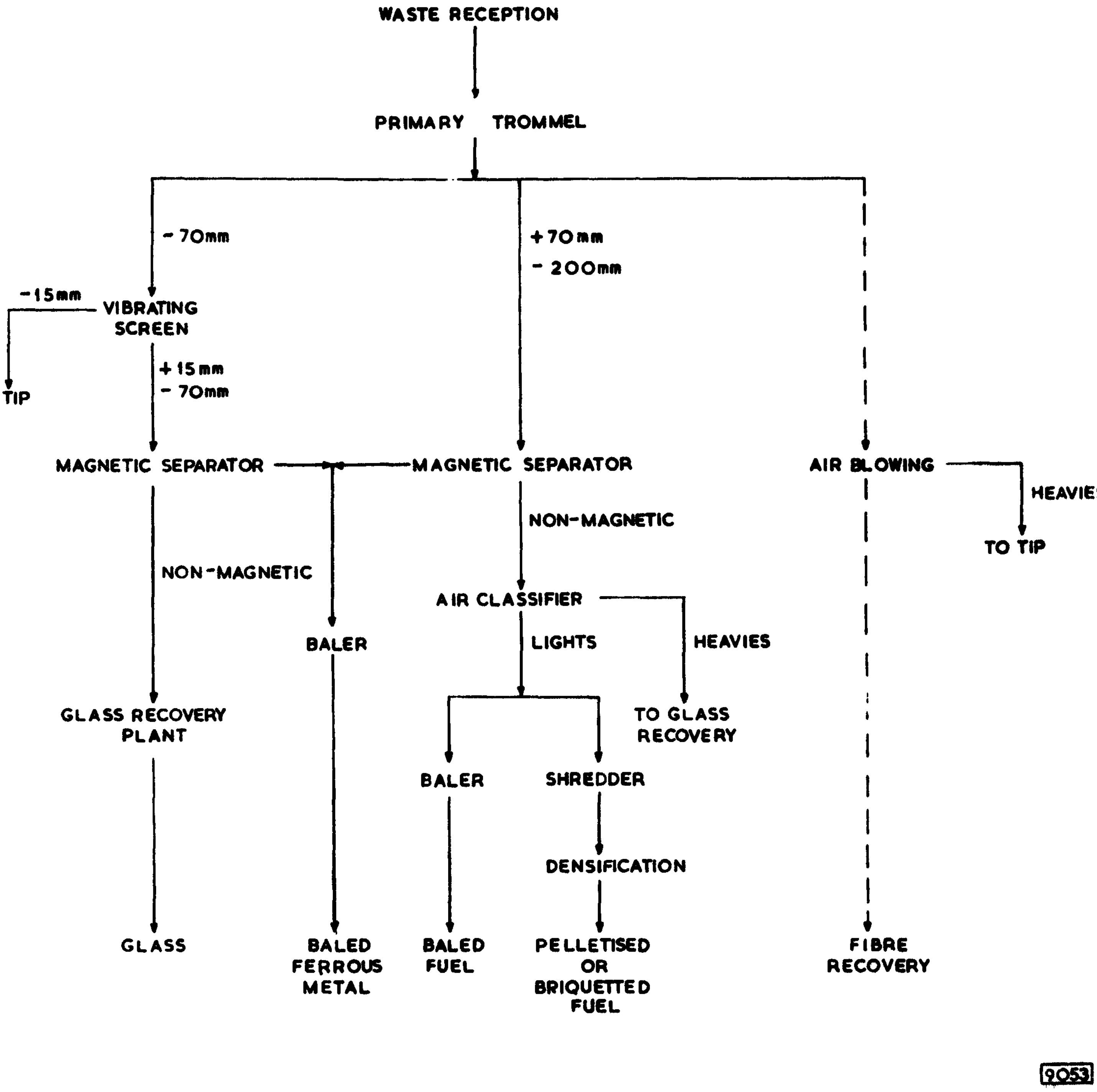

FIG.24 FLOWSHEET OF THE DONCASTER PLANT

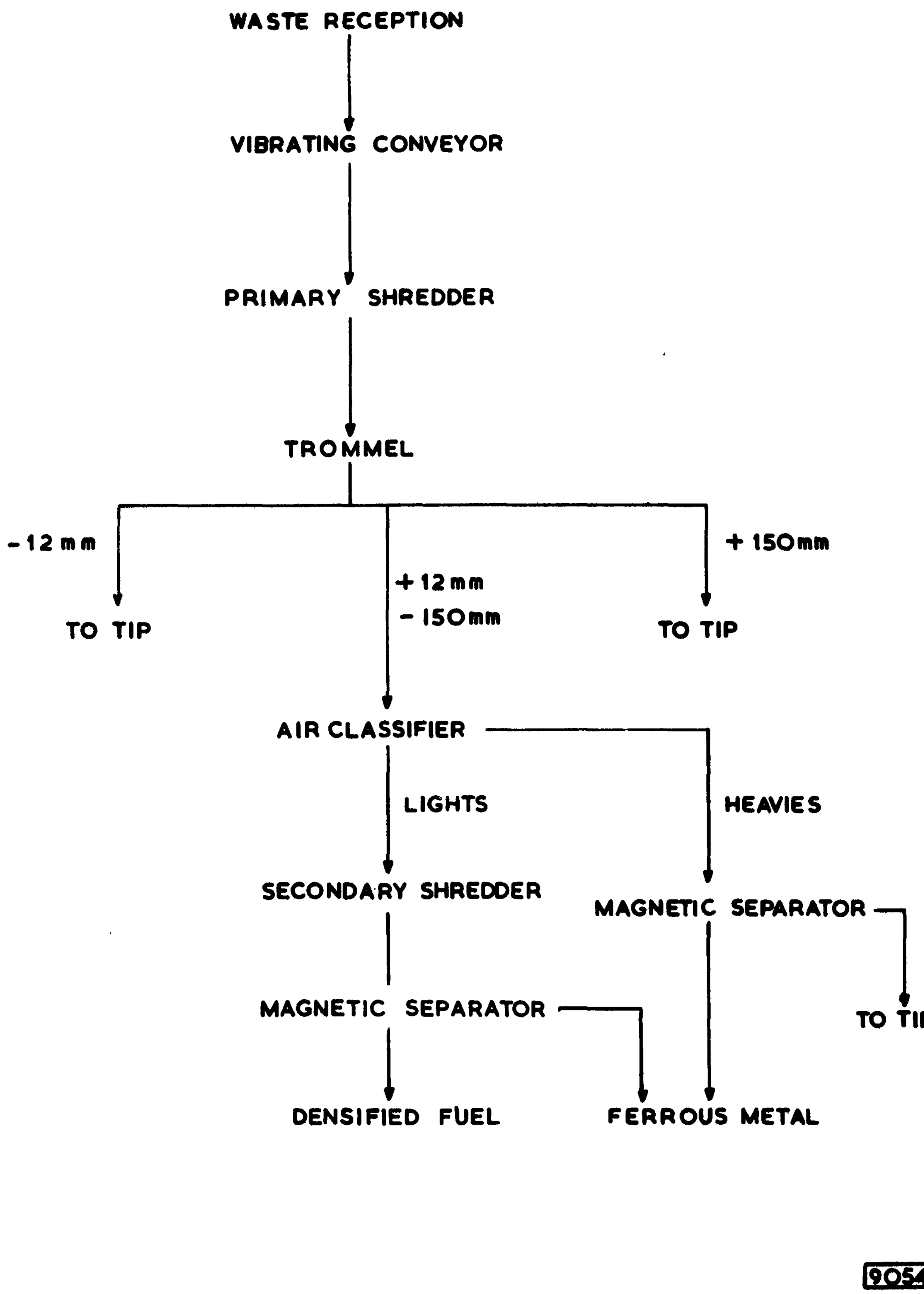

FIG.25 FLOWSHEET OF THE TYNE AND WEAR PLANT

The process flowsheet currently under test is shown in Fig. 26. Enadisma design philosophy has been to simplify the USBM process to make it more suitable for industrial operation. For example, there is only one stage of air classification, which has been adapted from the USBM light air classifier situated immediately after the shredder. Severe problems were encountered in the operation of the USBM horizontal air classifier, and this piece of equipment has been rejected from the flowsheet. The Enadimsa air classifier was described in Section 4.2. It would be interesting to compare the performance of this very simple design of air classifier with a zig-zag air classifier on wastes of varying composition.

The air classifier lights are treated in a new separator which has been supplied by SOCEA of France for testing and development. It consists of a trommel, inside which is a shaft fitted with knives, which rotates in the opposite direction to the trommel rotation. Water is sprayed on to the external surface of the trommel, the whole unit being shrouded. The effect of the separator is to partially pulp the paper so that it can be screened from the plastic. At the exit of the trommel the light plastic is aspirated while the heavy product passes on to a steeply inclined conveyor. This allows a separation of plastic bottles (which roll back down the conveyor) from textiles and any paper and plastic sheet which has not been previously removed. Thus the products are wet paper, plastic film and plastic bottles.

6.7 Sweden

Research work into the recovery of re-usable materials from household wastes is being undertaken in Sweden by the Fläkt company in close co-operation with the Swedish Board for Technical Development. A pilot plant with a nominal capacity of 5 tonnes/hour has been in operation at the Högdalen refuse incineration station in Stockholm since the beginning of 1975. The sale of a 25 tonne/hour plant to VAM in the Netherlands was announced in 1976.

The flowsheet is shown in Fig. 27. The process is aimed primarily at separation of a paper product. Primary shredding using a flail mill and two stages of air classification, with heat treatment in a modified pulp drier between the two air classifiers to render the plastics separable from the paper. Fuel requirements for the drier are high but less than those for drying a paper product from a wet separation system. The paper product appeared to be very clean and of good quality, but the product quality must be seen in relation to the paper-rich nature of Stockholm's waste. It will be interesting to see how the process has to be modified in its proposed application in Holland.

7. THE ECONOMICS OF WASTE SORTING

7.1 Capital Expenditure

Table 9 lists the available information on the capital costs of sorting plants in the USA and Canada. With the exception of the USBM process, for which the cost of a 1000 short ton/day plant has been estimated, all these plants are under construction or in operation. The penultimate column of the Table shows the capital costs of the various plants in 1977 dollars, calculated using a Marshall and Swift equipment cost index of 492 for the first quarter of 1977. Calculated capital costs for a 20 tonne/hour plant of each design are given in the last column.

Table 9 reveals considerable variation in the estimated capital costs when normalised to a capacity of 20 tonnes/hour. Some of this variation can be attributed to site-specific factors such as local labour rates, site preparation, standard of buildings etc., but there are also considerable differences in the complexity of the processing systems adopted. Superficially it is possible to find some explanation of the relative cheapness of the Teledyne and Ames processes. Both have relatively unsophisticated flow-sheets, and in neither case are the secondary recovery circuits for glass and aluminium fully developed. With the exception of NCRR the remaining systems are more costly and in general the available information gives only a rough indication of why this is so. The cost of the Raytheon plant includes a sophisticated and expensive control system and by-passes to allow the plant to continue to operate in the event of a major equipment

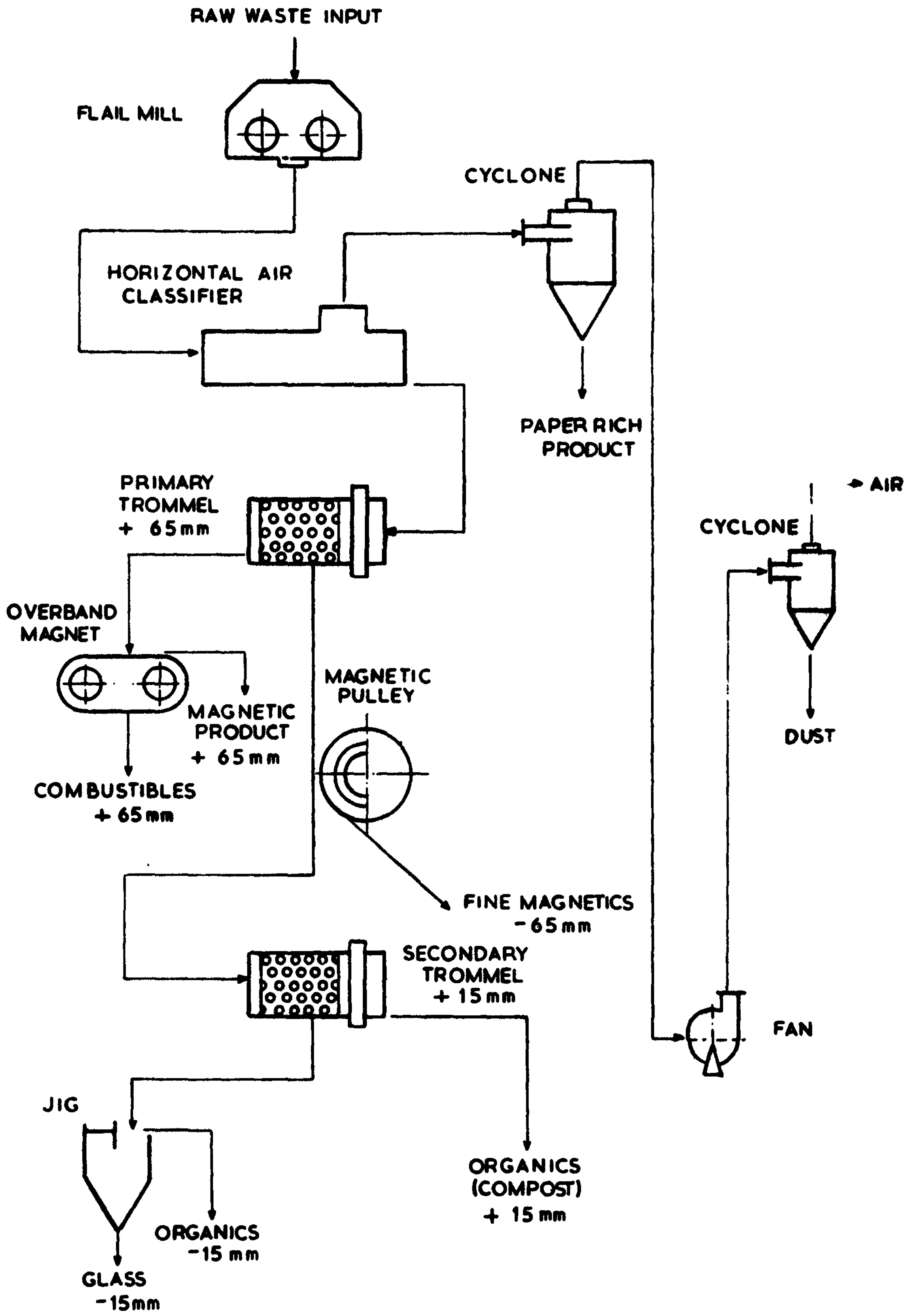

FIG.26 FLOWSHEET OF ENADIMSA PROCESS

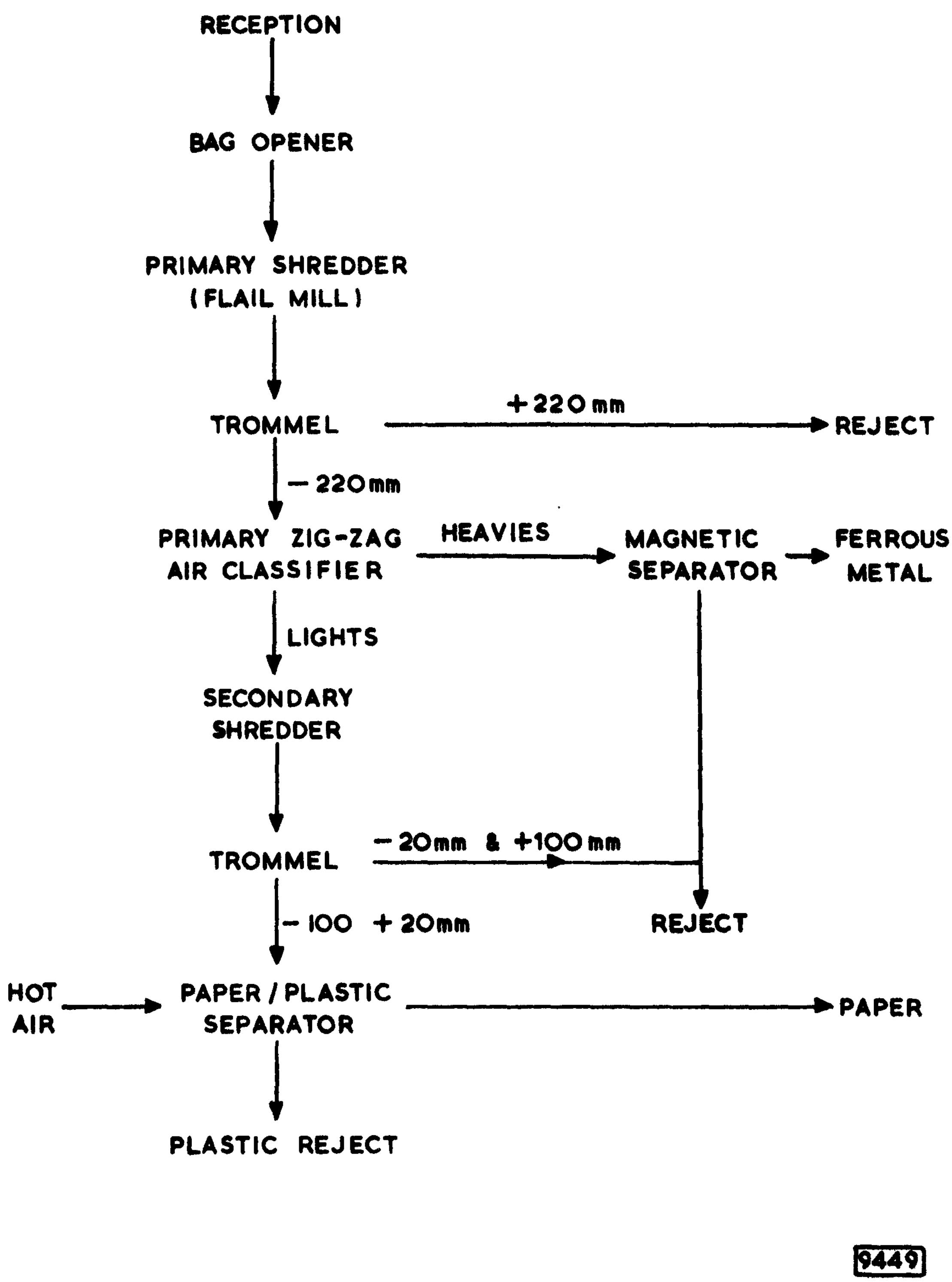

FIG. 27 FLAKT SYSTEM SIMPLIFIED FLOWSHEET

TABLE 9. - Capital Costs of American Processes

Organisation	Location of Plant	Products	Capacity tonnes/hour	Capital Cost $ (1977)	Estimated cost of 20 tonnes/hour plant $ (1977)
Raytheon	Monroe County, New York	Fuel Ferrous Metal Aluminium Glass, Sand	127	27m	8.9m
Black Clawson	Franklin, Ohio	Fibre, Fuel Ferrous Metal Aluminium Colour-sorted Glass	8	4.1m	7.0m
Teledyne	Baltimore County	Fuel Ferrous Metal Glass (contains stones) Aluminium	91	8.7m	3.5m
USBM	Pilot plant in Washington D.C.	Fuel Ferrous Metal Aluminium, Heavy Non-ferrous Glass	63.5	14.4m	7.2m
NCRR	New Orleans	Landfill Material Newspaper Ferrous Metal Aluminium Glass	57	7.3m	3.9m
Ontario Centre for Resource Recovery	Toronto	Fibre or Fuel, Glass Ferrous Metal Paper, Non-ferrous Metal Compost Energy for plant heating	36	14.4m	10.1m
City of Ames	Ames, Iowa	Fuel Ferrous Metal Aluminium	45	7.3m	4.5m
Parsons	Chicago	Fuel Ferrous Metal	145	21.1m	6.4m
Occidental	El Cajon (San Diego)	(Fuel fed to pyrolysis) Ferrous Metal Aluminium Glass Oil	26	9.3m	7.9m
American Can	Milwaukee	Fuel Ferrous Metal Aluminium Aggregate (Glass)	91	15.5m (excluding fuel storage bins)	6.2m

breakdown. Landscaping, rail sidings, and high quality buildings are all included. The Toronto plant includes an incinerator and composting plant as well as a sorting system, and the Occidental plant incorporates extra equipment and a large storage building to permit preparation of combustible materials for pyrolysis and continuous operation of the pyrolysis reactor.

The low cost of the NCRR plant is puzzling, although it was stated that some of the equipment had been purchased second-hand or even provided free of charge, and the buildings were simple steel structures with corrugated sheet walls. It is interesting to note that an EPA report[46] on resource recovery cost estimates also found the NCRR capital cost to be very much lower than competing designs. It was pointed out that the large difference in capital cost between the NCRR plant and a process designed by the General Electric Company for Hartford, Connecticut could be explained by technical and architectural design differences. For example, the General Electric design had considerably more material storage space and nearly twice the enclosed building area.

As pointed out earlier (Section 5.1) the USBM estimate includes provision of a standby primary separation line. Provision of spare capacity by duplication of equipment is common the several American systems, and is probably essential when dealing with such large daily throughputs of waste. In Europe, where plants are expected to be much smaller, it will probably be acceptable to temporarily divert the whole of the waste input to landfill in the event of a major breakdown. None of the European systems under consideration includes provision of a complete standby processing line in their capital cost estimates. To allow comparisons to be made with European processes it is necessary to be able to subtract the cost of standby equipment, and also non-ferrous metal recovery equipment, which is unlikely to be employed in most locations in Europe in the short term.

This can be done with the aid of published economic evaluations of the USBM[34] and Black Clawson[36] processes. It is shown in the Appendix that the capital costs of 20 tonne/hour plants comparable with European processes are \$5.9m for the USBM process and \$3.9m for the Black Clawson process.

Translation of American costs to a European basis also poses problems. Taking the UK as an example, although the cost of materials and equipment in the two countries might be expected to be approximately equivalent, labour is considerably more expensive in the USA. The installed cost of an equivalent plant is therefore likely to be somewhat higher in the USA than in the UK. Location indices (i.e. the ratio of the UK cost to the USA cost for equivalent plant) have been developed for chemical plant[47], but reliable data are not yet available for solid waste processing systems. However, a location index of 0.9 has been suggested for such processes[48]. Onthis basis and at a first quarter 1977 exchange rate of £1.72 = £1, plants costing \$7m - \$9m in the USA would cost £3.7m - £4.7m in the UK.

Capital cost estimates for European and American processes are compared in Table 10. The full American systems are substantially more expensive than the European systems, with the single exception of Sorain-Cecchini, but the latter includes incineration, animal feed sterilising and composting units as well as sorting equipment. The two projected UK plants, the TNO and the Fläkt systems all fall within the range 3-4 mua for a 20 tonne/hour plant. The simplified Black Clawson system and the USBM plant recovering only fuel and ferrous metal also have costs of the same order. The costs of the two German systems are on the low side, but it is understood that these costs are based on estimates for supplying systems for the Bundesmodell Abfallverwertung and do not include the full cost of buildings and civil engineering which would apply to independent plants. The remaining systems appear to be significantly cheaper, but there are some reservations about the information obtained. The COMBOR system, for example, has a very simple, and presumably cheap air classifier, which must be one reason why this waste-derived fuel system has a comparatively low capital cost. It seems very likely, however, that as a consequence of unselective air classification, the quality of the fuel product will be unacceptably low for industrial use. The very low price of the related Enadimsa and SOCEA systems is more difficult to understand. It is worth noting that calculations by the authors, based on unit costs of equipment in the flowsheet, gave much higher total capital costs, although still lower than the average range of 3-4 mua. Past experience has shown, however, that this method of cost estimation tends to underestimate buildings and civil engineering and to give low results.

TABLE 10. - Comparison of European and American Capital Costs

Process	Products	Estimated Cost of 20 tonnes/h plant		
		Local Currency millions	£ millions	Million Units of Account
Full American System	F Fe N G	$7-9	4-5	6-8
USBM	F Fe G	$5.9	3.1	4.8
	F Fe	$4.8	2.5	3.9
Black Clawson	F Fe Pa	$3.9	2.0	3.1
Sorain-Cecchini	F Pa Pl A C	L6400	4.3	6.6
UK - Doncaster	F Fe G	£2.2	2.2	3.4
	F Fe	£2.0	2.0	3.1
UK - Tyne and Wear	F Fe	£2.5	2.5	3.9
TNO	Fe Pa O	D.Fl 9	2.2	3.4
Fläkt	(F) Fe Pa	S.kr. 16.6	2.3	3.5
Aachen	Fe G Pa	DM 7.5	1.9	2.9
Krauss Maffei	Fe G Pa Pl	DM 6.6	1.7	2.6
	Fe Pa Pl	DM 5.7	1.4	2.2
COMBOR	F Fe	FF 10.5	1.2	1.9
Enadimsa	(F) Fe Pa Pl	Pta. 83.2	0.7	1.1
Enadimsa - WSL estimate	(F) Fe	-	1.4	-
" " "	(F) Fe Pa Pl	-	1.8	-
SOCEA	Fe Pa Pl	FF 5.9	0.7	1.1

Key: F = Fuel; Fe = Ferrous Metal; N = Non-ferrous Metal; G = Glass; Pa = Paper; Pl = plastics; A = Animal Feed; C = Compost; O = Organic Fines

(F) signifies a mixed combustible fraction which might be usable as fuel though not intended as such by the process designers.

NB. The capital costs quoted do not include taxes. Conversions to units of account were calculated assuming 1ua = £0.65.

Clearly, economic comparisons must be treated with some reservations. Generally speaking an overall capital cost including installation and buildings was quoted, and a detailed breakdown of capital costs for unit operations was not available. Civil engineering costs can be particularly variable because of site-specific factors such as local labour rates, labour productivity, site preparation and ancillary facilities such as weighbridges, car parks, office accommodation, etc. For these reasons differences in overall capital costs of less than at least 10%, possibly as much as 20%, are not considered to be significant. It is considered that the capital cost of a 20 tonne/hour sorting plant in the EEC recovering paper, fuel, ferrous metal and possibly glass should lie in the range 3-4 mua.

7.2 Operating Costs

It is not possible to generalise in the same way about operating costs because these will vary so much with local conditions. Capital charges are a major factor, accounting for at least 60% of operating costs, but composition of the input waste, markets for the products, labour and administration are also important. For these reasons operating costs have been calculated only as they would apply in the UK assuming all the processes operate on waste of the national average composition. This gives a basis for comparison of different processes, although differences of less than 10% are again not considered to be significant.

Full details of the calculation of operating costs are given in the Appendix, and the results are summarised in Table 11. Glass and non-ferrous metal recovery have been excluded from these comparisons so that the products are similar in each case.

TABLE 11. - Comparison of Operating Costs

Plant	Net Operating Cost £/tonne		Products
	10 tonnes/h	20 tonnes/h	
USBM	10.5	7.5	Fuel, Ferrous Metal
Black Clawson	11.2	8.2	Fibre, Fuel, Ferrous Metal
Doncaster	8.5	5.7	Paper, Fuel, Ferrous Metal
Tyne and Wear	10.1	7.0	Fuel, Ferrous Metal
Fläkt	8.5	5.6	Paper[1], Fuel[2], Ferrous Metal
TNO	8.4	5.7	Paper[1], Ferrous Metal, Fine Organics
COMBOR	5.2	3.9	Fuel, Ferrous Metal
Enadimsa	6.0	3.5	Paper[1], Fuel[2], Ferrous Metal

1. Calculations assume the wet paper product is dried before sale
2. Calculations assume a paper-rich product which would not be acceptable to the UK paper industry at the present time can be sold as fuel.

The difference between the calculated operating costs of the two American processes is probably not significant, although it should be noted that electricity and water consumption are high in the Black Clawson process and considerable effluent disposal facilities are required.

It can be seen that there is little difference between the calculated costs for the WSL, Fläkt and TNO processes. In the case of the Fläkt process the extra cost associated with paper recovery offsets the extra revenue so that, in the UK at least there is no economic incentive for this method of paper recovery provided a market for waste-derived fuel can be found. This is not so in Sweden where the paper content of the waste is much higher, and the net operating cost for a 20 tonne/h plant is reduced to £3.8 per tonne. Insufficient information was available to carry out a similar calculation for the TNO process, but it would be surprising if a similar conclusion were not reached.

The Tyne and Wear plant appears to be the more expensive to operate of the two UK processes, due to its higher capital cost and power requirements and the absence of revenue from paper recovery. Until the plants are in operation, however, and demonstrating their ability to produce and sell products at the projected rates it would be premature to declare a preference on the grounds of economics. It does emphasise however, how sensitive these calculations are to assumptions about revenue from products.

The Enadimsa and COMBOR processes appear to be significantly less costly to operate than the others, but in view of the reservations about capital cost estimates expressed earlier, it is considered likely that the calculated operating costs for these two processes are over-optimistic.

The Sorain-Cecchini process was not included in Table 11 because of the completely different market situation for the products in Italy. If it is assumed that all the products can be sold at the prices quoted by Cecchini, then at 20 tonnes/h the process would make a net profit of £3.8 per tonne. On the other hand, based on likely UK revenues the net operating cost of the process is £8.6 per tonne. This illustrates very clearly the dependence of the viability of sorting systems upon prevailing conditions which differ markedly from location to location.

7.3 Glass and Aluminium Recovery

The economics of glass and aluminium recovery can be expected to be marginally attractive only in the most favourable circumstances in Europe. Some approximate calculations have been carried out to illustrate this point.

Some estimates of the costs of glass recovery are summarised in Table 12. The capital costs include the equipment required for preparation of the glass-rich feed for processing by froth flotation or transparency sorting, together with the associated civil engineering work. In the case of froth flotation the cost of equipment for effluent treatment is included. The estimates for transparency sorting assume that a simple and inexpensive means of washing and drying the feed can be devised.

TABLE 12. - Estimates of the Cost of Adding Glass Recovery to a 20 tonne/h Sorting Plant

	Froth Flotation	Transparency Sorting
Capital cost	£220 000	£160 000
Annual operating cost	£58 000	£48 000
Cost per tonne of glass recovered: (assuming 50% recovery by flotation, 63% by transparency sorting)		
5% glass in waste	£39	£24
10% glass in waste	£20	£13
15% glass in waste	£13	£9

At an ex-works value of £8-£10/tonne for the glass product, it appears that transparency sorting may become economically attractive for waste with a high glass content of between 10 and 15%, but froth flotation is unlikely to be profitable. The situation may be more favourable in regions where there is a high demand for cullet.

USBM data have been used to estimate the costs of aluminium recovery[34]. The results of the calculations are summarised in Table 13.

TABLE 13. - Estimate of the Cost of Adding Aluminium Recovery to a 20 tonne/h Sorting Plant

Capital Cost	£255 000
Annual Operating Cost	£59 000
Cost per tonne of aluminium recovered: (assuming 60% recovery)	
0.5% aluminium in waste	£317
0.8% aluminium in waste	£198
1.0% aluminium in waste	£159

Experience in the USA indicates the aluminium can stock separated from domestic waste has a value equivalent to about £200/tonne. It is clear that aluminium recovery is only profitable when the aluminium content of the waste approaches 1%, and this is only likely to be the case in locations where there is a high consumption of aluminium beverage cans.

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APPENDIX

CALCULATION OF OPERATING COSTS

Basis for the Calculations (Assuming UK Conditions)

Plant Occupacity

Plants are assumed to operate for two eight hour shifts, five days per week. Actual daily running time is assumed to be 12 hours, corresponding to a capacity utilisation factor of 75%.

Depreciation and Interest

Amortisation is calculated over 15 years at a rate of interest of 10%.

Maintenance

The annual cost of maintenance is assumed to be 4% of the installed capital cost. This includes the wages and on-costs of maintenance personnel working on the plant.

Local Taxation

The effect of local taxation on running costs is not taken into account.

Labour

The following rates of pay are used:

Foreman on two shifts	£85 per week
Operator on two shifts	£72 per week
Day men	£60 per week

Labour on-costs are taken as 38% of gross wages to cover employer's National Health contributions, pension, overtime, holidays, etc. Administrative overheads are taken as 50% of operating labour including on-costs.

Utilities

The following costs are assumed for utilities:

Electricity	2.3p oer kWh
Natural Gas	16p per 10^5 kJ
Fuel Oil	7.5p per l
Water	9.24p per m^3
Discharge of treated effluent to sewer	6.34p per m^3

Nominal sums are assumed for fuel for space heating.

Working Capital

Working capital is assumed to be one month's gross operating costs (not including capital charges).

Residue Disposal

The cost of landfill for residue disposal is assumed to be £1.5 per tonne. No allowance is made for off-site transport.

Plant Input

The composition of the input waste for all calculations is assumed to be the UK national average for 1973[49]. The breakdown is as follows:

	% by weight
Fines (<20mm)	19
Vegetable and Putrescible	18
Paper	33
Metal (including non-ferrous)	10
Rag	3.5
Plastics	1.5
Glass	10
Other	5

US Bureau of Mines

Capital Cost

USBM estimate that the total plant cost for 1000 short tons per day capacity is \$13.7m at second quarter 1976 prices[34]. Subtracting the cost of the standby primary separation line, and the non-ferrous recovery section, the capital cost for 70 tons/hour (63.5 tonnes/hour) would be \$11.3m. Scaled down to 20 tonnes/hour and at first quarter 1977 prices the cost would be \$5.9m. Converting to sterling at £1 = \$1.72 and assuming a location index of 0.9 (see Section 7.1) the cost of an equivalent plant in the UK is calculated to be £3.1m.

Labour and Utility Requirements

USBM consider that the process requires 12 operators per shift. For the smaller capacity plant under consideration similar labour requirements to those envisaged for the WSL process appear reasonable, i.e.:

	10 tonnes/h	20 tonnes/h
Foreman	2	2
Shift operators	8	12
Day men	2	2

Power requirement: 21 kWh/tonne of input waste
Process water : 0.27m^3/tonne of input waste.

Recoveries

USBM data indicate that less than 2% of the light combustibles are lost from the fuel product[11]. In the absence of the non-ferrous metal recovery section the heavy combustibles would be discarded, and incorporation of the wet organic materials in the fuel would probably result in an unacceptably low quality product. It is therefore assumed that paper, plastics and textiles amounting to 36% of the feed are recoverable as fuel. A value of £5/tonne is assumed for the baled product.

Published materials balances[11] for the process indicate that 90% of the ferrous metal content of the waste is recoverable. A recovery of about 8% of the input as ferrous metal can therefore be expected.

As discussed in Section 4.6 a 70% recovery rate for glass is probably achievable, corresponding to 7% of the input waste.

Operating Costs

Plant Capacity	10 tonnes/h	20 tonnes/h
Waste Input	31000 tonnes/y	6200 tonnes/y
Capital cost	£2.0m	£3.1m
Working Capital	£0.02m	£0.03m

Annual Costs	£/y	£/y
Capital Charges	266 000	412 000
Wages	45 000	60 000
On Costs	17 000	23 000
Manager (including on costs)	5 000	9 000
Administration	31 000	41 000
Maintenance	80 000	124 000
Electricity (21 kWh/tonne)	15 000	30 000
Natural Gas for space heating	6 000	10 000
Process Water and Effluent Disposal ($0.27m^3$/tonne)	1 500	3 000
Chemicals (for froth flotation)	500	1 000
Residue Disposal (49% of input)	23 000	46 000
Total	490 000	759 000
Revenue		
Ferrous Metal at £12/tonne	30 000	60 000
Fuel at £5/tonne	56 000	112 000
Glass at £8/tonne	17 000	35 000
Total	103 000	207 000
Net Operating Cost	£387 000	£552 000
	or £12.5/tonne	or £8.9/tonne

If the glass recovery plant were not included the capital cost of a 20 tonne/h plant would be £2.5 million, and the operating costs would be as follows:

Annual Costs	£/y
Capital Charges	333 000
Wages (1 man/shift less)	53 000
On costs	20 000
Manager	9 000
Administration	37 000
Maintenance	100 000
Electricity (17.5 kWh/tonne)	25 000
Natural Gas	10 000
Residue Disposal (56% of input)	52 000
	639 000
Revenues	172 000
Net Annual Operating Cost	467 000
	or £7.5/tonne

Black Clawson

Capital Cost

The capital cost of the Franklin plant in 1969 was just under $2m, made up as follows:

Weighing and reception	$ 182 000
Pulping, separation and dewatering	$ 626 000
Fluid bed incinerator	$ 670 000
Fibre recovery	$ 509 000
Total	$ 1 987 000

Glass and non-ferrous metal recovery are not included in these estimates. The capital cost of the glass and non-ferrous metal recovery plant was estimated in 1976 to be $2.5m[35], based on 2000 short tons/day of raw waste input. This is equivalent to $0.9 for a 20 tonnes/hour plant.

The following capital cost estimates have been calculated for various plant configurations:

	10 tonnes/h	20 tonnes/h
Fuel, fibre and ferrous metal recovery	$2.6m	$3.9m
As above with incineration of residue	$4.0m	$6.1m
Complete plant including glass and non-ferrous metal recovery	$4.6m	$7.0m

For comparison with other processes the operating costs for the first of the above configurations have been calculated.

Labour and Utility Requirements

Labour requirements are estimated as follows:

	10 tonnes/h	20 tonnes/h
Foremen	2	2
Shift Operators	6	10
Day Men	2	2

Power requirement : 106 kWh/tonne of input waste
Process water : 12.9m^3/tonne " " "
Aqueous effluent : 10.5m^3/tonne " " "

The effluent has a BOD loading of 280 mg/l and suspended solids at 440 mg/l. It should be possible to pay for its disposal to sewer without further treatment.

Recoveries

The following rates of recovery are expected from waste in the UK:

Paper fibre	16% of input
Fuel	40% of input
Ferrous metal	8% of input
Reject	36% of input

The fuel has a poor specification and might not be readily saleable, but its fibre content is high and a value of £2.50/tonne has been assumed. The available information about the fibre product suggests that this is of a lower quality than can be recovered by a dry separation process, and a value of £15/tonne is assumed.

Operating Costs

Plant Capacity	10 tonnes/h	20 tonnes/h
Waste Input	31 000 tonnes/y	62 000 tonnes/y
Capital Cost	£1.4m	£2.0m
Working Capital	£0.03	£0.04

Annual Costs	£/y	£/y
Capital Charges	187 000	268 000
Wages	38 000	53 000
On Costs	14 000	20 000
Manager	5 000	9 000
Administration	26 000	37 000
Maintenance	56 000	80 000
Electricity (106 kWh/tonne)	76 000	151 000
Natural Gas for space heating	6 000	10 000
Water (12.9m^3/tonne)	37 000	74 000
Effluent Disposal (10.5m^3/tonne)	21 000	41 000
Residue Disposal	17 000	34 000
Total	482 000	777 000

Revenues

Ferrous Metal	at £12/tonne	30 000	60 000
Paper Fibre	at £15/tonne	74 000	149 000
Fuel	at £2.50/tonne	31 000	62 000
	Total	135 000	271 000
Net Operating Cost		£348 000	£506 000
	or	£11.2/tonne	£8.2/tonne

WSL Process

The process economics are calculated for a plant recovering ferrous metal, pelletised fuel, glass, and a small quantity of paper and cardboard. The flowsheet is assumed to be similar to the one for Doncaster shown in Fig. 24, but the composition of the feedstock is assumed to correspond to the national average; glass recovery is taken to be by froth flotation.

Capital Cost

An estimated cost of the Doncaster plant at February 1977 prices is £2.227m, made up as follows:

Plant and Installation	£
Primary sorting and waste-derived fuel	723 000
Metal recovery	60 000
Glass recovery	90 000
Paper baling	40 000
Compactors (1 for residue removal, 2 on standby in case of plant breakdown)	20 000
Design, development and supervision	207 000
Sub-Total	£1 140 000
Building and Civil Engineering	£1 087 000
Total	£2 227 000

The total capital cost estimate of £2.23 million includes provision for administration, accommodation, weighbridges, roads, car parks, landscaping, etc, but not land. It may not be strictly comparable with capital cost estimates for other European processes, which in general have included the costs of equipment, installation, and a basic building only.

Labour and Utility Requirements

Labour requirements are as follows:

	10 tonne/h	20 tonne/h
Foremen	2	2
Shift operators	8	12
Day men	2	2

Total power requirements are estimated to be 40 kWh/tonne of input waste, of which 10 kWh/tonne are for shredding and pelletising the fuel product, and 5 kWh/tonne are for glass recovery. The aqueous effluent from the glass recovery plant is 2.6m^3/tonne of input waste. Assuming 80% recycle after thickening, make-up water and effluent to sewer will both amount to 0.52m^3/tonne. The concentration of solids in the aqueous effluent will be 29 g/l.

Recoveries

Pilot scale trials at WSL on waste of composition close to the national average indicate that the following rates of recovery are achievable:

Fuel (pelletised)	30% of input
Ferrous metal	7% of input
Glass	5% of input
Paper	5% of input (90% paper)

Operating Costs

Plant Capacity	10 tonnes/h	20 tonnes/h
Waste Input	31 000 tonnes/y	62 000 tonnes/y
Capital Cost	£1.47m	£2.23m
Working Capital	£0.02m	£0.03m
Annual Costs	£/y	£/y
Capital Charges	196 000	297 000
Wages	45 000	60 000
On-Costs	17 000	23 000
Manager	5 000	9 000
Administration	31 000	41 000
Maintenance	59 000	89 000
Electricity (40 kWh/tonne)	29 000	57 000
Natural Gas for space heating	6 000	10 000
Water	2 500	5 000
Chemicals	500	1 000
Residue disposal (56% of input)	25 000	50 000
Total	416 000	642 000
Revenues		
Ferrous Metal at £12/tonne	26 000	52 000
Fuels at £7/tonne	65 000	130 000
Glass at £8/tonne	12 000	25 000
Paper at £15/tonne	23 000	46 000
Total	126 000	253 000
Net Operating Cost	£290 000 or £9.3/tonne	£389 000 or £6.3/tonne

If glass recovery were not included it is estimated that the capital cost of a 20 tonne/h plant would be £2.0 million, and the operating costs would be as follows:

Annual Costs	£/y
Capital Charges	267 000
Wages (1 man/shift less)	53 000
On-Costs	20 000
Manager	9 000
Administration	37 000
Maintenance	80 000
Electricity	50 000
Natural Gas	10 000
Residue Disposal (61% of input)	55 000
Total	581 000
Revenues	228 000
Net Annual Operating Cost	353 000
or	£5.7/tonne

Tyne and Wear Process

Capital Cost

The estimated capital cost for the 30 tonne/hour plant is £3.2 million, of which £1.5 million is for buildings and civil engineering. As in the case of the Doncaster plant, the capital cost includes accommodation, weighbridges, a standby transfer facility for crude waste, roads, car parks, landscaping, full dust control plant, etc., but not land. Again this may not be comparable with estimates for other European processes, because of site specific factors. For the purposes of this study, economic calculations have been carried out for scaled down plants of 10 and 20 tonne/hour, although it is probably unrealistic to contamplate a 10 tonne/hour flowline, because the shredder will be chosen for its feed opening size, its capacity being generally greater than required.

Labour and Utility Requirements

Labour requirements are assumed to be as follows:

	10 tonne/h	20 tonne/h
Foremen	2	2
Shift operators	6	10
Day men	2	2

Power consumption is expected to be of the order of 50 kWh/tonne of input waste, made up as follows:

Primary shredder	12
Air classifier	20
Secondary shredder and pelletising	10
Conveyors, etc	8
Total	50

Air classifier power consumption is high because it was compressed air.

Recoveries

There are no pilot plant data on which estimates of rates of recovery could be based. Following American estimates for similar processes it is assumed that paper, plastics and textiles amounting to 36% of the feed are recoverable as fuel. It is also assumed that 45% of the vegetable and putrescible materials are transferred to paper, card and rag constituents by the primary shredder, making a total fuel fraction of 44% of the feed. Ferrous metal recovery is assumed to be 7% of the input waste.

Operating Costs

Plant Capacity	10 tonnes/h	20 tonnes/h
Waste Input	31 000 tonnes/y	62 000 tonnes/y
Capital Cost	£1.65m	£2.5m
Working Capital	£0.02m	£0.03m

Annual Costs

Capital Charges	220 000	333 000
Wages	38 000	53 000
On Costs	14 000	20 000
Manager	5 000	9 000
Administration	26 000	37 000
Maintenance	66 000	100 000
Electricity (50 kWh/tonne)	36 000	71 000
Natural Gas for space heating	6 000	10 000
Residue Disposal (47% of input)	22 000	44 000
Total	433 000	677 000

Revenues

Ferrous metal at £12/tonne	26 000	52 000
Fuel at £7/tonne	95 000	191 000
Total	121 000	243 000
Net Annual Operating Cost	£312 000 or £10.1/tonne	£434 000 £7.0/tonne

Fläkt

Capital Cost

Fläkt's estimates of the capital cost of a 10 tonne/h plant are:

Machinery: S kr 8-10m installed, of which 25-35% is for the paper recovery equipment.
Building: S kr 2m for a plain, light steel structure with heat insulated walls, 45 x 25m (not including reception bunker).

Total cost of 10 tonne/h plant = S kr 11m (say)
= £1.53m.

On this basis a 20 tonne/h plant would cost £2.3m. (In the Netherlands VAM have recently announced their intention to install the Fläkt process at Mierlo. They estimate that a 25 tonne/h plant will cost D.Fl 10m or £2.4m).

Labour Requirements

Fläkt say only 3 operators are required per shift for a 10 tonne/h plant, one for process control, one feeding and one handling products. These requirements seem inadequate and for the purpose of calculating operating costs it is assumed that a shift foreman and two day-men are also required. Thus labour requirements are:

	10 tonne/h	20 tonne/h
Foremen	2	2
Shift operators	6	10
Day men	2	2

Power Consumption

Mechanical: 25 kWh/tonne of incoming waste, 50% of which is used in the two shredding operations, the rest by fans.

Paper Drying: 75 kWh/tonne, or 6.5l of fuel oil/tonne of incoming waste.

Recoveries

Using Stockholm's waste the following rates of recovery are achieved:

Ferrous metal	5.5%
Light paper	22.5%
Heavy paper	10%
Water removed	10%
Residue	52%
	100%

Approximately 20% of the paper content of the as-received waste is lost in the process. No information is available on the efficiency of paper recovery from waste of lower fibre content, but for the purpose of estimating the economics of the process for UK waste it is assumed that 24% of the input is recovered as paper products. The price for the light paper product quoted by Fläkt is equivalent to the value of mixed waste paper in the UK, i.e. ca. £25/tonne. On the assumption that some incentive would be required to sell a domestic waste derived product to the UK paper industry, a value of £20/tonne is assumed. It is also assumed that the heavy paper product would not be acceptable to the UK paper industry, but that it would have a value of £6/tonne as a fuel. It is reasonable to assume that in the latter event the plus 100mm reject from the secondary trommel could be disposed of in the same way.

It is assumed that 7% of UK waste could be recovered as ferrous metal with a value of £12/tonne.

On the above basis the following annual revenues and residue disposal costs can be expected from UK waste, and from waste similar to Swedish with 50% paper content:

	32% Paper		50% Paper	
	31 000 tonne/y	62 000 tonne/y	31 000 tonne/y	62 000 tonne/y
Ferrous metal (7% at £12/tonne)	£26 000	£52 000	£26 000	£52 000
Light paper at £20/tonne (16 or 22.5% of input)	£99 000	£198 000	£140 000	£280 000
Fuel at £6/tonne (13 or 19% of input)	£24 000	£48 000	£35 000	£71 000
Totals	£149 000	£298 000	£201 000	£403 000
Residue Disposal at £1.5/tonne (58% or 49% of input)	£27 000	£54 000	£23 000	£46 000

Operating Costs

Plant capacity	10 tonnes/h	20 tonnes/h
Annual throughput	31 000 tonnes/y	62 000 tonnes/y
Capital cost	£1.53m	£2.3m
Working capital	£0.01m	£0.02m

Annual Costs	£/y	£/y
Capital charges	202 000	305 000
Wages	38 000	53 000
On-Costs	14 000	20 000
Manager	5 000	9 000
Administration	26 000	37 000
Maintenance	60 000	92 000
Electricity	18 000	36 000
Fuel oil for paper recovery	15 000	30 000
Fuel for space heating	6 000	10 000
Totals	384 000	593 000

For waste containing 32% paper:

		10 tonnes/h £/y	20 tonnes/h £/y
Operating costs		384 000	593 000
Residue disposal		27 000	54 000
less Revenues		149 000	298 000
Net operating cost		262 000	349 000
	or	£8.5/tonne	£5.6/tonne

For waste containing 50% paper:

		10 tonnes/h £/y	20 tonnes/h £/y
Operating costs		384 000	593 000
Residue disposal		23 000	46 000
less Revenues		201 000	403 000
Net operating cost		206 000	236 000
	or	£6.7/tonne	£3.8/tonne

It should be noted that in spite of the high energy consumption required for the paper recovery process, its impact on the total operating cost of plant is quite small. Rather surprisingly it turns out to be less than the cost of electrical power for the sorting process, but this is because of the relative cheapness of oil compared with electricity.

The capital cost of the drying equipment is, however, substantial and it is interesting to calculate the effect of omitting this section of the plant and using the whole of the paper content of the waste as a fuel product. The capital costs would then be £1.1m for a 10 tonne/h plant or £1.7m for a 20 tonne/h plant. The annual costs then come out as follows:

For waste containing 32% paper:

		£/y	£/y
Operating costs		292 000	449 000
Residue disposal		27 000	54 000
less Revenues		76 000	153 000
Net operating cost		243 000	350 000
	or	£7.8/tonne	£5.7/tonne

For waste containing 50% paper:

		£/y	£/y
Operating costs		292 000	449 000
Residue disposal		23 000	46 000
less Revenues		93 000	186 000
Net operating cost		222 000	309 000
	or	£7.2/tonne	£5.0/tonne

The increased revenues from paper recovery are offset to a large extent by the increased capital cost of the plant, although when the paper content of the waste is as high as 50% there does appear to be some economic advantage in paper recovery. In the UK there would be no such advantage; indeed if the recovery efficiency for paper were appreciably lower, due to the greater contamination of the paper in the waste, fuel recovery could be a cheaper option.

TNO

Capital Cost

Estel estimate that a 20 tonne/h plant would cost D Fl 8-10m. Taking the mean value this is equivalent to about £2.2m. Assuming an exponential scaling factor of

0.6, a 10 tonne/h plant would cost £1.45m. These costs include the complete sorting circuit, installation and civil engineering.

Labour and Utility Requirements

Plant operation will require 4-6 men per shift. In the UK the following labour requirements would appear reasonable for two shift operation:

	10 tonne/h	20 tonne/h
Foremen	2	2
Shift operators	6	10
Day men	2	2

Electrical power consumption is estimated to be 20 kWh/tonne of incoming waste.

Energy requirements for drying the paper product are 0.13 G.cal/tonne of incoming waste when the paper product is 15% of the input waste. Assuming light fuel oil with a calorific value of 44 000 kJ/kg is used, oil consumption will be 12.27 kg (13.1l) per tonne of input. It should be possible to reduce fuel consumption by 15% by removing some of the water mechanically, and the extra capital cost would be negligible. In this case an oil consumption of 11 l/tonne of waste should be achieved.

Products

The average paper content of UK waste is of the same order as in Haarlem. The lower organic and higher ash content of UK waste would ne doubt require some modification to the TNO process to recover paper of equivalent quality. Nevertheless it seems reasonable to assume that 15% of the waste input could be recovered as a paper product with less than 5% contraries. Such a product should be acceptable to the British paper industry at a price of around £20/tonne.

The value of the fines product is more difficult to assess because the composition of this product from UK waste could be expected to be quite different from its composition in Holland. There is no basis at present for estimating its value to the UK brick industry, but it would probably be less suitable in Britain because of lower organic and higher inorganic non-combustible content. Nevertheless, it is an interesting outlet which would warrant further investigation. As a preliminary guess it might be assumed that 50% of the vegetable and putrescible material and most of the fines in UK waste could be removed in this product. It would then amount to 30% of the input, and would consist of 66% inorganics. In order to make a tentative estimate of process costs, a nominal value of £2/tonne is assumed. It is reasonable to assume that a ferrous product amounting to 7% of the input could be recovered from UK waste.

Operating Costs

Plant Capacity	10 tonnes/h	20 tonnes/h
Annual throughput	31 000 tonnes/y	62 000 tonnes/y
Capital cost	£1.45m	£2.2m
Working capital	£0.02m	£0.03m
Annual Costs	£/y	£/y
Capital charges	193 000	293 000
Wages	38 000	53 000
On-Costs	14 000	20 000
Administration	26 000	37 000
Manager	5 000	9 000
Maintenance	58 000	88 000
Electricity	14 000	28 000
Fuel for paper drying	26 000	51 000
Water	negligible	negligible
Fuel for space heating	6 000	10 000
Residue disposal (40% of input)	19 000	38 000
Totals	399 000	627 000

Revenues

Paper, 15% of input after drying, at £20/tonne	93 000	186 000
Ferrous metal, 7% of input at £12/tonne	26 000	52 000
Fines 30% of input at £2/tonne	19 000	37 000
Totals	138 000	275 000
Net annual operating cost	261 000	352 000
or	£8.4/tonne	£5.7/tonne

Sorain-Cecchini

The net operating cost has been calculated on the basis of treating waste in Rome and also average UK domestic waste of the following composition:

Constituent	%	Cecchini Classification	
Paper	32	Paper	(33)
Vegetable and putrescible	18	Organic matter	(18)
Metal	9	Metal	(10)
Glass	11	Glass	(10)
Plastic	2	Plastic	(1.5)
Textiles	3		
Fines (20mm)	19	Miscellaneous	(27.5)
Unclassified	6		
	100.0		

Composition of Rome Waste

Constituent	%	Product %		Recovery %
Organic matter 38	50	Compost	24	48% of organic
Fine organics 12		Animal feed	16	32% of organic
Paper	18	Paper	13.5	75
Ferrous	3	Ferrous	2.8	93
Plastic	4	Plastic	2.0	50
Glass	4			
Unclassified	21	Incinerated	41.7	41.7 incinerated
	100		100.0	100.0

Products based on UK Refuse Composition

Compost	8.6%
Animal feed	5.8%
Paper	24.8%
Ferrous	9.3%
Plastic	0.8%
Incinerated	50.7%
	100.0

Product Values per tonne of Incoming Waste

Product	Price/tonne	Value per tonne Italian Waste	Value per tonne British Waste
Compost	-	-	
Animal feed	£46.66	£7.46	£2.71
Paper	£43.33	£5.85	£10.75
Ferrous	£46.66	£1.31	£4.34
Plastic	£280	£5.60	£2.24
Total Value £/tonne		£20.2	£20.2

Basis for Costings

1. Plant at Rome - comparative plant based on 2 x 8 hr shifts for sorting unit and 3 x 8 hr shifts for incineration/food preparation plant. Occupacity of 75%.

2. Labour requirements as follows:

	Rome Plant (2 x 20 tonnes/h)	10 tonnes/h	20 tonnes/h
Manager	1	0.56	1
Foremen	3	3	3
Shift operators	36	12	22
Day men	6	2	3

3. Cost of residue disposal is neglected for this system since compost is available for use albeit at zero value.

4. Other factors, as set out at the beginning of the Appendix.

Operating Costs

	Rome	Comparative plants - UK Waste	
Plant capacity	-	10 tonnes/h	20 tonnes/h
Nominal daily capacity	600 tonnes/d	160 tonnes/d	320 tonnes/d
Waste input	200 000 tonnes/y (estimated)	31 000 tonnes/y	62 000 tonnes/y
Capital cost	£7.8m	£2.7m (at L25m/daily tonne)	£4.3m (at L20m/daily tonne)
Working capital	£0.07m	£0.02m	£0.04m
Annual Costs			
Capital charges	1 035 000	358 000	571 000
Operating costs:			
Wages	155 000	64 000	95 000
On-Costs	59 000	24 000	36 000
Manager	9 000	5 000	9 000
Admin Overheads	107 000	44 000	66 000
Maintenance	312 000	108 000	172 000
Electricity (27 kWh/tonne)	124 000	19 000	38 000
Fuel oil (1.66l/tonne)	25 000	4 000	8 000
Water (1m^3/tonne)	19 000	3 000	6 000
Water treatment (say 1m^3/tonne)	13 000	2 000	4 000
Gross Annual Cost	1 858 000	631 000	1 005 000
Gross Cost/tonne	£9.3	£20.4	£16.2

Revenue (based on Italian values) tonne	£20.2	£20.0	£20.0
Net cost per tonne	-£10.9	£0.4	£3.8

Revenue based on likely UK values for products ($12/tonne Fe, £20/tonne paper, £6/tonne for fuel with assumed fuel recovery of 25%).

	£4.6	£7.6	£7.6
Net cost per ton	£4.7	£12.8	£8.6

The calculations show that, with the high revenues available in Italy, the process almost breaks even at 10 tonnes/h, and is apparently highly profitable on the scale of the plant in Rome. If the capital investment is amortised at the rates quoted for Italy (20% over 8 years for equipment, 15 years for buildings) the capital charges are increased by £4.6/tonne, reducing the overall profit to £6.3/tonne. Although Cecchini would probably calculate the economics differently it seems that the operation must be profitable, even if the disposal charge paid by the municipality is neglected. On the other hand, in the UK, the relatively low revenues obtainable make the process very expensive to run, and there would be little incentive to operate a plant in the form in which it exists in Italy.

COMBOR

Capital Costs

The following capital cost estimates were provided for plants of 8 and 16 tonnes/hour capacity at throughputs of 100 and 200 tonnes/day respectively (i.e. 16 hours per day at an occupacity of 78%).

	Capital Cost, thousand francs	
	8 tonnes/hour	16 tonnes/hour
Equipment and installation	3000	5500
Electrical:	260	450
Plant building and storage site for 1 month's production :	1200	2200
Civil engineering :	320	620
Landscaping :	250	400
	5030	9170

Scaling up using an exponential factor of 0.6 and converting to sterling at £1 = F8.50 the capital costs of 10 and 20 tonne/hour plants would be £0.7m and £1.23m respectively.

Labour and Utility Requirements

For consistency with other processes considered earlier in the study the following labour requirements are assumed. They are a little higher than those recommended by the SOCETING company

	10 tonne/h	20 tonne/h
Foremen at £85/week	2	2
Shift operators at £72/week	6	10
Day men at £60/week	2	2

Electrical power consumption is estimated to be 50 kWh/tonne of waste treated. In addition drying of the shredded combustibles consumes 2% of the product.

Recoveries

Allowing for the removal of moisture and consumption of product for drying purposes, recovery of COMBOR should be of the order of 45% of UK waste. In view of the low ash fusion temperature of the fuel and an average calorific value of 14.5 MJ/kg its value is assumed to be £5/tonne. Recovery of ferrous metal is assumed to be 7% of the input waste.

Operating Costs

Using the standard assumptions agreed for the CREST study the operating costs for a plant in the UK have been calculated as follows:

	10 tonnes/h	20 tonnes/h
Annual throughput	31 000 tonnes/y	62 000 tonnes/y
Capital cost	£0.7m	£1.23
Annual Costs	£/y	£/y
Capital charges	92 000	162 000
Wages	38 000	53 000
On-Costs	14 000	20 000
Administration	26 000	37 000
Manager	5 000	9 000
Maintenance	28 000	49 000
Electricity	36 000	71 000
Fuel for spac e heating	6 000	10 000
Residue disposal (23% of input at £1.5/tonne)	11 000	21 000
Totals	256 000	432 000
Revenues		
Fuel, 45% of input at £5/tonne	70 000	140 000
Ferrous Metal, 7% of input at £12/tonne	26 000	52 000
Totals	96 000	192 000
Net annual operating costs	£160 000	£240 000
or	£5.2/tonne	£3.9/tonne

Enadims[a]/SOCEA

Capital Costs

A capital cost of 70 million pesetas (~£0.6m) was quoted for the 15 tonne/hour plant which is to be built at Almeria. The quoted cost includes installation and civil engineering but only the items shown in Fig. 8 (with the exception of the jig). Equipment for paper/plastic separation, ferrous metal cleaning, and glass recovery are not included. Nevertheless this capital cost estimate seems very low.

In the absence of more detailed cost information an attempt has been made to calculate the likely capital cost in the UK of the Enadisma process, excluding paper/plastic separation, tin-can cleaning, or glass recovery, but including such items as baling equipment for the products, mobile plant, weighbridge, etc. The estimated capital costs are as follows:

10 tonne/hour plant : £0.9m
20 tonne/hour plant : £1.4m

Note: These figures are a little lower than the ones quoted for the front-end of the Fläkt process, (£1.1m and £1.7m respectively), which includes similar equipment. The higher cost of the Fläkt process is reasonable since it includes a secondary shredder, and a zig-zag air classifier.

Labour and Utility Requirements

Enadimsa estimate that a total of 9 men (including supervision) will be required for a 15 tonne/h plant operating one shift per day. The following labour requirements appear reasonable for two shift operation:

	10 tonne/h	20 tonne/h
Foremen	2	2
Shift operators	6	10
Day men	2	2

Power consumption is estimated to be 15 kWh/tonne of incoming waste.

Water will be required for the glass recovery and paper cleaning operations but it is not yet possible to estimate the water usage.

Products

The value of the products in Spain is expected to be as follows:

	Values	
	pesetas/kg	£/tonne
Air classifier lights (for sale to paper industry)	1.5	13
Paper product after plastic separation	3.5	30
Plastic bottles	8.0	68
Ferrous metal	3-3.5	30
Ferrous metal after cleaning	6-7	60
Compost	up to 0.9	7.6

It seems unlikely that the air classifier lights would be acceptable to the UK paper industry, but they could be expected to find a market as fuel. The plus 65mm non-magnetics also have potential as a fuel product, though the calorific value would be lower. By combining these two products a baled, shredded waste-derived-fuel could be obtained for which a value of £5/tonne is assumed.

Some modifications to the dimensions of the equipment might be required to sort waste of lower organic content, but it is assumed that the recovery efficiencies would be similar for UK waste. On this basis the following rates of recovery could be expected from UK waste.

Product	Constituents	% of Constituents in UK waste		% of input recovered
Air classifier lights	80% of paper	32		25.6
	42% of plastics	2		0.8
	48% of rags	3		1.4
			Total	27.8
+65mm non-magnetics	20% of paper	32		6.4
	32% of plastics	2		0.6
	52% of rags	3		1.6
			Total	8.6

A total of about 36% of the input could be recovered as a fuel product, neglecting the effect of minor constituents such as wood, rubber and leather.

The paper/plastic separator should be capable of recovering 95% of the paper in the air classifier lights with a plastic content of 3-5%. This should be saleable at a value of, say, £20/tonne. In this case 25% of the input would be recovered as paper, but to allow for the initial moisture content of the paper in the waste it is assumed that 22% is recovered as fibre. A fuel product amounting to 13% of the input would be produced, for which a value of £4/tonne is assumed to allow for its lower calorific value.

It is assumed that 7% of UK waste could be recovered as ferrous metal with a value of £12/tonne.

Operating Costs

The operating costs have been calculated for two cases, viz. a) fuel and ferrous metal recovery, and b) paper, fuel and ferrous metal recovery.

a) Fuel and Ferrous Metal Recovery

Capacity	10 tonnes/h	20 tonnes/h
Annual throughput	31 000 tonnes/y	62 000 tonnes/y
Capital cost	£0.9m	£1.4m
Working capital	£0.01m	£0.02m
Operating Costs	£/y	£/y
Capital charges	120 000	187 000
Wages	38 000	53 000
On-Costs	14 000	20 000
Manager	5 000	9 000
Administration	26 000	37 000
Maintenance	36 000	56 000
Electricity	11 000	21 000
Fuel for space heating	6 000	10 000
Residue disposal (57% of input at £1.5/tonne)	27 000	53 000
Totals	283 000	446 000
Revenues		
Fuel 36% of input at £6/tonne	67 000	134 000
Ferrous metal 7% of input at £12/tonne	26 000	52 000
Totals	93 000	186 000
Net Annual Operating Cost	£190 000	£260 000
or	£6.1/tonne	£4.2/tonne

b) Paper, Fuel and Ferrous Metal Recovery

Enadimsa have made a preliminary estimate of 5-6 million pesetas for the cost of the paper/plastic separator for a 15 tonne/h plant. Taking the higher figures this is equivalent to £51 000. Using a Lang factor of 3.0 and adding on a contingency factor of 100% to allow for further development of the separator and ancillary equipment requirements, it is assumed that the installed capital cost would be £0.3m for a 15 tonne/h plant. The corresponding figures for 10 and 20 tonnes/h capacities are £0.24m and £0.36m respectively.

Additional Operating Costs, £/y

		10 tonnes/h		20 tonnes/h
Capital charges		32 000		47 000
Maintenance		10 000		14 000
Labour + On-costs and Administration (1 extra man/shift)		14 000		14 000
Electricity (2.7 kWh/tonne of input waste		2 000		4 000
Total Additional Cost		58 000		79 000
Total Annual Operating Cost		£340 000		£525 000
Revenues				
Paper 22% of input at £20/tonne		136 000		272 000
Fuel 13% of input at £6/tonne		24 000		48 000
Ferrous metal 7% of input at £12/tonne		26 000		52 000
Total Revenues		186 000		371 000
Net Annual Operating Cost		£154 000		£153 000
	or	£5.0/tonne	or	£2.5/tonne

The calculations indicate that inclusion of the paper/plastic separation stage might allow a substantial reduction in the net operating cost of the sorting process. (It should be noted that this reduction would be much less marked if the air classifier lights could be sold to the paper industry at £13/tonne as in Spain). It must be emphasised, however, that a large number of assumptions have been made in carrying out the calculations It may not be possible to achieve the same recovery efficiency for paper from UK waste without the addition of a second stage of air classification, which would add to the capital expenditure. It might also be necessary to have an additional screening stage to remove fines from the air classifier lights. Also there would probably be problems in marketing the wet paper product, and the assumed value might therefore be too high. If it were necessaru to dry the paper product it has been estimated by the authors that the net processing cost would be increased by £1 per tonne of waste treated. In most situations, therefore, the above operating costs should be increased by £1 per tonne.

Source of Illustrations

Fig. 1	L-9437-MR
Fig. 2	L-8935-MR
Fig. 3	MH912:MH250/75
Fig. 4	From reference 9
Fig. 5	From reference 8
Fig. 6	From Triple S Dynamics Brochure
Fig. 7	L-8549-MR
Fig. 8	From reference 27
Fig. 9	L-8244-MR
Fig. 10	From reference 34
Fig. 11	L-9438-MR
Fig. 12	L-9439-MR
Fig. 13	L-9440-MR
Fig. 14	L9441-MR
Fig. 15	L-9442-MR
Fig. 16	L-9443-MR
Fig. 17	L-9444-MR
Fig. 18	L-9445-MR
Fig. 19	L-9446-MR
Fig. 20	L-9447-MR
Fig. 21	L-9452-MR
Fig. 22	L-9057-MR
Fig. 23	L-9448-MR
Fig. 24	L-9053-MR
Fig. 25	L-9054-MR
Fig. 26	L-9056-MR
Fig. 27	L-9449-MR

References of figures 1 to 3, 7, 9 and 11 to 27 are those of Warren Spring Laboratory reports.

COMMISSION OF THE EUROPEAN COMMUNITIES

(Directorate General XII - Research, Science and Education)

THE DISPOSAL OF URBAN WASTE IN ITALY

A report

by

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INTRODUCTION

The present study was commissioned by the European Economic Community and is being conducted for Italy by the Fiat Engineering Company. It forms part of a European-wide study involving Great Britain (the pilot country, represented by the Warren Spring Laboratory), France and Germany (co-pilot countries along with Italy) and the other countries in Europe. The recycling experience of the U. S. A. and Canada will also be taken into consideration.

The subject of the study is a comparative analysis of the techniques used in Europe and the U. S. A. to recycle solid urban waste; numerous visits were made to European and American plants.

The present report refers on the existing situation in Italy; describes the Rome and Perugia plants, visited together with the other participants to the study, and supplies news on other prototype plants (Ambivere, Turin) and on the possibility of Italian industry in this field.
In the end some researches, particularly urgent in Italy, are proposed.

1 SOLID WASTE PRODUCED IN ITALY: STATISTICAL DATA

1. 1 GENERAL

Solid waste products are grouped into three classes:

- Domestic or urban solid waste:
  comprises waste of commercial origin from shops, warehouses, offices; domestic waste proper such as kitchen garbage; street cleaning rubbish.
- Industrial solid waste:
  comprises scrap from industrial processes.
- Agricultural solid waste:
  waste arising out of agricultural and zootechnical activities.

The present study concerns the first class. Law No. 366 of 20. 3. 1941 subdivides urban solid waste according to where it is produced and accumulated, i. e. :

- outdoor waste which includes 'the rubbish and waste products arising in pubblic places or in places given over even temporarily to public use';
- indoor waste comprising 'rubbish and, in general, t ordinary waste produced in buildings, however they are used'.

Broadly speaking, the former includes waste from the streets and the second waste from shops, offices or dwellings, i. e. produced by users of the municipal refu collection service.

1.2 RESULTS OF THE INVESTIGATION CARRIED OUT IN 1973 ON BEHALF OF THE ITALIAN SENATE

Per capita production and annual quantities produced are summed up in Table 1, region by region. The national average is about 0.715 kg per inhabitant per day; every year about 14,500,000 tonnes are accumulated and produced.

Fluctuations with respect to the average vary from 0.52 kg per inhabitant per day in Basilicata to 0.815 kg per inhabitant per day in Campania.

We would note first of all that regions presenting the highest economic wellbeing are below the national average. Above are all regions on the Tyrrhenian and Adriatic coasts as a result of the high production in coastal towns.

Activities linked to agriculture, floriculture, fishing, wholesale trade in fruit and vegetables (markets) and the preserves sector involving the processing and preparation of foodstuffs all mean huge production of waste.

It is essentially because of the type of trade carried on rather than the fact that the commercial activities of the hinterland are also generally handled there that coastal towns have such a high production of solid wastes.

This is certainly true of Campania where the intense fruit and vegetable trade carried on in the Naples and Caserta areas is the reason for the region's highest per capita level of waste production.

Table 2 provides pointers to the specific production of urban waste on the basis of the activities carried on by the population (Siteco survey carried out in Piedmont).

A final result of some interest concerns the subdivision into 'indoor' and 'outdoor' (from street cleaning) waste.

In Northern Italy, outdoor waste represents about 10% of the total collected; in Southern towns this percentage rises to up to 20% on average and in some cases 40-50%. This means that part of the indoor waste is found in the street and the departments of garbage collection and street cleaning which in some northern towns are operated by two different managements within the same town, here become indistinguishable.

Table 1 - Solid urban waste produced in Italy in 1973
(results of a survey carried out on behalf of the Italian Senate)

	RESIDENT INHABITANTS	PER CAPITA PRODUCTION * (g/inhab./day)	WASTE PRODUCED	
			QUANTITY ** (t/annum)	%
PIEMONTE	4.432.313	560	906.000	6,2
VALLE D'AOSTA	109.150	710	28.000	0,2
LIGURIA	1.853.578	680	460.000	3,2
LOMBARDIA	8.543.387	705	2.247.000	15,5
VENETO	4.123.411	695	1.094.000	7,5
TRENTINO-ALTO ADIGE	841.886	645	208.000	1,4
FRIULI-VENEZIA GIULIA	1.213.532	650	301.000	2,1
EMILIA ROMAGNA	3.846.755	740	1.106.000	7,6
TOSCANA	3.473.097	760	995.000	6,9
MARCHE	1.359.907	750	440.000	3,0
UMBRIA	775.783	635	184.000	1,3
LAZIO	4.689.482	780	1.327.000	9,1
ABRUZZI	1.166.694	760	348.000	2,4
MOLISE	319.807	610	74.000	0,5
CAMPANIA	5.059.343	815	1.534.000	10,6
PUGLIA	3.582.787	760	980.000	6,7
BASILICATA	603.064	520	120.000	0,8
CALABRIA	1.988.051	770	570.000	3,9
SICILIA	4.679.014	695	1.200.000	8,3
SARDEGNA	1.473.800	730	403.000	2,8
TOTAL IN ITALY	54.134.846	715	14.525.000	100

* grammes/inhabitant/day
** tonnes/annum

Table 2 - Specific production of urban waste on the basis of population activity in Piedmont

PREVALENT ACTIVITY OF THE POPULATION IN THE AREA CONSIDERED	DAILY PRODUCTION PER PERSON (g)
PREVALENT POPULATION: WORKER AND SIMILAR	590 - 630
AREA WITH INTENSE COMMERCIAL ACTIVITY	570 - 610
TOURIST AREA	570 - 610
RESIDENTIAL AREA WITH HIGH NUMBER OF MEMBERS OF THE PROFESSIONAL CLASSES AND SIMILAR	500 - 550
RURAL AREA WITH PREVALENTLY FARMING ACTIVITIES	400 - 450

3 TRENDS

The trends in solid wastes collected during the year in any one centre reflect the economic life of that centre.

By way of example we quote the figures relative to the towns of Bologna and Cortina:

	Bologna (cu. m.)	Cortina (cu. m.)
January	62.591	4.135
February	55.750	3.635
March	67.035	3.530
April	64.871	2.105
May	64.960	2.170
June	52.027	2.415
July	57.947	3.715
August	49.545	4.604
September	60.974	3.250
October	64.785	2.050
November	59.110	2.225
December	63.574	3.325
Total	723.169	38.794

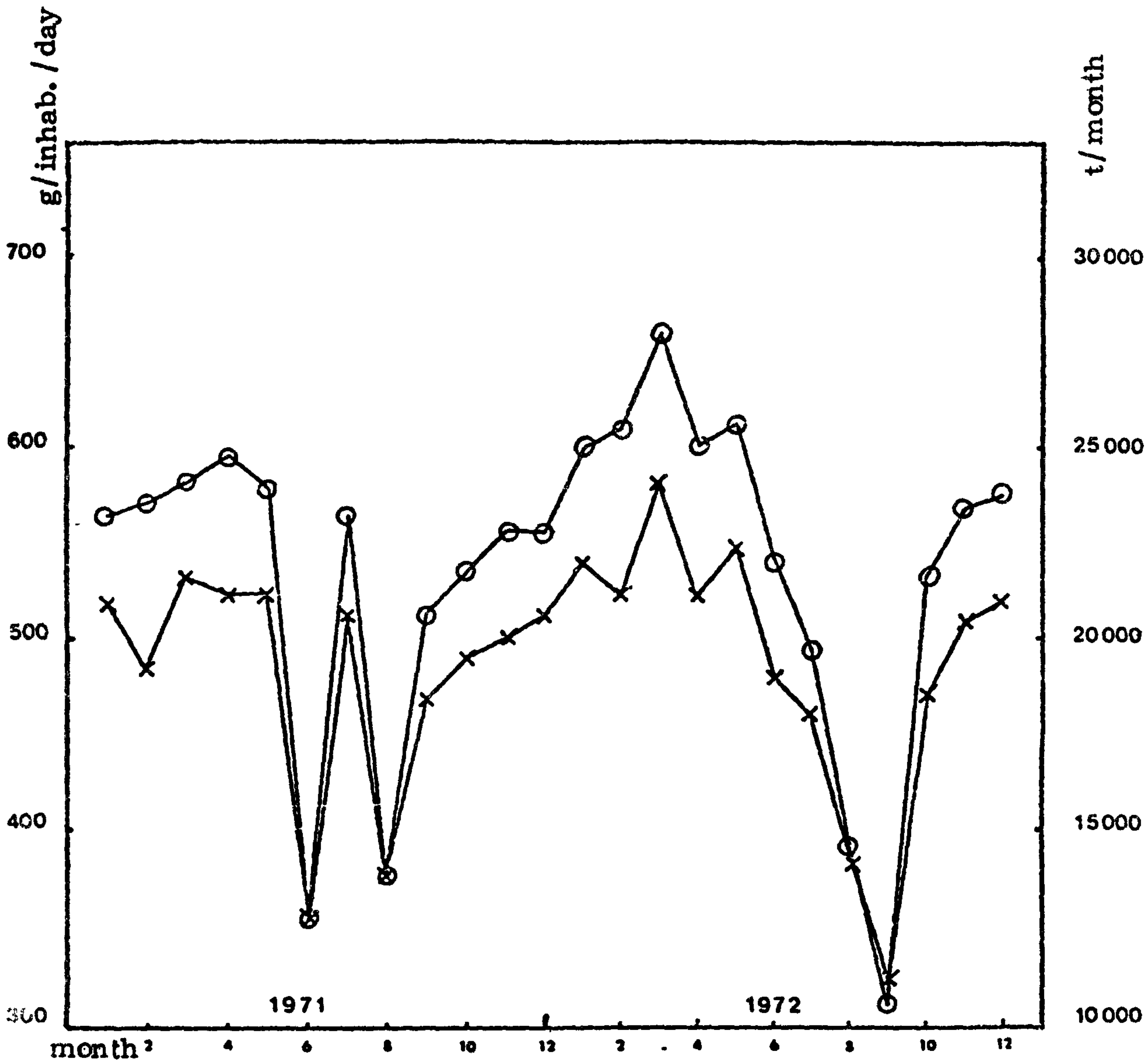
Bologna has a negative peak in August owing to the summer exodus; in Cortina, on the other hand, there are two positive peaks corresponding to the winter (December-March) and summer (July-September) holiday seasons.

Many towns in the South present trends similar to that of a tourist resort owing to emigrants returning to spend their holidays in Italy.

Variations during the year are also linked to consumption; in the Campidano plain in Sardinia there are double quantities of beans and peas during the season while the same thing happens in some towns in the province of Ferrara in the case of water-melons.

Fig. 1 plots the curve of solid waste collection over a two-year period (1971-72) in a large industrial town (Turin).

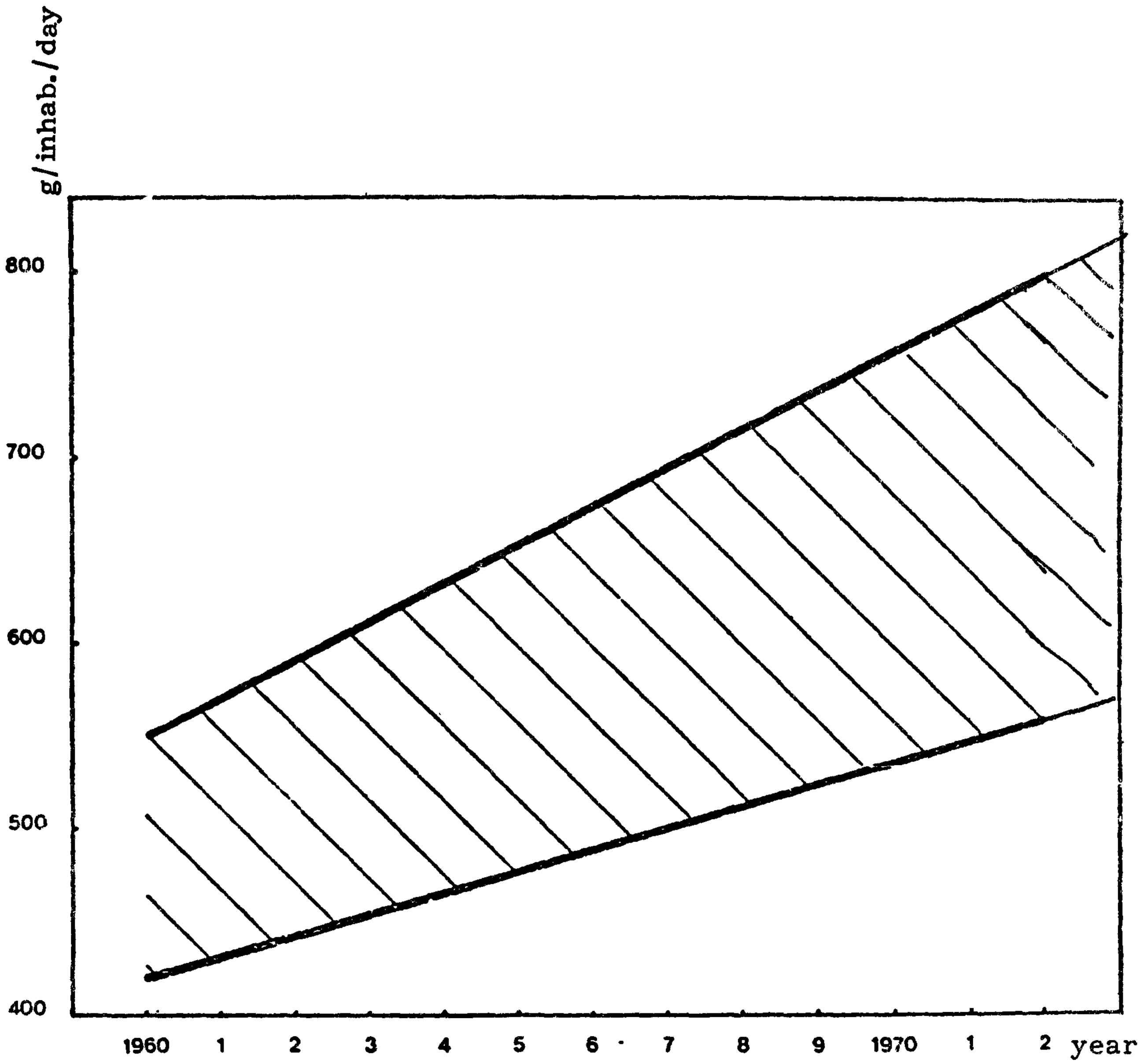
Fig. 2, finally, provides an indication of growth trends of per capita solid waste production in Italy.



monthly waste production (t/month)

monthly average production (g/inhab./day)

1.3 Fig. 1 - Monthly quantities of waste collected in Turin and average per capita production



1.3 . Fig. 2 - Variation in per capita solid waste production in Italy

2 COMPOSITION OF WASTE

2.1 GENERAL

Solid urban waste involves an enormous variety of form dimensions and component properties. Waste also varie with the period of the year and the substances contained in the waste change: organic and inorganic matter, food waste, glass, metals, paper, etc.

In order to describe its properties, the following analys are generally made of waste:

- commodity composition;
- combustion analysis;

and the following properties are determined:

- density (kg/l);
- lower usable heat value (Kcal/kg).

More rarely screening analyses are carried out to enab a granulometric curve of waste products to be plotted; also chemical analyses identify chemical elements present and other properties are also determined, e.g. heat conductivity and thermometric diffusion.

Commodity analysis consists of breaking up waste into component 'commodities', e.g. vegetables, plastic, pap wood, rubber, foodstaffs, glass, metals, etc.

Combustion analysis subdivides waste into three parts: humidity, substances that burn (organic substances or combustible matter) and substances that do not burn (inert).

2 RESULTS OF EXISTING ANALYSES

Very few analyses have been carried out in Italy so far and these are often impossible to compare because they have used different procedures (we have, for example, commodity analyses that differ by number of 'commodities' identified) and they refer to different periods.

Systematic analyses have, for practical purpose, only been carried out on an annual basis in Milan and Bologna (Table 3 a and 3b).
In other towns these studies have only been made on special occasions and have therefore been episodic.

Table 4 provides an indication of the typical composition of waste in Italy, while Table 5 gives us a broad idea of the average composition of waste in different regions.

Table 6 and 7, from Siteco studies carried out for the Region of Piedmont, give data on the composition of solid urban waste in Piedmont and Turin.

Table 3a - Composition of waste

DESCRIPTION		JANUARY 1961	MAY 1961	OCTOBER 1961	JULY 1965	NOVEMBER 1965	MAY 1966	NOVEMBER 1967	NOVEMBER 1968	MAY 1969	MAY 1970	MAY/JUNE 1971	SEPT/OCT 1972
COMMODITY COMPOSITION													
. MINUTE AT SCREEN 0.5 mm	%	17,02	9,19	13,23	7,05	10,82	7,02	7,46	6,32	4,68	5,22	3,65	3,48
. MINUTE AT SCREEN 5 - 20 mm	%	19,62	16,74	19,42	15,15	15,98	12,32	14,78	15,80	13,41	9,97	6,62	8,19
. ANIMAL ORGAN. MATTER	%	2,35	2,29	2,83	1,69	1,67	1,37	2,19	1,73	1,22	1,38	0,64	0,94
. VEGETABLE ORGAN. MATTER	%	17,71	26,05	16,19	15,95	13,28	22,40	17,62	22,20	23,43	19,36	27,86	19,93
. CELLULOSE	%	30,37	34,66	35,34	41,95	45,52	41,50	43,27	38,67	39,56	45,78	44,45	47,08
. PLASTIC	%	0,79	0,85	0,78	1,75	1,89	1,78	2,36	3,11	3,71	5,20	5,27	7
. COMBUSTION WASTE	%	1,17	—	0,20	—	0,01	—	0,09	—	—	—	—	—
. INCOMBUSTIBLE MATTER	%	10,97	10,22	12,01	16,46	10,83	13,61	12,23	12,17	13,99	13,09	11,51	13,38
TOTAL	%	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
CHEMICAL COMPOSITION													
. WATER	%	37,06	42,85	38,30	35,12	34,57	37,44	35,32	36,95	36,14	36,15	36,94	35,50
. COMBUSTIBLES	%	36,17	36,30	36,90	27,62	43,17	39,87	42,22	39,63	39,85	42,60	43,24	43,83
. ASH	%	26,77	20,85	24,80	37,26	22,26	22,69	22,46	23,42	24,01	21,25	19,82	20,67
TOTAL	%	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00	100,00
PHYSICAL CONSTANT													
. PCI		1524	1328	1464	1435	1671	1449	1697	1643	1532	1641	1511	1718

Table 3b - Commodity composition - Milan waste

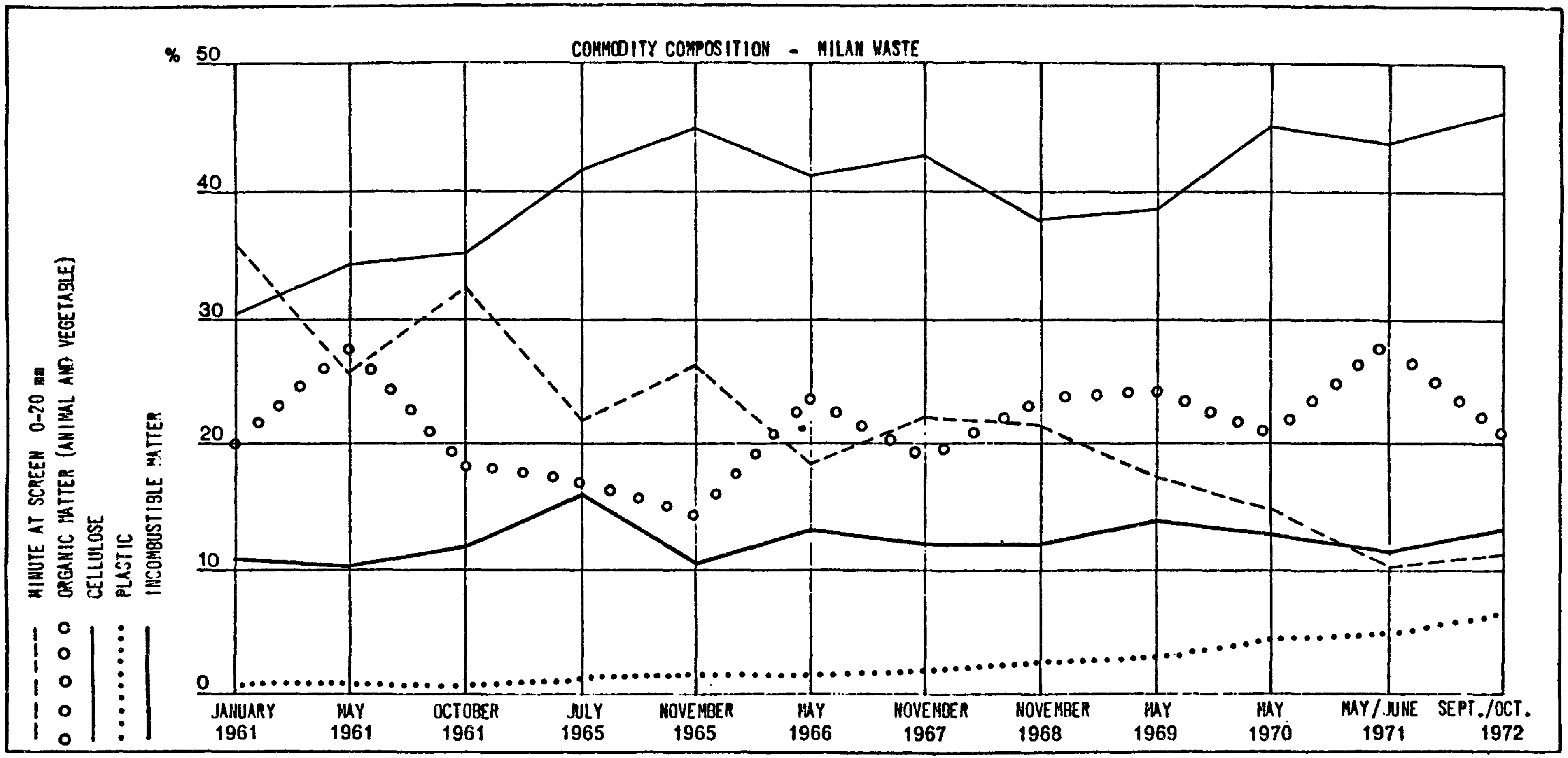


Table 4 - Composition and properties of solid urban waste in 'typical' towns (Italian Senate survey)

	INDUSTRIAL COMMERCIAL TOWNS OF LARGE-MEDIUM DIMENSIONS	TOWN WITH AGRIC. COMMERCIAL ECONOMIES OF MEDIUM DIMENSIONS	SMALL TOWNS
COMMODITY COMPOSITION %			
. CELLULOSE SUBSTANCES	45 ÷ 50	35 ÷ 40	30 ÷ 35
. PLASTIC SUBSTANCES	4 ÷ 6	3 ÷ 5	2 ÷ 3
. PUTRESCIBLE ORGANIC SUBSTANCES	15 ÷ 20	25 ÷ 30	30 ÷ 35
. INERT	10 ÷ 15	15 ÷ 20	15 ÷ 20
. SCREENING RESIDUE (1)	15 ÷ 20	15 ÷ 20	15 ÷ 20
T O T A L	100	100	100
COMBUSTION ANALYSIS %			
. COMBUSTIBLE SUBSTANCES	38 ÷ 42	34 ÷ 38	28 ÷ 32
. INERT SUBSTANCES	18 ÷ 22	18 ÷ 22	16 ÷ 20
. HUMIDITY	36 ÷ 44	48 ÷ 40	48 ÷ 56
T O T A L	100	100	100
PROPERTIES			
. LOWER USABLE HEAT VALUE (kcal/kg)	1.600 ÷ 1.800	1.400 ÷ 1.600	900 ÷ 1.000
. DENSITY (kg/l)	0.17 ÷ 0.14	0.20 ÷ 0.17	0.25 ÷ 0.30

(1) CONSISTING OF INERT SUBSTANCES + FINE VEGETABLE SUBSTANCES

Table 5 - Composition and properties of solid urban waste - regional and national averages (1973)
(Italian Senate survey)

	COMPOSITION %					PROPERTIES	
	CELLULOSE SUBSTANCES	PLASTIC & RUBBER SUBST.	PUTR.ORGAN. SUBSTANCES	INERT SUBSTANCES	TOTAL	DENSITY (kg/l)	LUHV * (kcal/kg)
PIEMONTE	34.5	4.0	33.0	28.5	100	0.18	1.550
LIGURIA	35.5	4.0	35.0	25.5	100	0.19	1.500
VALLE D'AOSTA	26.0	1.5	38.5	34.0	100	0.21	1.400
LOMBARDIA	37.0	4.5	32.5	26.0	100	0.17	1.600
VENETO	30.0	3.5	34.5	32.0	100	0.19	1.450
TRENTINO ALTO ADIGE	28.0	1.5	38.5	32.0	100	0.21	1.400
FRIULI VENEZIA GIULIA	30.0	3.0	34.0	33.0	100	0.21	1.400
EMILIA-ROMAGNA	30.0	3.0	36.0	31.0	100	0.19	1.450
TOSCANA	31.0	3.0	39.5	26.5	100	0.21	1.400
MARCHE	27.5	2.5	40.0	30.0	100	0.24	1.300
UMBRIA	29.0	1.5	40.5	29.0	100	0.24	1.300
LAZIO	31.0	3.5	38.0	27.5	100	0.21	1.400
ABRUZZI	28.5	2.0	41.5	28.0	100	0.30	1.150
MOLISE	25.0	1.5	41.0	32.5	100	0.35	1.050
CAMPANIA	32.5	2.5	45.0	20.0	100	0.30	1.150
PUGLIE	27.0	2.0	42.0	29.0	100	0.30	1.150
BASILICATA	23.0	1.5	39.0	36.5	100	0.35	1.050
CALABRIA	25.0	1.5	42.0	31.5	100	0.35	1.050
SICILIA	26.5	2.0	40.0	31.5	100	0.33	1.100
SARDEGNA	28.0	2.0	39.5	30.5	100	0.30	1.150
TOTAL IN ITALY	31.0	3.0	37.9	28.1	100	0.24	1.350

* LOWER USABLE HEAT VALUE

Table 6 - Composition of waste in Piedmont and subdivision according to the prevalent activity of the population

COMPONENTS		GENERAL AVERAGE	AREA WITH PREVALENT WORKING CLASS POPULATION	AREA WITH CONSIDERABLE COMMERCIAL ACTIVITY	TOURIST AREA	AREA OF PROFESSIONAL CLASSES AND SIMILAR	AGRICULTURAL AREA
DUST AND ASHES	%	25	25	20	20	27	10
PUTRESCIBLE MATTER	%	17	16	20	20	15	50
CELLULOSIC MATTER (PAPER, RAGS, WOOD)	%	35	36	40	38	35	35
PLASTIC AND RUBBER MATERIALS	%	3	3	3	4	3	10
INERT MATERIALS (METALS, GLASS, DETRITUS)	%	20	20	17	18	20	40
LOWER HEAT VALUE	kcal	1.500	1.500	1.600	1.600	1.500	1.400

Table 7 - Results of the analysis of a waste sample from Turin

DUST AND ASHES	PAPER AND CARDBOARD	EDIBLE WASTE	PLASTICS	FERROUS MATERIALS	GLASS	NON CLASSIFIED
20,0%	14,7%	3,3%	4,1%	3,0%	4,3%	50,0%

.3 TRENDS

As we have mentioned, the chemico-physical nature and properties of waste vary during the year: in winter the heat value increases and density falls, and the opposite happens in spring-summer when waste is enriched with organic vegetable substances.

For disposal purposes, variations in the next few years are more important than the variation in properties during the year.

The determination of waste product properties is important in general for the purposes of building a disposal plant; for those methods (compost, recovery or recycling) the success of which is closely bound up with the composition of the waste, such determination is indispensable. It is equally important to be able to predict how composition and the corresponding properties of the waste will develop.

There are compost plants that give a downgraded product because they treat waste other than the waste for which they are most suitable.

Extrapolating trends encountered in the last few years, it can be deduced that the Heat Value is tending to increase by 50 Kcal/kg per annum on average while density is falling (see Figure 3); it can be reasonably hypothesized, on the basis of experience abroad, that this trend will continue until a threshold is reached. In the case of Lower Usable Heat Value this will be 2,500-3,000 Kcal/kg and of density 0. 11-0. 12 kg/l as encountered in countries of greatest economic wellbeing.

In similar fashion it can be expected that we shall find an increase in the percentage of paper, cardboards, and plastic and a percentage fall in putrescible organic substances.

Another tendency which could have a considerable influence on the recycling of waste products is the differentiated collection of urban waste (preselection). An experiment of this type has been in progress at Cambiano (a town close to Turin) for more than a year; another experiment has been carried out at Modena. Users of the service are given 2 bags, one for organic and the other for inert substances.

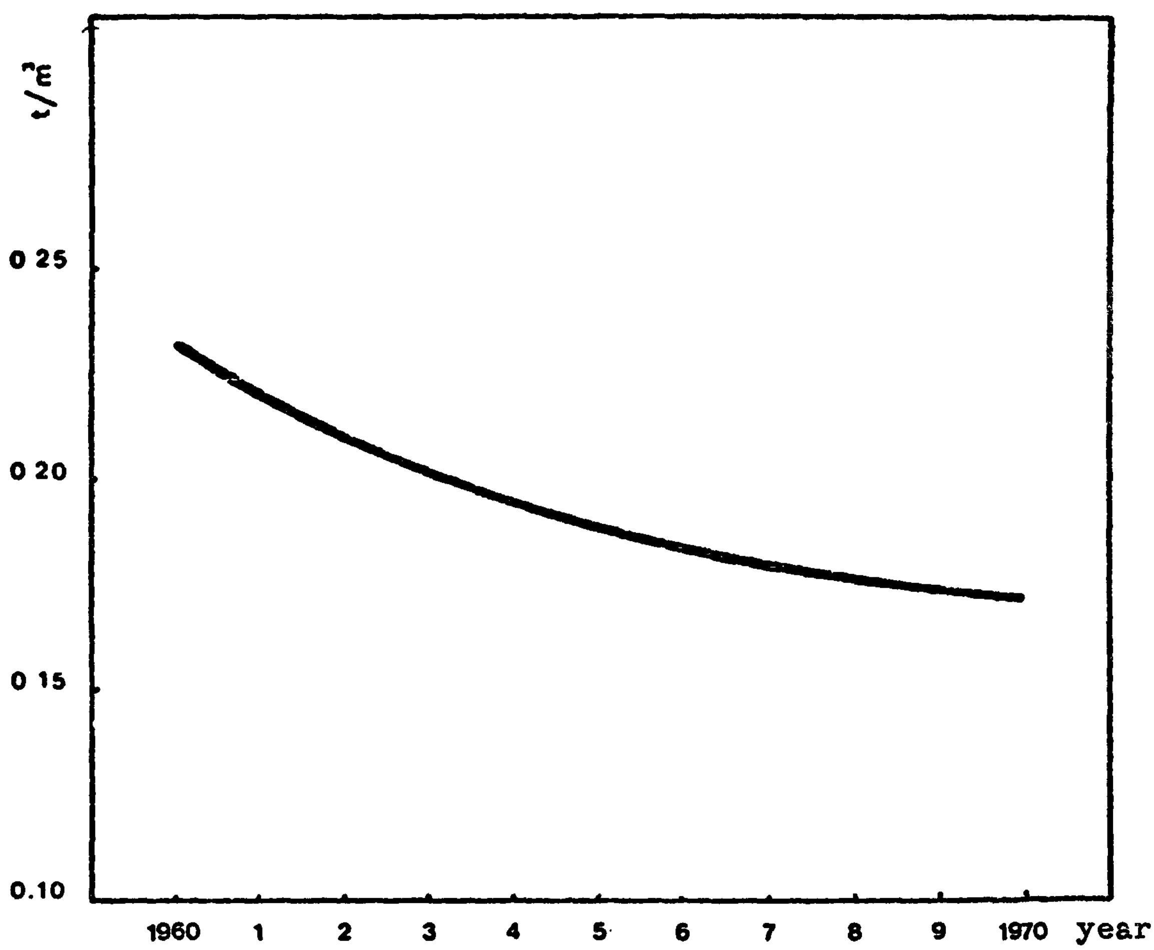


Fig. 3 - Trend graph of the specific weight of solid wastes in Italy

COSTS INVOLVED IN OPERATING DISPOSAL PLANTS

These costs embrace those items that appear constantly in plant operating cost analyses, e.g. electricity, water, fuel, labour.

Electrical energy: on average the cost is 30 Lit./KWh for systems between 100 and 1,000 KW installed; an increase is scheduled next year.

Water: this varies from town to town but it can be assumed to be between 40 and 80 Lit./m^3; average value: 50 Lit./m^3.

Auxiliary fuels: these are subject to market variations; prices at present are as follows:

. fuel oil	60	Lit./kg
. diesel oil	95	"
. methane	53 ÷ 57	"

As for labour (the cost of which increases in proportion to inflation) the following rough costs may be indicated for the present time:

. manager	20	million/	annum
. office and technical staff on monthly salaries	12	"	"
. specialized labour (mechanics, electricians)	8	"	"
. labourer	6	"	"

P. S.: All prices are in Italian Lira (Lit.)

4 MARKET FOR RECYCLED AND RECOVERED PRODUCTS

Market analysis for recycled products (existence of a market, quality demanded of products, acceptable quantity, commercial value of the recycled product) is the most difficult aspect of the present study. It is influe ed by innumerable external factors (psychological reacti to recycled products on the part of users, behaviour of raw material suppliers, action taken by public authoritie etc.) and internal factors (quality of the recycled produc constant quality over time, production and use time modalities, cost of the products, incidence of transport costs, etc.).

A complete examination will be carried out as the study proceeds, considerations regarding recycled products being set against production modalities. In this prelimin report we will provide an early broad idea of the market in recovered materials:

• heavy alloys (brass, bronze, copper alloys, etc.)	250÷500	Lit. /kg
• light alloys (aluminium and its alloys)	100÷200	"
• scrap iron (unworked or worked)	25÷60	"
• glass waste (assorted or selected by colour)	15÷30	"
• paper pulp	60÷70	"

It goes without saying that the highest prices are paid for the choicer materials.

5 DISPOSAL SYSTEMS EMPLOYED IN ITALY

5. 1 DISPOSAL SYSTEMS

The following systems are currently adopted on a wide scale in Italy:

- Sanitary landfill (with or without trituration of the waste)
- Composting
- Incineration
- Recycling

Other methods, such as pyrolysis of waste or its compression into blocks for use in the construction industry (embankments, dams, etc.) should be considered experimental and more work will have to be done on them.

5. 2 COMPOSTING

The principle of this method is to stabilize organic waste by exploiting the action of the accompanying micro-organisms.
Composting is basically an aerobic-thermophilic process. Following stabilization, the material presents organoleptic features similar to those of humus whose mineral salt content and physical nature make it utilizable as a fertiliser, especially thanks to its pedological aspects.
The stabilized material (compost) performs a variety of operations with respect to the ground (structure): prevention of erosion due to water and wind; increased permeability. From the chemical viewpoint, the part played by oligo and nutritive elements is still to be appraised.
The composting process goes hand in hand with a reduction in the initial bacterial complement as a result of the chemico-physical transformation and of the thermal action consequent on the heat that develops during the composting process.

From a technological point of view we might recall that the transformation process can be carried out in two ways

a) Naturally: the material to be composed is piled up in the open and turned over every so often with a power shovel.

b) Artificially: a variety of techniques, generally patente involves homogenization and mixing of the material in rotating cylinders (rotary fermenters) and subsequent maturation in piles on the threshing floor.

In the present study composting plants are not considered (they are the subject of another E.E.C. study) unless the production of compost is a by-product of a more complex recycling plant.

5.3 INCINERATION

Incineration is the most widely employed system in Italy today.
It requires a much smaller surface than other methods and resulting products are inert.
Against this, incineration produces a great quantity of as (weighing up to 30% of the waste, equal to 10% in volume) and gas effluents are produced by the combustion proces Both types of residual products present a disposal proble Among the ecological implications of incineration plants we might mention:

a) Atmospheric pollution: combustion may lead to noxio substances being released into the atmosphere;prese -day fume cleaning processes are in fact cooling and dust collection operations, namely they control temperature and the quantity of the solid substances contained.
But in the operating conditions of the combustion chamber (1,000°C), Cl_2, F_2 and SO_2 are formed if

chlorinated (PVC), fluoridated (Teflon) and sulphur-containing (rubber) substances are present respectively. For the sake of safety, the substances whose combustion generates these damaging components must only be present in tiny percentages so that the corresponding gaseous components released from the stack are within the acceptability limit.

b) Pollution of waters deriving from incomplete or partial combustion, with the result that putrescible substances are found in high percentages in the residue.

Incineration plants are not considered in the present study unless they form part of more complex recycling plants.

We should add one further consideration: incineration plants might also involve recycling plants. Scrap iron, which is separated after combustion by means of electromagnetic systems and then sold, is in fact already being recycled.

Further, recent studies (1) carried out by the Department of Mining, University of Cagliari, have shown that from 100t of ashes deriving from urban waste furnaces it is possible by means of selective trituration, magnetic, electrostatic and gravimetric separation to obtain:

675 kg of heavy alloys (brass, bronze, copper alloys, etc.)
390 " " light " (aluminium alloys);
4.990 " " iron;
26.300 " " glass;

the estimated value being 6,000 lire per t of ash.

With a plant potential of more than 200-300 t/day of treated ash, the commercial value of the materials recovered should offer an acceptable profit.

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(1) Alfano-Antonioli-Del Fà 'On the recovery of metals and non-metallic materials from urban waste incineration residues' - The Mining Industry - January 1976

5.4 RECYCLING PLANTS

Italy has a long tradition of recycling waste products dating back to wartime autarchy.
Law No. 366 of 20/3/1941 on the collection and disposal of solid urban waste prescribed the reutilization of waste and its recovery for industrial and agricultural purposes.
Until the fifties, Milan and other large northern towns operated composting plants preceded by manual selection: paper, glass, metals, shoes, bones etc. were recovered and sold.
The increase in labour costs made such recoveries uneconomical and the method was abandoned. Nowadays it is sanitary-social reasons rather than technical or economical ones which preclude consideration of any form of manually based waste selection.
Clearly, automation of the recovery process would make a disposal system based on this principle feasible again, for what in 1941 was the problem of a nation at war is destineted to become, in the near future, a problem for the whole of mankind.
Four recycling plants are currently being operated in Italy (owned by SARR, SORAIN, Cecchini and the town of Perugia - 3 of them in Rome and one in Perugia).
Waste products are divided automatically into ferrous materials, paper, cardboard, substances convertible into fodder, undistinguished organic parts, gross waste.
The plant is fitted with a section for the conversion of paper into paper pulp, a section for the production of animal fodder, a section for the conversion of ferrous materials into bales, a composting section and a waste incineration furnace equipped with boilers for heat recove
The incinerator receives 35% of the waste by weight.
The diagram of the plant is shown in Figure 4.

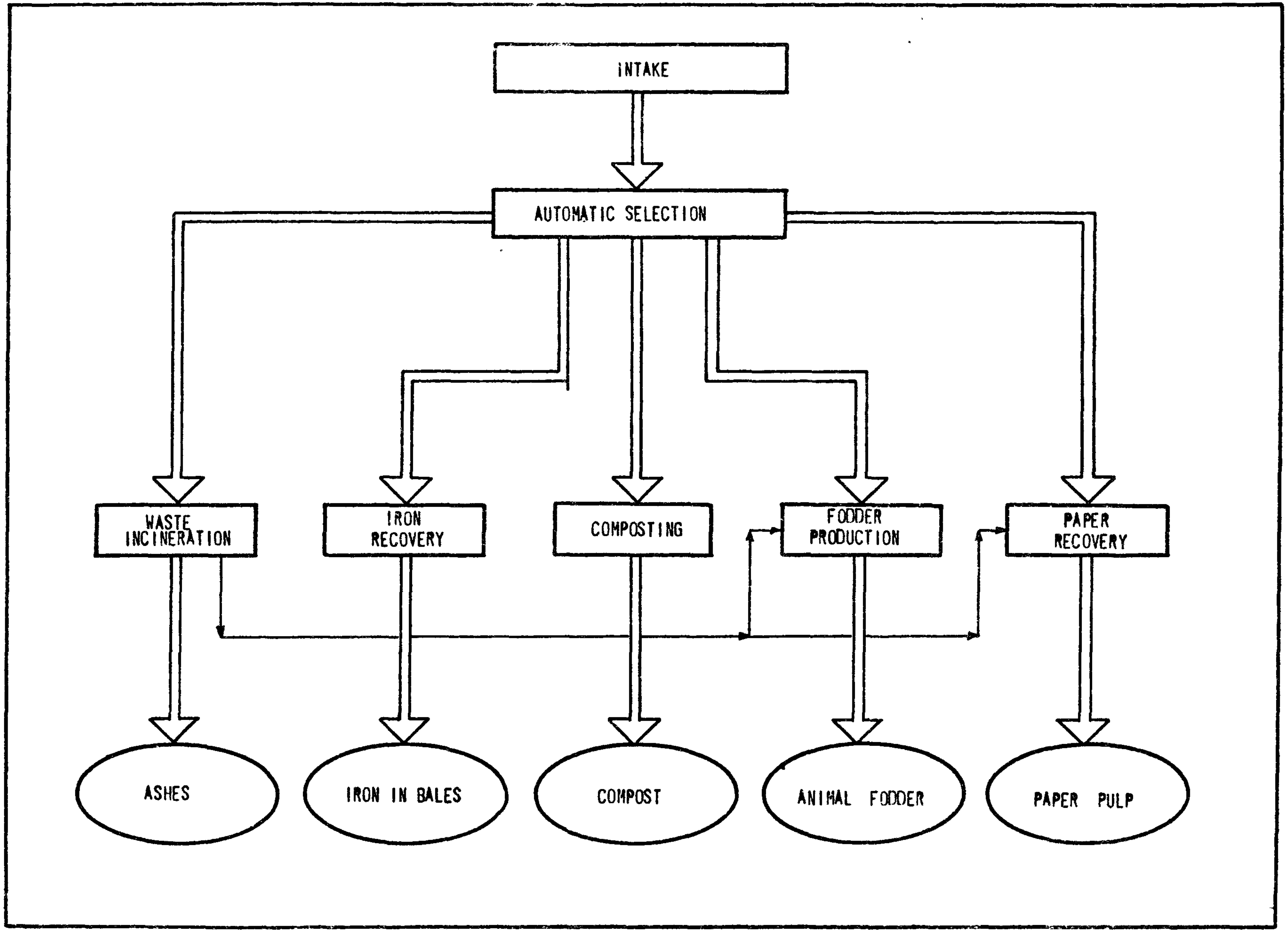


Figure 4 - Rome recycling plants: block diagram

5.5 STATISTICS ON PLANTS OPERATING IN ITALY

In Italy about 160 plants treat ~ 15,000 t/day of urban waste; they have an average unit capacity of 94 t/day per plant and an average utilization factor of 62%.

In addition there are about 30 plants under construction with a capacity of 4,200 t/day and an average unit capacit of ~ 130 t/day (dimensions are tending to increase).

The 190 plants under construction or already operating are subdivided as follows:

• incineration plants	148	(13,000 t/day)
• composting + incineration plants	32	(3,700 ")
• plants for composting alone	6	(500 ")
• recycling plants	4	(2,000 ")
	190	(19,200 t/day)

The recycling plants are:

• Perugia plant (built by the Cecchini Company)	100 t/day	(*)
• Plant No. 2 (Rome) (Sorain Company)	650 "	
• Plant No. 3 (Rome) (Cecchini Company)	650 "	
• Plant No. 4 (Rome) (SARR Company)	550 "	

(*) Being extended

6 VISIT TO THE RECYCLING PLANT BUILT BY THE CECCHINI COMPANY AT PERUGIA (1st March 1977)

The plant was idle at the time because extension work is being carried out to increase capacity from 100 t/day to 200-220 t/day; the extension is being financed by the Region of Umbria.

Plant cost: initial (1969) 1,3 billion lire; cost of current extension 1,180 billion lire.

Current cost of a plant: ≥300t/day, 20 million lire/t/day.

No. of employees: 39 (including shift-workers, administrative staff, etc.) at the maximum; numbers will be reduced to 31 after plant renovation; for a 300 t/day plant: 47 employees.

Installed electric power: 700 kW; 2 million lire a month is spent on electrical energy (*); fuel consumption = 200 kg/h of fuel oil; water consumption 8 l/second.

Plant diagram: see attached Figure 1.

Plant description: Enclosure I.

Features of the material treated: unselected urban waste from Perugia and environs, total inhabitants 300,000, equal to 200-220 t/day; make-up:

. paper	22%
. ferrous scrap	3 - 3,5%
. plastic	4%
. glass	2-2,5%
. gross organic matter	27%
. fine organic matter	15%
. unclassifiable inert	26-27%

Output products:

. paper	12%
. animal fodder	5% (humidity 5-7%)
. ferrous scrap	3-3,5%
. compost	15% (or 20% with ash recovery)
. plastic	3,5%
. incinerated matter	35%
. humidity	30%

(*) Equal to about 66,000 kWh/month; equal to 13 kWh/t of waste, i.e. about 400 lire of electrical energy/ton of treated waste

Commercial value of recovered products:

. scrap iron up to	60 lire/kg
. compost	4 " "
. fodder	50-60 lire/kg
. paper 'commercial dray'	80 " for pulp
. plastic (*)	80-100 lire/kg

Operation of the plant:

- the 'sorting' unit works in 2 shifts;
- the 'fodder' unit works in 3 shifts;
- the 'scrap iron' unit works in 3 shifts;
- the 'incineration' unit works in 3 shifts.

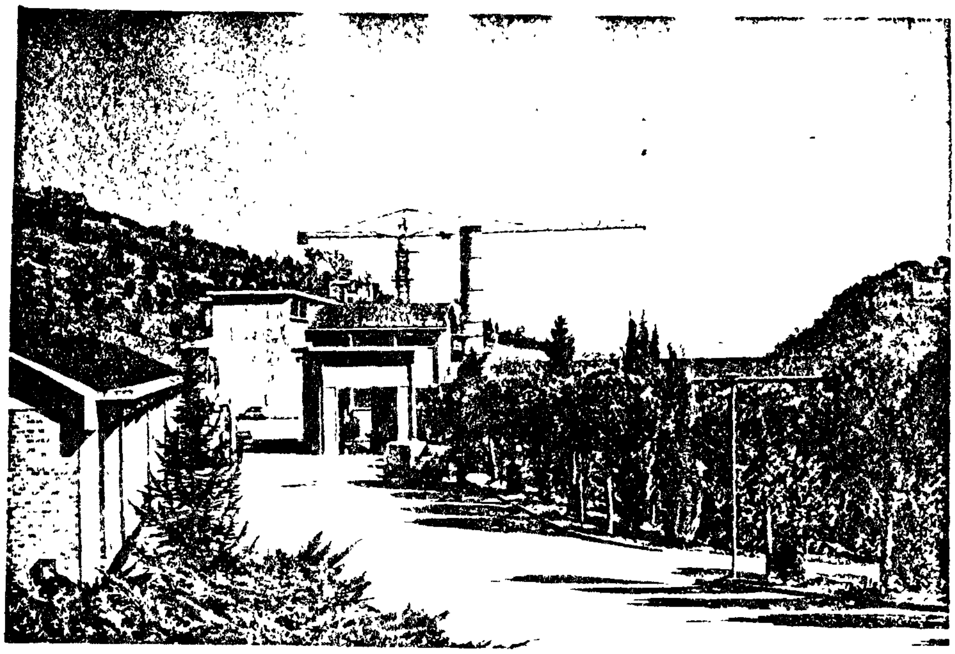
Overall opinion: the plant is genuinely automatic, without any hand sorting; it is right up to date; each unit has its own control panels.
Fumes are cleaned in the damp stack (water spray).
The water is decanted and undergoes primary clarifying treatment in the plant; subsequently all plant and adjacent river waters are clarified biologically; the biological muds are added along with the ash to the compost.

The following pictures show some views of the plant.

(*) Sent to plants in Tuscany and in the Marche where recovery takes place

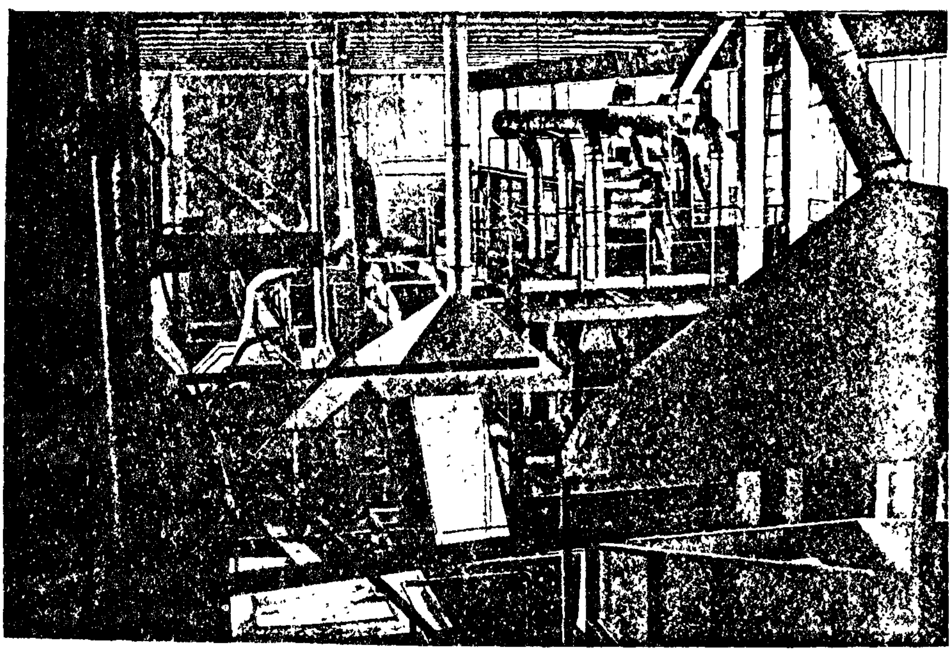
Vista generale dell'impianto

(Perugia sorting plant)



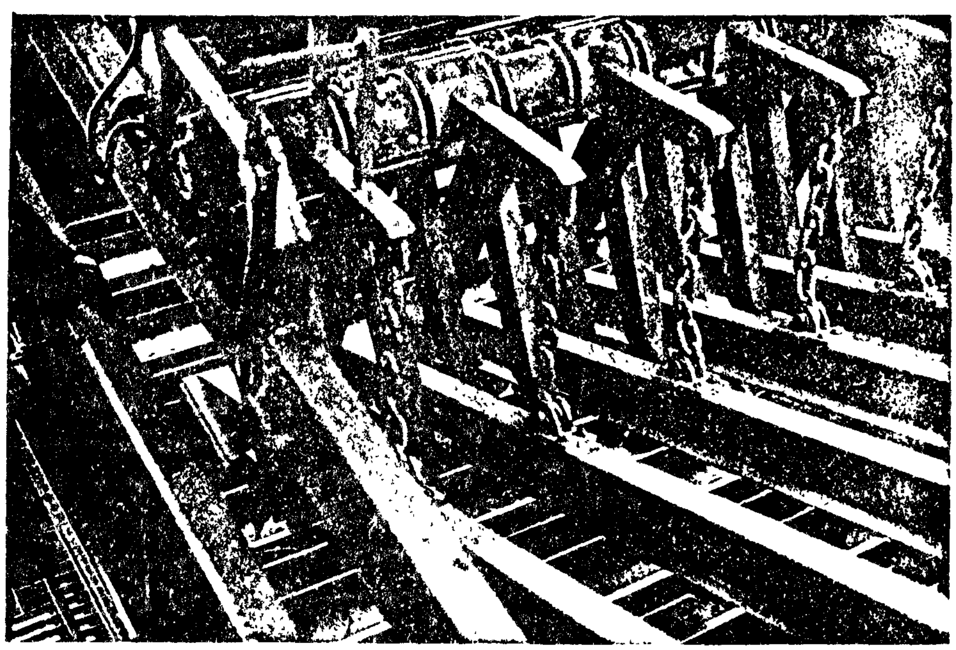
Vista generale dell'impianto all'interno del capannone

(General view)



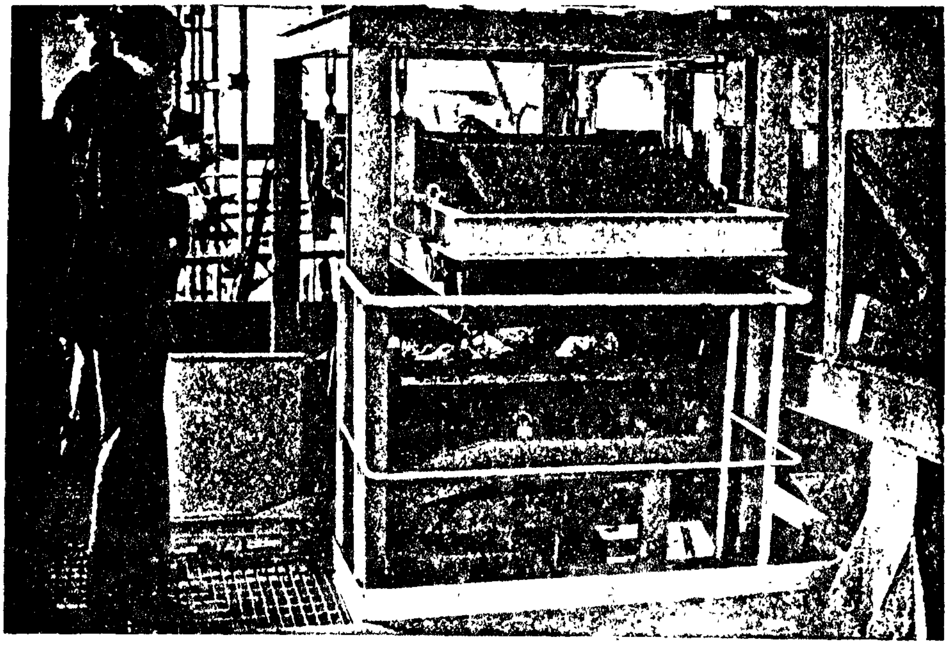
Macchina strappasacchetti

(Bag burster)



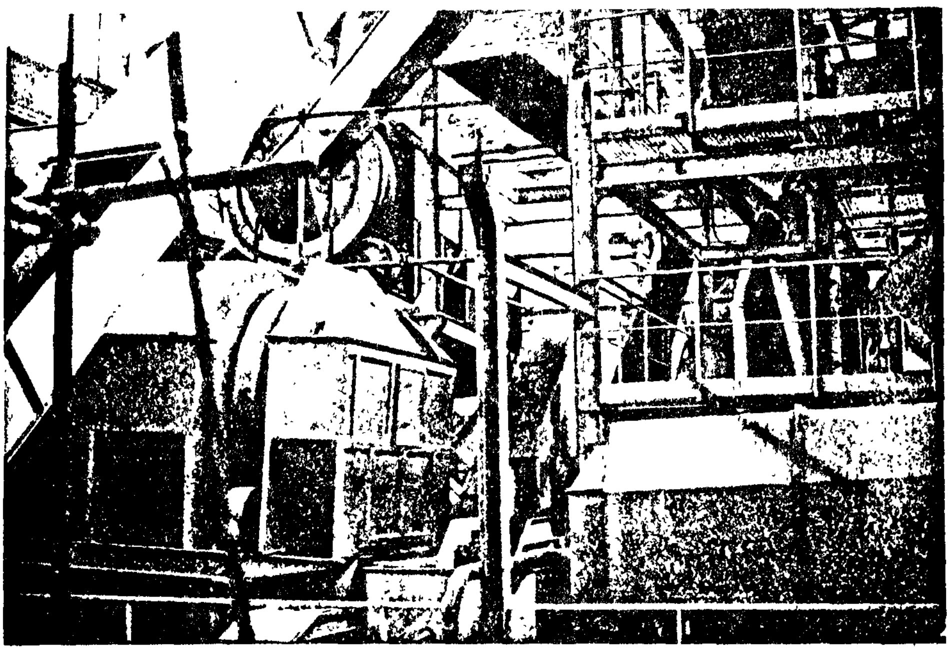
Separatore magnetico

(O/B magnet)



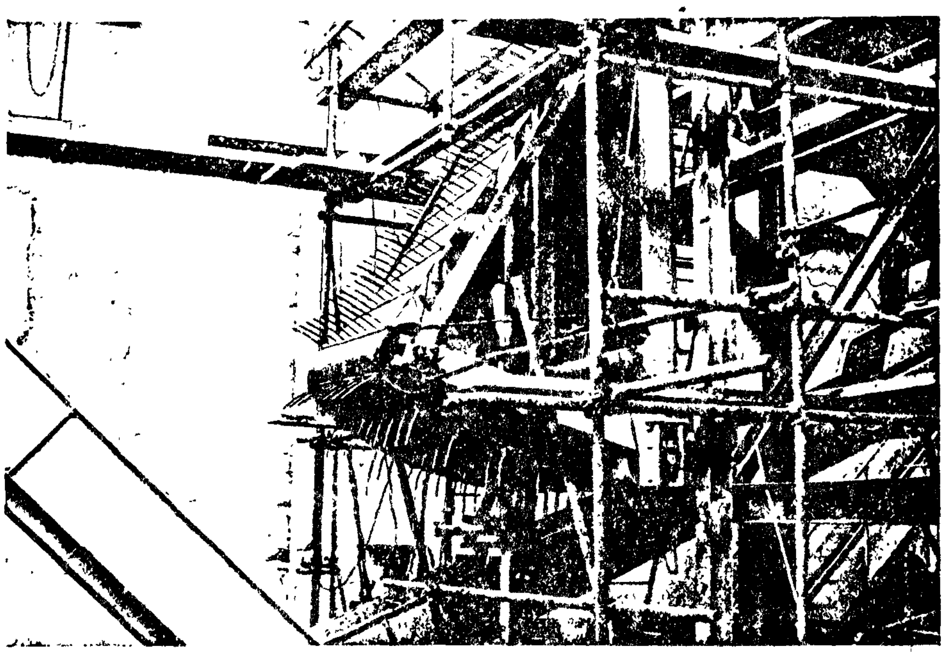
2° e 3° separatore volumetrico

(Trommels)



Nastro separatore stracci

(Ragger)



ENCLOSE I - PLANT FOR THE DISPOSAL AND TRANSFORMATION OF URBAN SOLID WASTE MATERIALS *

The City of Perugia on the occasion of the license renewal for the 'refuse gathering and disposal service' with the 'A. Cecchini & Co.' firm, has included in the specification of the contract the obligation of modernizing the Ponte Rio plant.

In order to select a disposal system the City had long discussions and made a precise examination of the most common methods used in this case, as follows:

a) system of integral incineration with or without heat recovery;

b) system of transformation in compost with or without addition;

c) controlled dump.

They also examined the 'recycling system' suggested by the A. Cecchini & Co. firm.

Chosen system

The recycling system suggested by the A. Cecchini & Co. firm has been selected from among the others. As a matter of fact, the above system has been considered as the ideal system to satisfy the complete disposal of solid urban waste.
Moreover, the projected and realized plant answers the double purpose of disposing the waste through the described processing as well as through an integral incineration. The furnace has been designed to incinerate the whole amount of refuse.

The building of the plant, together with the workshop, started on the 23rd of July 1969 and finished on the 31st of December 1972. Both the technological and the building works have been carried out by the 'A. Cecchini & Co.' firm.

For the City of Perugia the direction of the said works has been executed by:

- the ing. Capo Comunale (dott. ing. Silvestro Aluigi)for the building section;
- the Capo Sezione Tecnologia (geom. Renato Moroni) for the technological section.

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* from a report of Perugia City - September 1975

Description of refuse disposal plant

The refuse disposal plant of Perugia had a working capacity of 100 tons during twelve hours of activity, now increased to 220 t/d.

It is divided into the following main sections:

1. Reception and deposit of the waste material
2. Conveyance to the operating plant of the waste material
3. Preparation of the waste material
4. Mechanical sorting
5. Treatment of large organic materials
6. Paper treatment
7. Treatment of ferrous materials
8. Treatment of small organic materials
9. Incineration of non-reusable materials.

1. Reception and deposit of the waste material

The motor vehicles for the refuse collection and trans port, after having collected the materials, head for the plant, (which is km 3 from the town centre), where there are: the disposal plant; the offices; the weighing machine; the sanitary services; the dressing-rooms; the lining-room; the garage; the workshop; the body shop; the service station; the watchman's house; and a large green area.

Each vehicle is weighed by an automatic platform balance which releases a card indicating the weight. In addition to an up-to-date statistic of the daily and seasonal quantity of the waste material, the weighing machine is useful to predict the total disposal work capacity regarding the amount, as well as the weighing and the statistic of the various materials obtained from processing the refuse.

After this operation, the vehicles dump the waste into a storage pit which is large enough to contain the waste of about three days. This is done in order to face eventual break-downs of the plant or extraordinary accumulations of waste materials.

The non-reusable materials, already processed, and ready for incineration, are thrown into another pit, separated from the first one, but drawn up in the same line. Between the two pits there is a conveyor that feeds the processing line and on which certain devices are situated which break the refuse containers (plastic bags, etc.).

This is a way to solve all the needs to convey the refuse either to the processing or to the incineration areas as well as to send a part of non-recyclable waste directly to the incinerator.

There is also a third emergency pit in which to discharge a special kind of waste materials that cannot be processed nor incinerated.

2. Conveyance of the waste materials to the operating plant

The storage pits, as well as the conveyor, are served by a bridge crane equipped with an octopus-type crane which feeds the processing line, the furnace, and even motor vehicles if the pits must be emptied.

3. Preparation of the waste materials

The plastic bags hygienically and quickly solved the problem concerning the temporary deposit and collection of urban waste. But the bags have also caused many problems concerning the waste recycling. As a matter of fact, to start the process, the waste materials must be removed from the bags.

In fact the plant is equipped, in addition to the devices for the first breakage of the bags which are on the feeding conveyor, with a section that concludes the breakage and divides the waste materials from the bags. The broken bags were incinerated. Now they are reclaimed and sent to a plastic regeneration plant.

After this process the actual treatment of the waste materials can begin.

4. Mechanical selection

The selection of the various materials contained in the refuse is completely automatic.

The conveyor carries the refuse continuously, on a vibrating sieve with bars and steps, especially contrived for the treatment of solid waste material. This is done in order to make an initial volume selection of the materials. The larger parts are held back by the bars and headed to a conveyor with an electromagnet to reclaim the ferrous materials. The residue (such as wooden crates, pieces of wood, tyres, etc.) is sent on a conveyor to the incineration furnace to be destroyed.

After this first rough separation (which also allows the separation of the fine organic parts, which are sent directly to the 'compost'), follows a more accurate separation: of the ferrous materials through electromagnets situated along the recycling line; of the raw paper reclaimed with different processes of sifting and ventilation; of large organic parts with other various processes of sifting and ventilation to separate them from most broken pieces of glass, stones and non-ferrous metals and then be washed so as to free them from the soil and dust that can cling to their surface. Having effected this final operation the organic material is headed to a storage unit, before it is processed in the proper section.

5. Treatment of large organic parts

The organic material selected and prepared as explained above, is now processed in the following way:

- sterilization;
- homogenization;
- dehydration;
- depuration;
- pulverization;
- packaging.

It is a well-known fact that the solid urban waste materials contain high percentages (over 25%) of eatable substances. Instead of being incinerated with high expenses of combustion because of their high percentage of moisture, or meant to be 'compost' with other expenses and low profits, these materials can be used as animal feed, obtaining by so doing, good quantities of fundamental feeding, on condition that they are treated so as to destroy possible germs.

The plant has been created for this purpose. In fact the sterilization consists of passing the organic parts into autoclaves, where they are cooked at a temperature above 140°C and at a pressure of 4 atm. for over 2 hrs. A stirrer which is in the autoclave insures that the organic parts are mixed together. During this phase, apart from the destruction of the bacterial flora, homogenization and a predrying of the product are obtained.

The autoclaves are driven by the steam obtained from the heat recovered from the flue gases of the non--reusable material incineration.

The material then passes into a dehydrator, where a current of hot air, obtained from the steam, as explain ed above, lowers its moisture percentage under 10%, a limit which allows a perfect preservation of the product for an unlimited period.

The organic material, sterilized and dehydrated, still contains a very low percentage of foreign bodies (pieces of glass, wood, plastic, etc.), which various mechanisms that are united in one tower, through progressive phases of sifting, pneumatic separation and density separation are completely eliminated. A mill reduces to powder the product that is transformed by now into animal feed with an amount of nourishing power equal to that of maize.

The next step is a cube machine and a weighing carried out by an automatic balance, which is also a packer. This concludes the packaging and cycle of the large organic parts. The daily dry animal feed obtained with the waste materials of Perugia can reach five tons, sufficient to breed, in one year, over two thousand heads of cattle, bringing them from 80 to about 250 kg each.

6. Treatment of paper

It is a product that is constantly increasing because of the increment in packing and the large number of news-papers and magazines. For this reason the salvage of paper is of great importance for reclaiming the cellulose fibre. This is important not only for economic purposes, but also for ecology.

In fact by reclaiming this fibre there is no need to destroy too many trees, with benefit for the whole ecological life. It has been established that each ton of salvaged paper allows saving from 7 to 8 trees.

The percentage, in weight, of paper contained in the waste materials can reach 18%.

According to the type of selection (which is determined by the amount of waste materials to be processed) a reclamation that varies from 10% to 15% can be achieved.

The separation is carried out with various procedures of sifting and ventilation to eliminate the heavier bodies; but however accurate it may be, pieces of plastic with characteristics that are very similar to those of the paper, remain mixed with the parper.

Therefore to make the product marketable, this plastic must be eliminated. And this is the main operation which is carried out in the section 'treatment of peper' of the Perugia plant.

The amount of waste materials to be processed now is increased, because of other associations of nearby municipalities and a plant of paper pulping is installed. In this way the paper is transformed into fibre (paper pulp) not only bringing the depuration to a higher level, but also obtaining a higher percentage and a product which is more appreciated commercially.

7. Treatment of ferrous materials

These materials can be easily selected through the installation of a series of electromagnets along the waste operating cycle.

The ferrous materials are prevailingly composed of tins, bottle caps, small pieces of sheet metal and iron.

The said materials are mechanically put into a continuosly revolving furnace with the object of eliminating any residue and impurity, as well as the tinning, which is harmful for siderurgical furnaces.

After leaving the furnace, the so cleaned ferrous materials enter a hydraulic press that packs them in bales ready to be sent to the industries, which obtain from them the iron for constructions etc.

The recovered amount is, in wheight, about 2,50-3,50% of all the waste material.

The capacity of the Perugia plant was sufficient to obtain 600/700 tons of iron per year; now is doubling.

8. Treatment of fine organic materials

The material is composed of small organic parts mixed with mould.

The selection takes place through small holes of the sieve which accounts for the first volumetric separation of the refuse. This product offers the advantage of being withdrawn at the beginning of the cycle. It enables in this way the following treatments to eliminate most of the dust.

It is not mixed with solid inactive bodies, and, being very fine and gauged, it is transformed into a fertilizer, through a maturation in a specific locale in the plant.

It is a good additive to the manure, because it lacks paper and other harmful solid bodies; besides, in a short time, it becomes humus, so called sweet, which is the best from an agricultural point of view.

The compost, for its great capacity of inhibition towards water, keeps the soil fresh, and for its colloidal properties, reduces also the toughness of the clayey soils and modifies the excessive looseness of the sandy soils.

Its percentage is not over the 10% of the amount of waste, and so because of the small amount and its better quality compared to the 'compost' obtained from the entire treatment of the waste material, it is highly marketable. Many horticulturists use it during the fermentation period, for the preparation of the so called 'hot beds'.

9. Incineration of non-reusable materials

This product cannot be placed among the salvaged ones, as shown above, but it is a very important material for the cycle of treatment of the waste materials.

In fact it produces energy by being reclaimed as steam produced by the heat of the furnace gases. This steam is then used for the treatment of both animal feed and paper, and also for heating the yard premises.

We can say that the cycle of newly utilizing the waste materials is entirely over. Furthermore the incineration of this material, which is nearly free of organic parts, permits an easy combustion, leaving completely mineralized slugs, low pollutant gases with all the practical and ecological advantages that follow.

Should the amount of refuse to incinerate increase, a plant for the trituration of slugs would be advantageous so that they could be mixed with the 'compost' entichening by so doing its content of potassium.

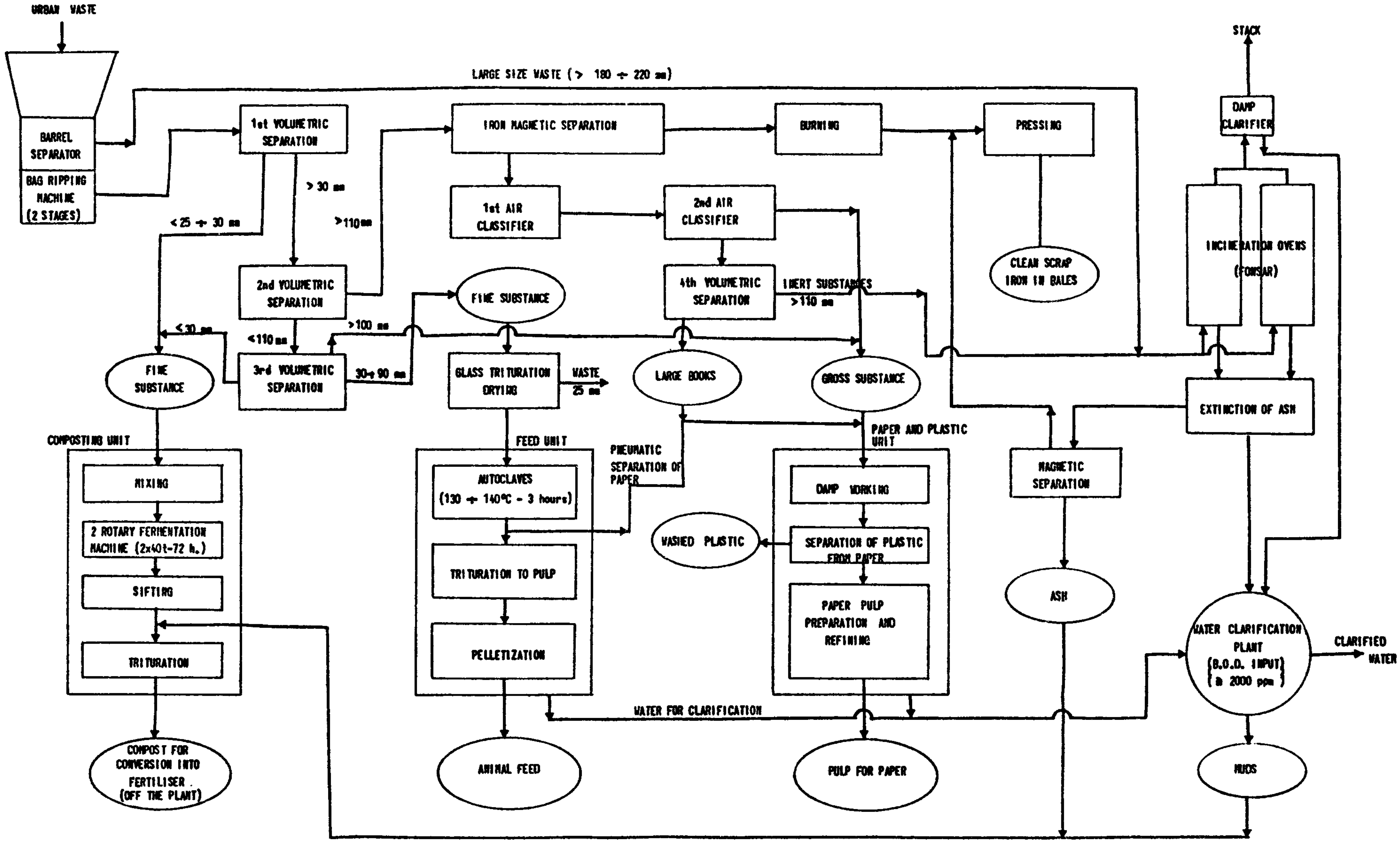
The two furnaces have a capacity of 65 tons each, sufficient to incinerate, if needed the total quantity of waste materials in the twenty four hours.

The whole plant for the transformation and the disposal of the waste material is equipped with installations to collect dust.

All the elctric boards of the various sections are assembled in a controlled power plant. Two synoptic luminous control boards (one for the whole treatment--of-waste process, the other for the section of treatment of the animal feed) enable one to follow the operating of the whole plant, and also to stop certain motors or communicate, by means of an interphonic circuit , with the different sections of treatment.

The whole plant can work automatically or manually and while in the first case the machinery is electrically linked, in the second it is independent.

PERUGIA URBAN WASTE RECYCLING PLANT



7 VISIT TO THE EX SARR PLANT SOUTH ROME (1st March 1977)

It should be noted that whereas previously the three Rome plants belonged to three different Companies (Cecchini S. p. A., Sorain and SARR), they now all belong to Sorain--Cecchini.

Sorain-Cecchini has granted the licence for its plant to an Anglo-Canadian company (Reed Paper Ltd.).

Enclosure II, taken from an official Sorain document, describes the recycling plant and also offers some information about Rome waste.

Treatment capacity is 600 t/day in this plant and 1,200 t/day in the other in East Rome.

Incoming waste consists on average (by weight) of:

- 38% organic matter;
- 12% fine organic matter;
- 18% paper;
- 3% ferrous material;
- 4% plastic;
- 4% glass;
- 21% unclassifiable inert matter.

The general destination of these materials is as follows:

- 41.7% is incinerated and produces steam;
- 24% is converted into compost;
- 16% is converted into animal feed;
- 13.5% is converted into paper pulp;
- 2.8% is recovered as iron;
- 2% is recovered as plastic in film.

The plastic can be used:

- to produce printed items;
- to refilm the material and make bags for urban waste (Sorain-Cecchini S. p. A. are setting up a plant for this purpose and it will be coming into operation in the next few months).

The 'compost' produced hitherto had nil commercial value; at present, an experimental plant (6 t/day) converts it into a dry, homogeneous pelletized glass-free product which is easier to transport and sack. This is called 'orfer' (organic fertilizer) and it contains 75% of organic substance - 1.7% N organic - 0.8% P_2O_5 - 0.7% K_2O and has a C/N of 10-14.

The animal feed consists of: 13-15% protein, 8-10% fats and lipides; ash 10%; its nutritional qualities are 60% those of maize and it is supplied to cattle farms.

Paper is recovered in pulp form and sold to paper mills at a price linked to that of the corrugated paper market.

Iron is purified by baking - in the oven it loses part of the tin present - and is pressed into bales. It is generally used for the production of constructional rod and its price obeys that of the scrap iron market.

The Municipality of Rome pays Sorain-Cecchini 5,000 lire/t (3,850 lire/t according to contract + recognition of charges). This price also includes 70% of plant depreciation. Recycling plant is depreciated over 8 years as regards its technological aspects and over 15 years for the civil works. The cost split is 35% civil works and 65% technological plant.

Sorain-Cecchini considers 400 t/day to be the minimum potential for a recycling plant with waste of similar composition to that of Rome. Where composition is different, this limit may rise or fall. Dimensions of this kind cost 20 million lire/t/day (i. e. a Rome Sud type plant of 600 t/day would cost 12 billion lire).

Sorain-Cecchini goes for plants with incinerators because this provides them with low cost steam that can be employed in some of the technological phases of the other processing cycles. Only in the case of countries where the cost of fuels is relatively important can different solutions for the non-selected fraction be contemplated.
In Italy where the ovens used are not over sophisticated, the cost of incinerators and of the steam production system is 30-40% of the cost of the technological part, i. e. 20-25% of the cost of the whole plant.

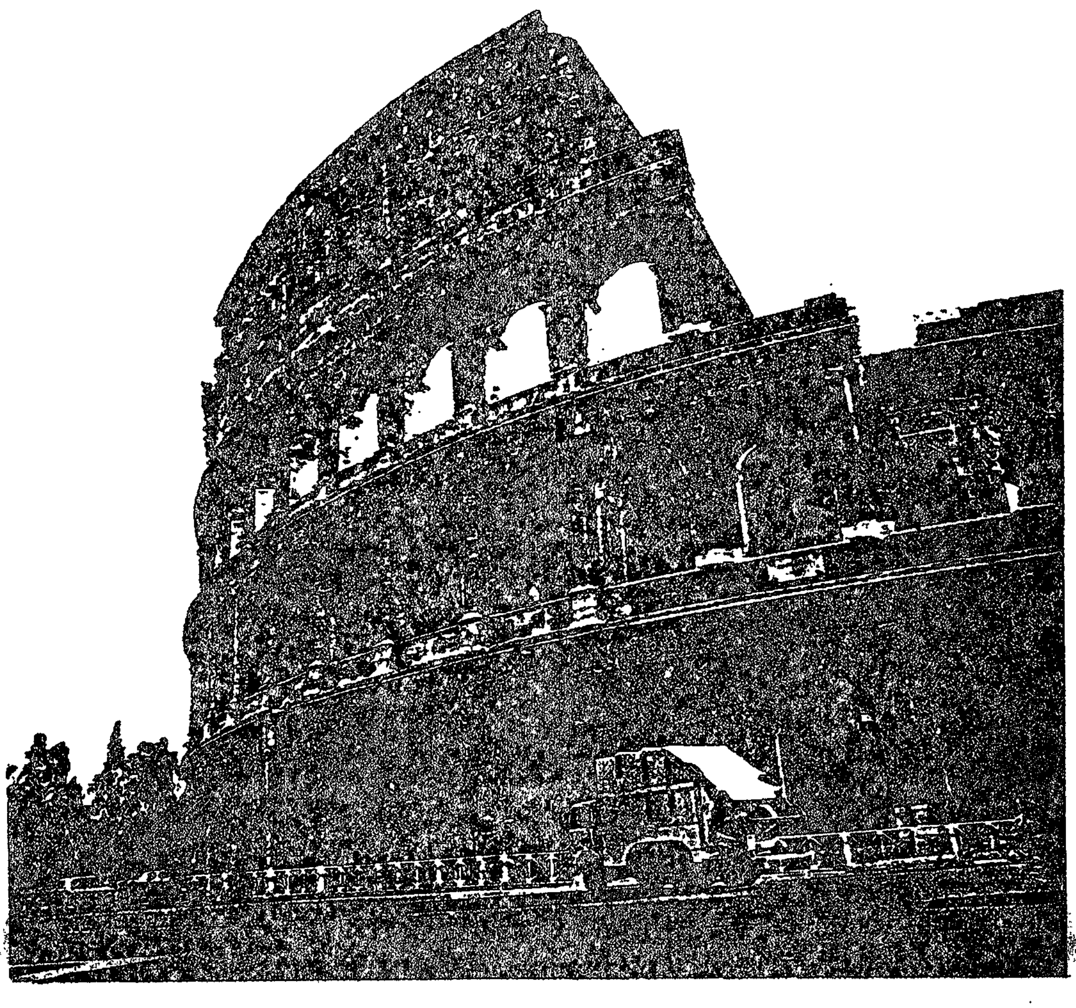
People employed at the Ponte Malnome plant (excluding those engaged in research and design) number 78 (1 manager + 10 office staff + 67 workers); 2 shifts of 8 hours each are worked in the automatic selection unit, 3 shifts in the incineration, paper pulp, feed etc. units; 20 people do not work shifts, 58 do.

Installed electric power amounts to 1,400 kW; energy consumption is about 27 kWh/t of waste, consumption of auxiliary fuel is 1 m^3 per day mainly used in the ferrous material annealing department; water consumption amounts to 1 m^3/t of waste; waste waters are entirely recycled.

ENCLOSE II

ROME

Rome has almost 3 million inhabitants, generating annually, approximately 750 thousand tons of refuse (see diagram). This volume of refuse is collected and processed every day of the year, including Sundays.



The city is divided into four sections, each of which is equipped with a disposal plant.
Three of these plants utilize SORAIN-CECCHINI recycling processes, and form part of our company. The fourth plant is a composting unit. Refuse is deposited in disposable plastic bags, usually suspended inside metal holders stored near the entrance of the buildings.

These are collected by municipal garbage trucks which are almost exclusively compacting systems which optimally compress the refuse without size reduction of the material.
Each truck makes two daily pickups and transports approximately 3,500 kgs. per pickup.

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00198 - ROMA
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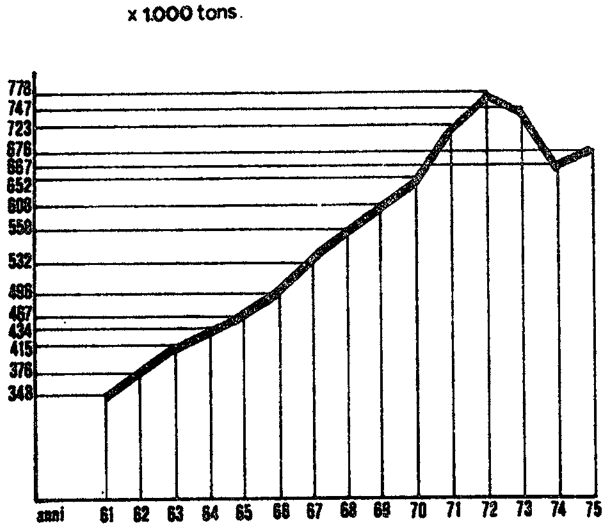
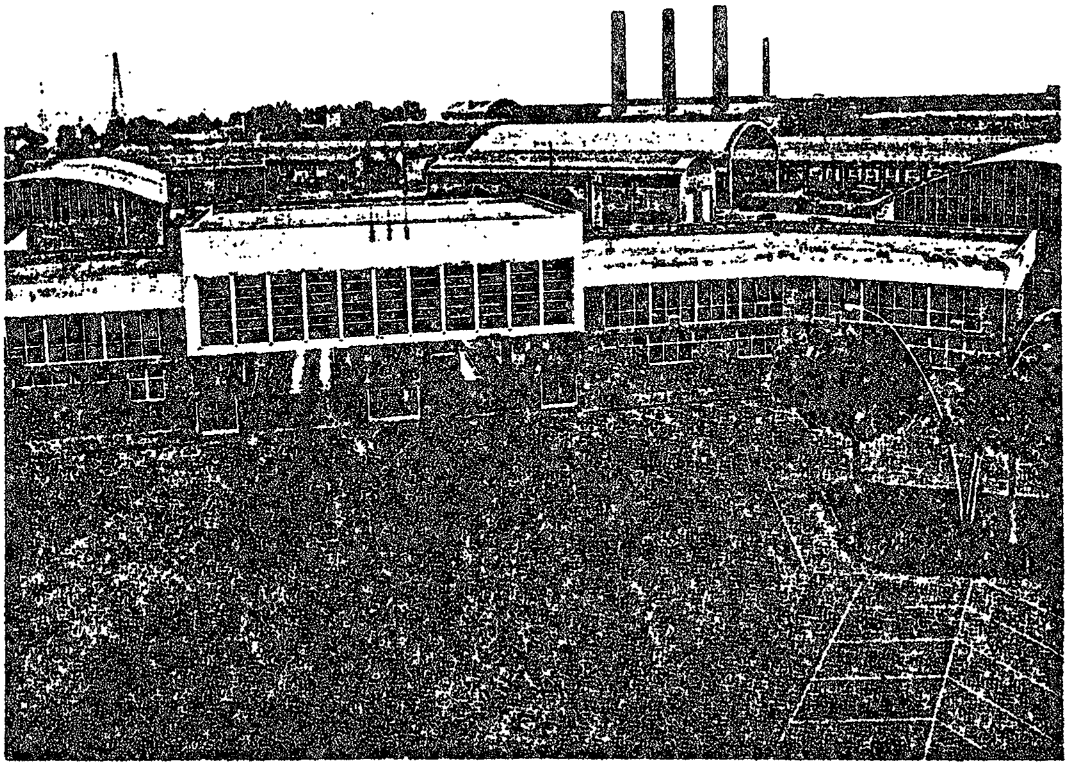
Telex: 58251 - SORAIN



QUANTITY OF REFUSE COLLECTED IN ROME

Apart from household refuse, waste from public markets, street sweepings, commercial and industrial wastes are collected.

The annual waste generated shown in the above diagram can be related to the general economic conditions prevailing.



ROME:
RECYCLING PLANTS

There are two recycling plants in Rome:

— a plant in the West of the city which has a processing capacity of 600 tons per day. Commencing operations in 1964, it occupies approximately 11,000 square meters, with a building volume of 110 thousand cubic meters.
— another in the East, which is capable of processing 1,200 tons per day, was constructed in 1967, covers an area of 25 thousand square meters and the building volume is 250 thousand cubic meters.

The processing capacity of these plants is based on two shifts per day. Some of the departments, such as incineration, animal feed production, and paper pulping operate continuously.

Flexibility has been provided in both plant layouts to allow for future expansion. The average refuse composition is shown overleaf in the diagram. The presence of considerable quantities of waste paper products, as well as organic materials (which usually constitute the major portion of the refuse), has caused

us to direct our recycling technology to both components.
As a result of several years experience, we are able to recycle refuse efficiently, regardless of its composition and even where one of the main components substantially exceeds the other. In addition to waste paper and organic materials, the SORAIN-CECCHINI process recovers ferrous

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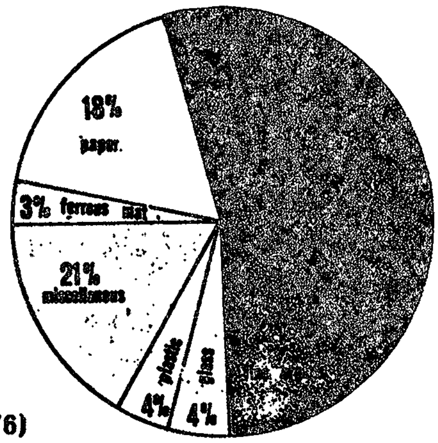
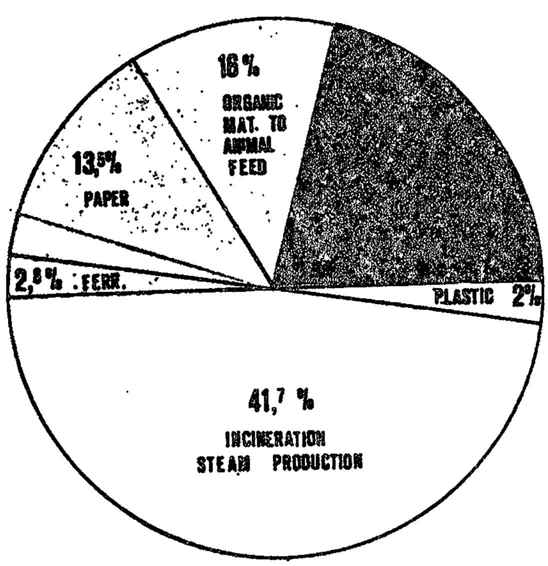


(1975-76)

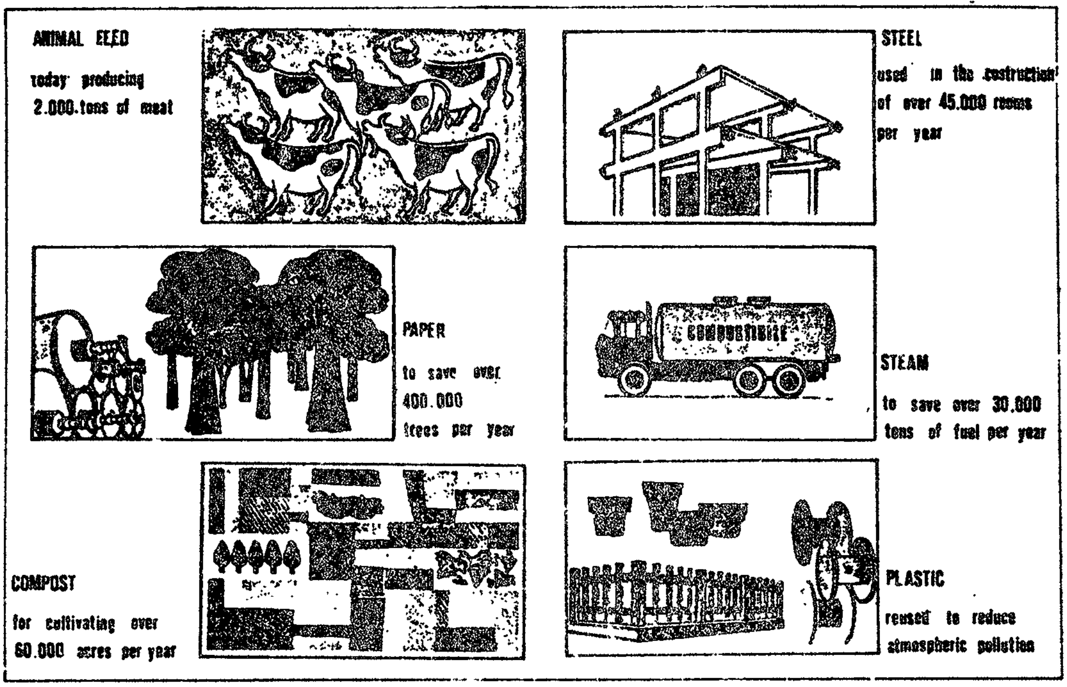
COMPOSITION OF MUNICIPAL SOLID WASTE

metals, plastic film and glass on a pilot plant basis. The percentages of reclaimed materials shown below, refer to average annual quantities. These percentages can vary according to seasonal factors.



MATERIALS RECOVERED IN PERCENTAGE

The percentage of non-reclaimables is converted to steam by incineration, and is used in plant, reducing fuel costs.



ECONOMY OF THE RECYCLING PROCESS

These recycling plants have economic, ecological and social benefits. The most obvious of these are shown in the illustration. Generally speaking, they can be summarized as follows:

ECONOMIC RESULTS

— reduced costs in the disposal of urban solid waste for the local authority and therefore for the individual citizen; depending on the composition of refuse, the saving is of the order of 30%, or in favourable circumstances, even up to 100% when compared with other conventional systems of waste disposal.

— an improvement in the balance of payments. In the case of Italy, we suffer from a serious deficiency of precisely those products which are salvageable from refuse: paper, ferrous metal, animal feed, oil (plastic).

— substantial energy savings by exploiting the heat potential of the nonreclaimables both for in-plant use (sterilization, reclamation, drying processes) as well as for other uses (steam for neighbouring industries, provision of hot water for local housing, electrical power, etc.).

ECOLOGICAL EFFECTS

— conservation of natural resources such as oil, timber, minerals etc.
— diminished ground and air pollution compared with other systems of disposal (sanitary landfill, total incineration etc.) and pollution of water sources.

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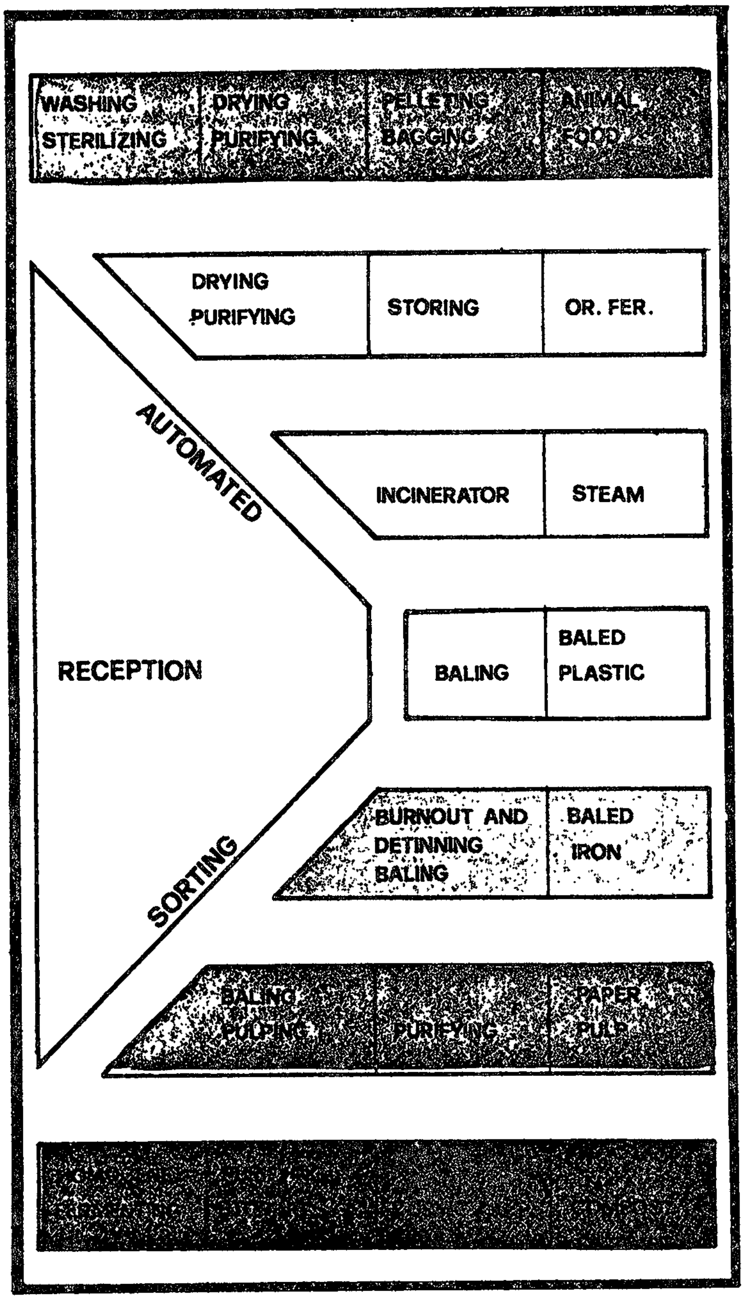
FLOWSHEET



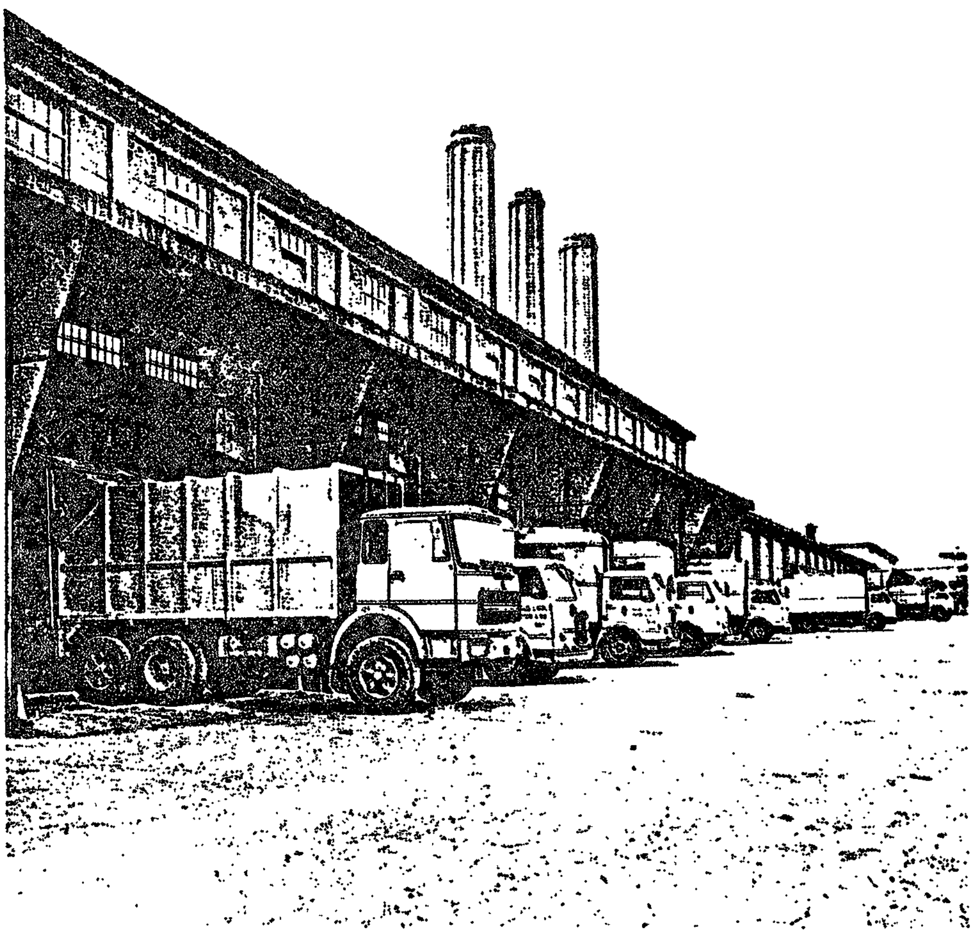
SOCIAL EFFECTS

— the creation of jobs, both directly and indirectly, to a much greater extent than other systems, the costs of which are already taken into account in the overall budget.
— research, development and disposal commercialization of new and original technology, useful outside the immediate field of solid urban waste disposal.

RECEPTION OF THE SOLID WASTE

On arrival at our plants, refuse trucks can unload at several points:

— directly onto automatic conveyors of the primary selection lines.



— into side receiving pits.

— into the receiving pits of the incinerators (for that portion of the waste to be incinerated immediately).

— into the receiving pits of the composting section (for that portion of the waste collected in food markets or for the street sweepings suitable only for composting).

All of the receiving pits are equipped with overhead cranes and electro-hydraulic grapples to move the refuse. The receiving pits are capable of receiving and storing up to two day's refuse, thus allowing for plant shutdowns over one day holidays and necessary large scale repairs.

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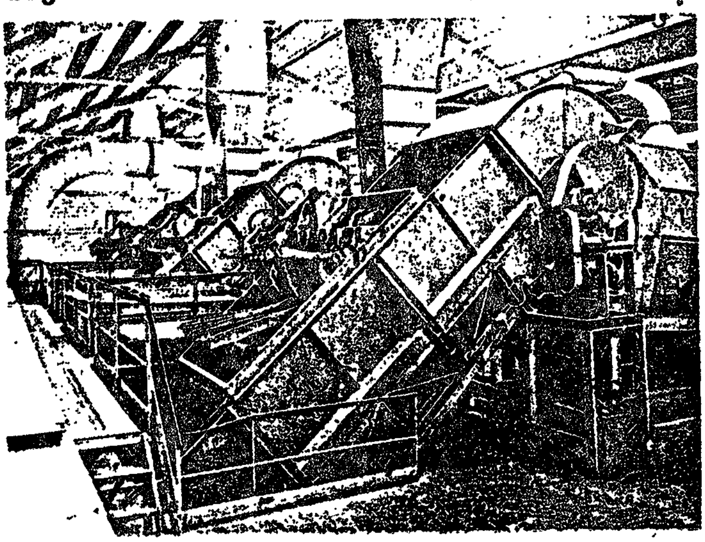
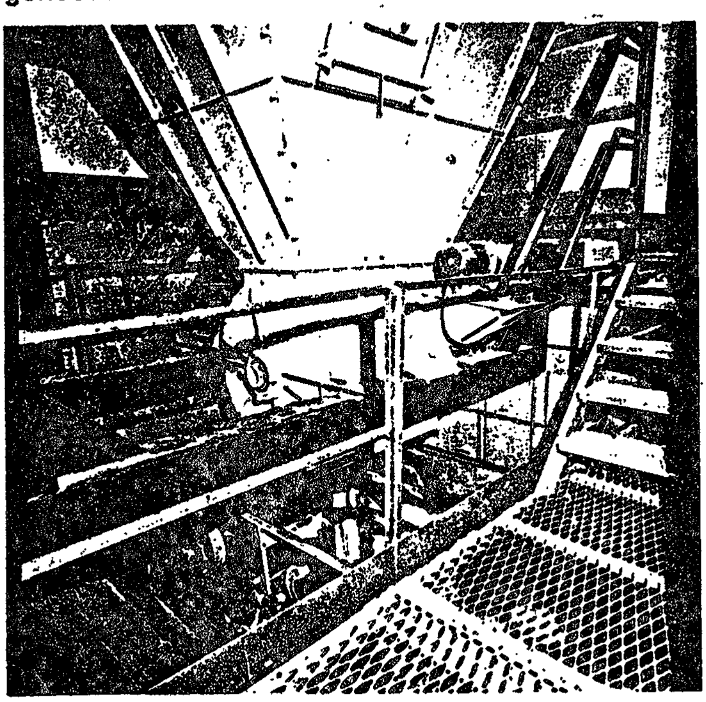
The primary selection lines are of two technically similar types, with a capacity of either 12 tons per hour, or of 20 tons per hour, and differ only in their rated capacity. The waste is fed to the plant by conveyors with a special feed mechanism which maintains a constant flow of refuse and prevents bulky items, eg: refrigerators, mattresses, etc. from entering the system.
Plastic bags are then torn open and emptied. The bags are then removed, since they would interfere



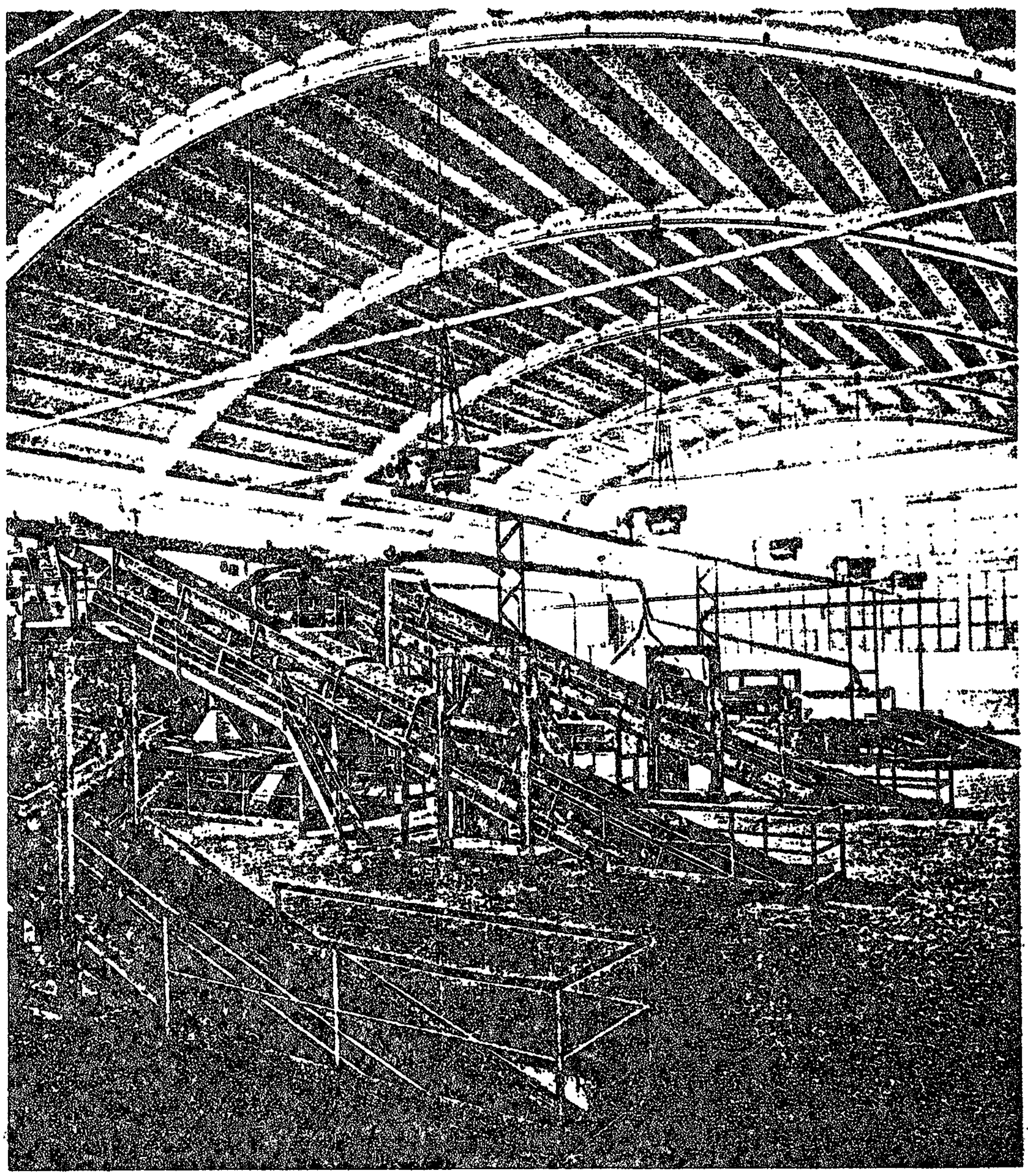
with subsequent automatic dry selection sections. The operations of feeding at constant rates, elimination of bulky items, opening and emptying of the bags, are essential to the later selection processes, because only by processing a homogeneous loose waste at constant flow, can re-



covery with satisfactory results of quality and quantity be obtained.

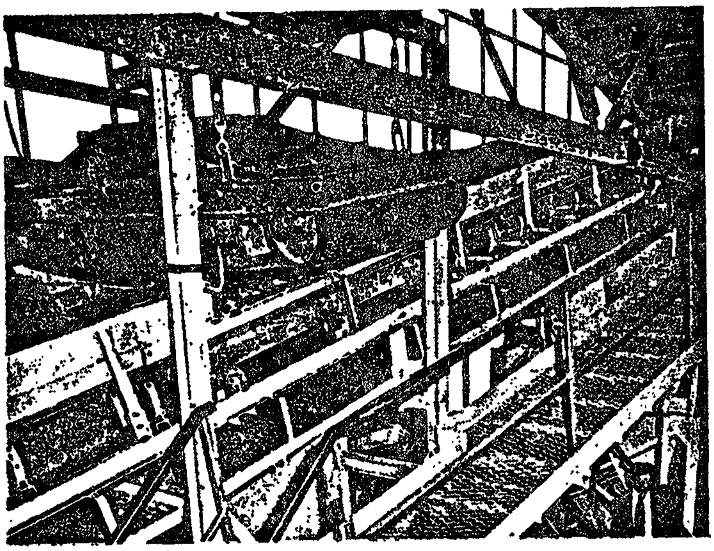
AUTOMATIC SELECTION

Once the bags have been torn open and emptied, the automatic selection process can begin. Each selection line is independent and modular (12 or 20 tons per hour). This guarantees efficient functioning of the system in that maintenance and unexpected breakdowns only affect a fraction of total capacity.



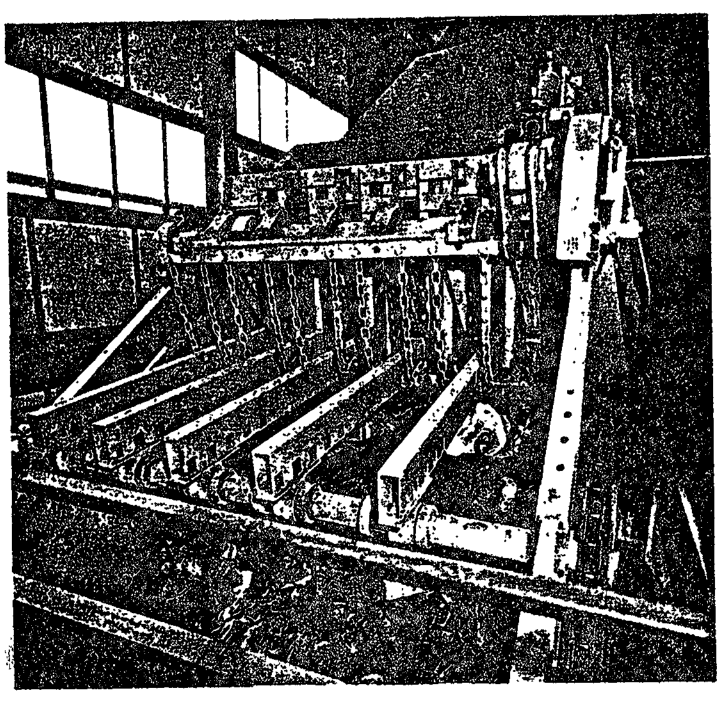
The machines which segregate the different materials make use of those characteristics which distinguish one material from another, both their physical properties; weight, fragility, electromagnetic qualities, flexibility, resilience etc., as well as

their static ones; size, shape, etc. To exploit these characteristics, the machines have been designed and manufactured specifically for this application, although the basic principles have been employed in other industries for a long time.
At present, in the plants of Rome, the selection process has achieved levels of commercial production for:



— paper and cardboard
— animal feed
— organic material for compost
— ferrous metals.

As far as plastic film and glass are concerned, pilot plant recovery is being achieved.



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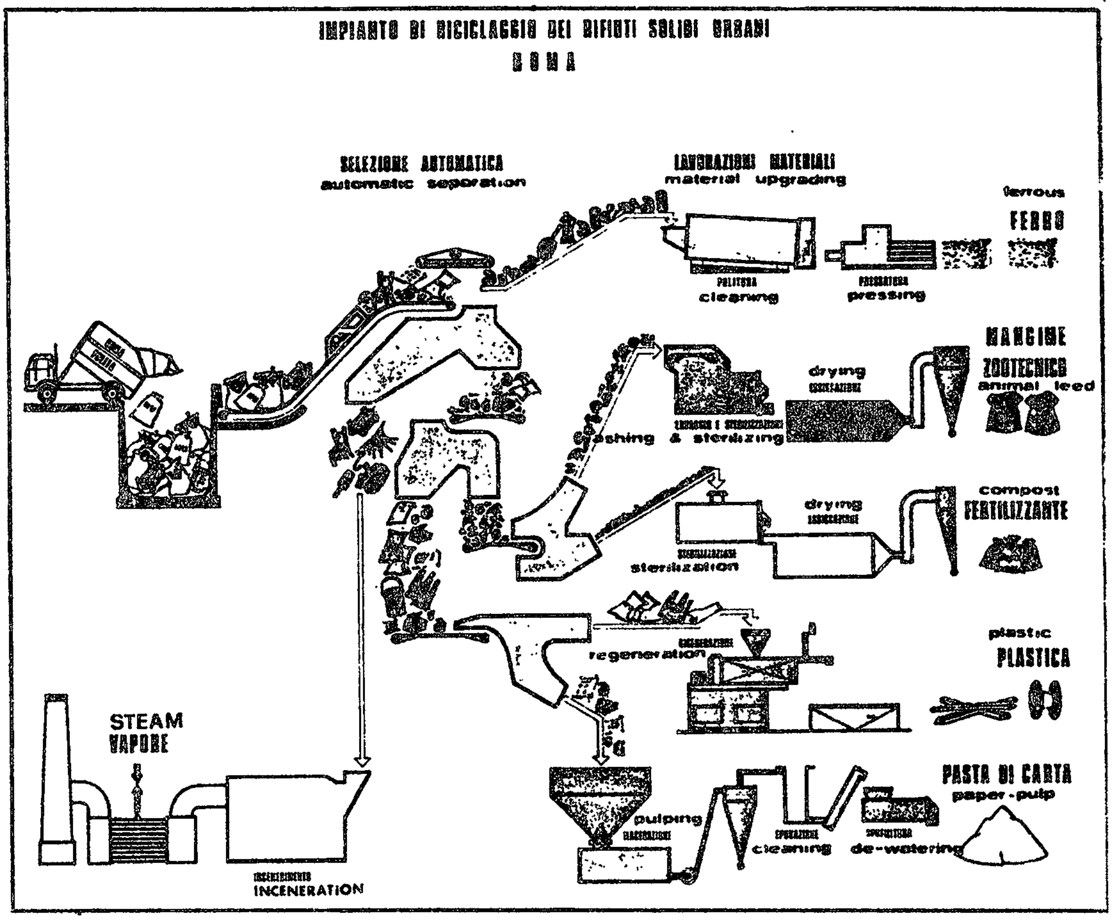


PROCESS FLOW CHART

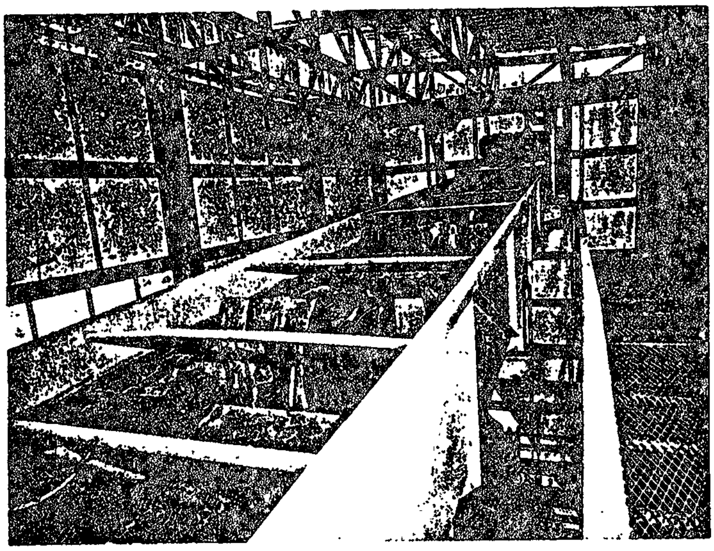
Six products emerge from the automatic selection lines:

— bales of paper
— coarse organics, suitable for transformation into animal feed
— organic material destined for use as compost
— ferrous metals
— bales of plastic
— non-reclaimables for incineration.

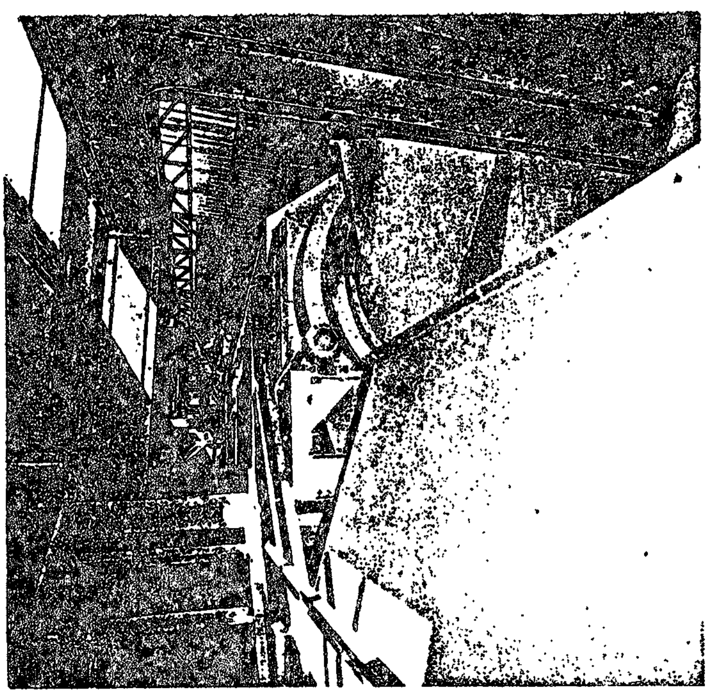
The "products" like paper, organic material, ferrous, etc. have clear commercial potential, but given that they still contain impurities, they are not of immediate commercial use in this condition. It is the function of other satellite plants to further remove impurities so that the materials are acceptable to industry and agriculture.

The percentages of materials recovered, should be considered average values; the flexibility of the process in fact, permits by-passing where necessary, any product recovery where a market temporary does not exist, without impairing the ability to maintain a total disposal service.

By "non-reclaimable", we mean that portions of the refuse consisting of materials considered unsalvageable, or parts of those materials which during the selection phase were either not easy to recover, or were deliberately rejected. It should be remembered that as already stated, incineration of such non-reclaimables, disposes of them as a source of heat energy which services the



transformation processes. In that this heat substitutes for oil as a fuel, it has an economic value. Our installations are so designed that where desirable, steam can be converted to electricity. The required technology already exists on the



market and its application is made even more simple in our case, because the combustible material is both homogeneous and of constant quality.

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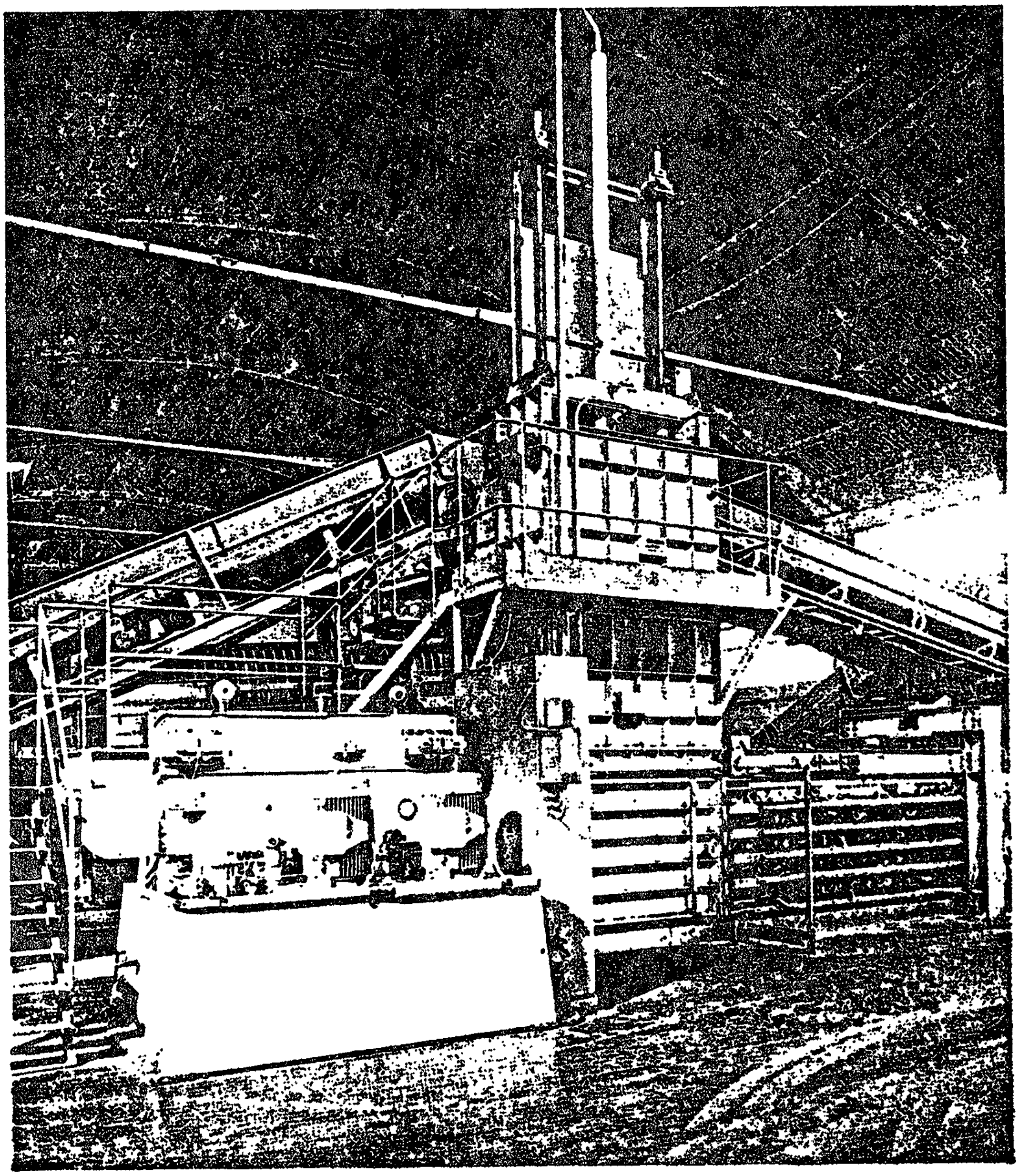
PAPER

Selected baled paper and cardboard cannot be commercially exploited until contaminants: rags, plastic, polystyrene etc. have been removed.



It was necessary, therefore, to develop techniques to remove them: soaking and wetting in a pulper, removing extraneous material, pressing and sterilization. The final product is a pulp containing 60% water. Clearly the most delicate and complicated part of the operation is the cleansing stage. The water used in this process is recycled.

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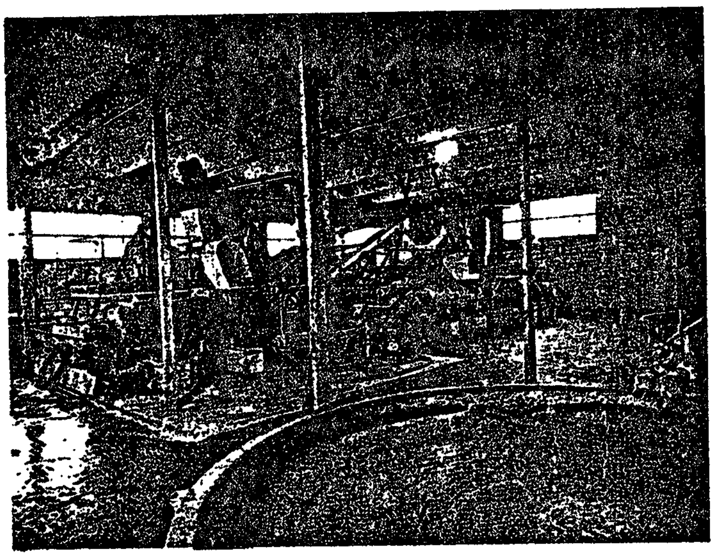
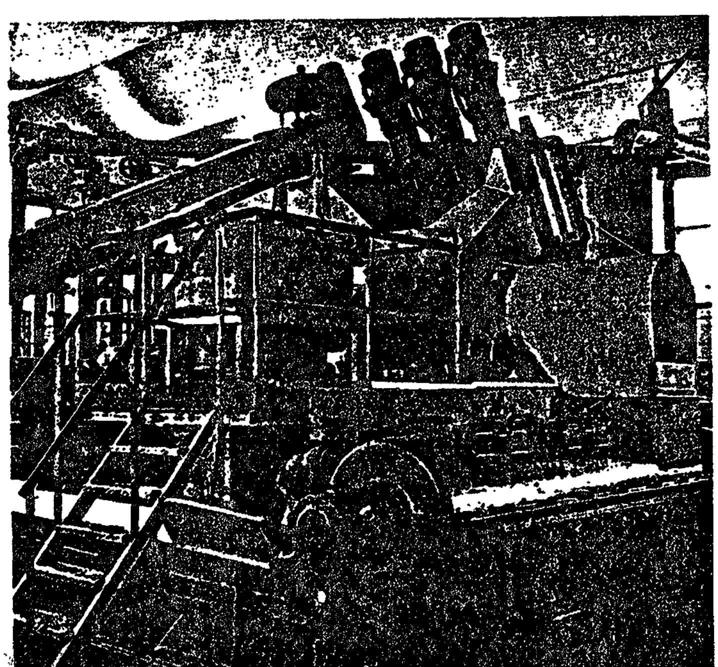
This is made possible because make-up water is required, which is shipped out in the pulp product. The resulting waste from the cleansing process is incinerated after having been dehydrated. The quality of the product has shown a consistency regardless of seasonal factors.
The need for an inventory of bales between the selection and pulping sections is due to:



— the pulping plants are considerably more efficient if pre-pressed rather than if loose material is fed into them, since the latter is more voluminous.



— the two operations can remain independent and thus it is possible to carry out selection on two shifts and pulping on a continuous basis.

PAPER-PULP
In the recycling plants of Rome, it is possible to produce approximately 200 tons of paper fibre per day (as received moisture basis).

This received volume is enough to make a significant contribution to paper mills.
The main purposes of the plants concerned with upgrading of paper recovered from waste are:
- elimination of contaminants of various kinds: plastic, polystyrene, heavy substances, glues, waxes, fat etc.
- to reach che quality standards demanded by the market.
- sterilization.
- reduction of effluent problems at the paper mills.
- reduction in the need to remove solid conta-

— consistent furnish for paper mills with consequent predictable processing conditions.

Even maintaining those quality standards already laid down and meeting public health requirements, it is still possible to carry out the process at different levels of quality taking into consideration, the respective final uses of the pulp.

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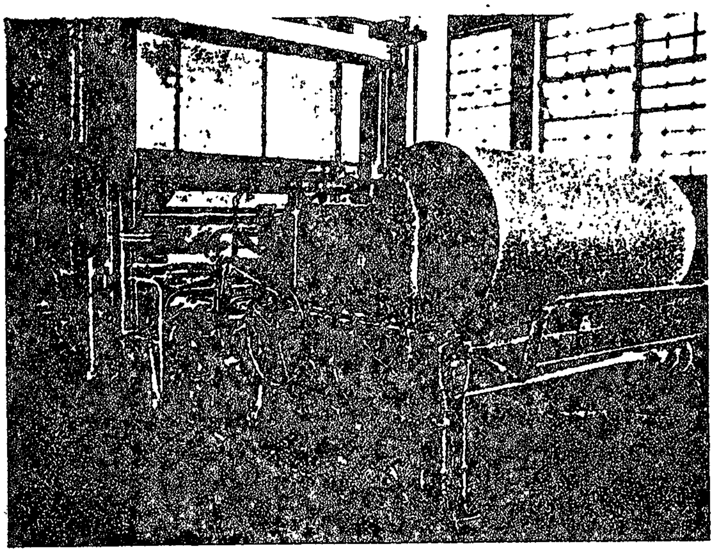
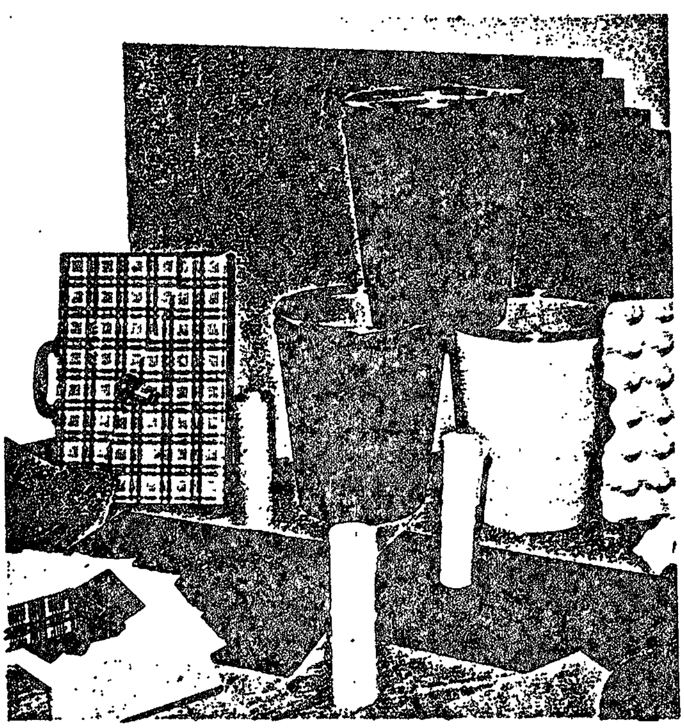
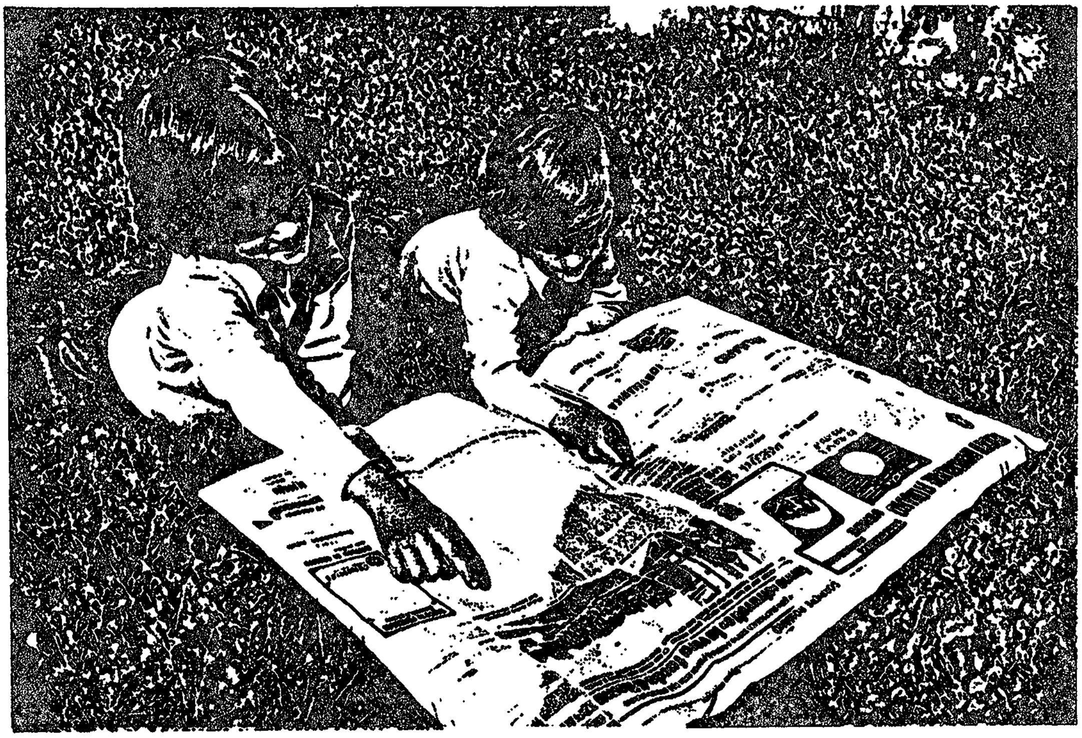


Where the highest quality is not required, such as in the manufacture of cardboard, wrapping papers, packaging cardboards and finished cardboards etc., special techniques are not necessary. The pulp, after removal of waxes, bitumens and fats, can be despatched to the paper mills, which



are equipped with the usual screening and cleaning equipment, which is usually part of the paper and cardboard manufacturing process.

PAPER-PULP
Paper pulp reclaimed from refuse can be used to substitute fibre obtained from trade mixed papers. Different techniques are applied where a superior quality of pulp is needed in order to substitute for wood pulp.



The recovered pulp can also be used to a certain extent, for products such as newsprint, rotogravure paper, creped toilet papers etc. To achieve this quality, sophisticated upgrading processes are necessary—de-inking and refining—resulting in significantly higher upgrading costs. These are, however, offset by a more favourable return in the market.

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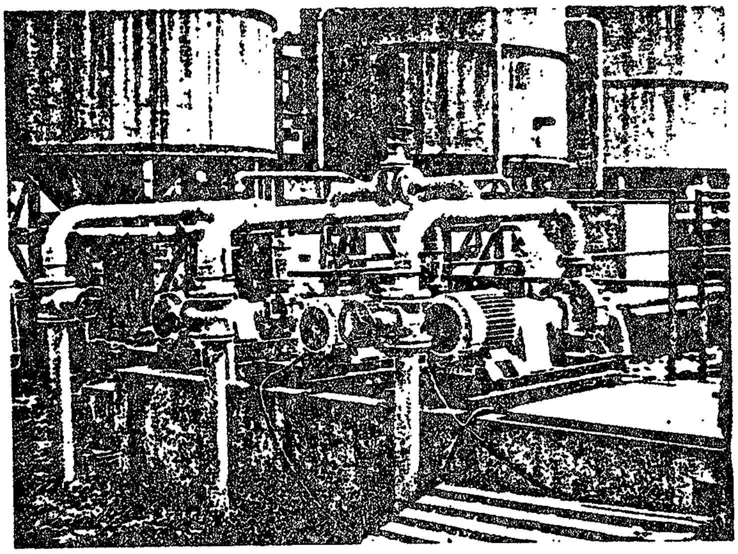
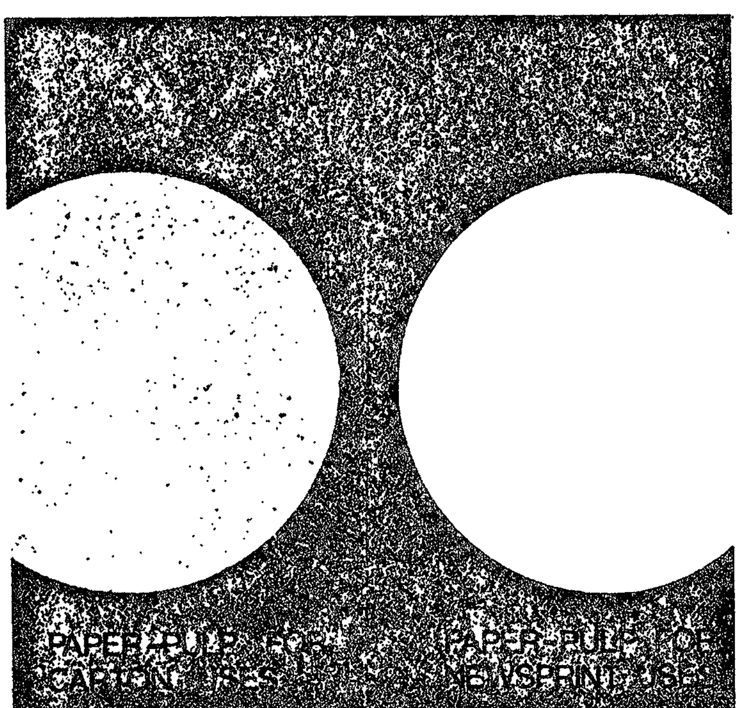
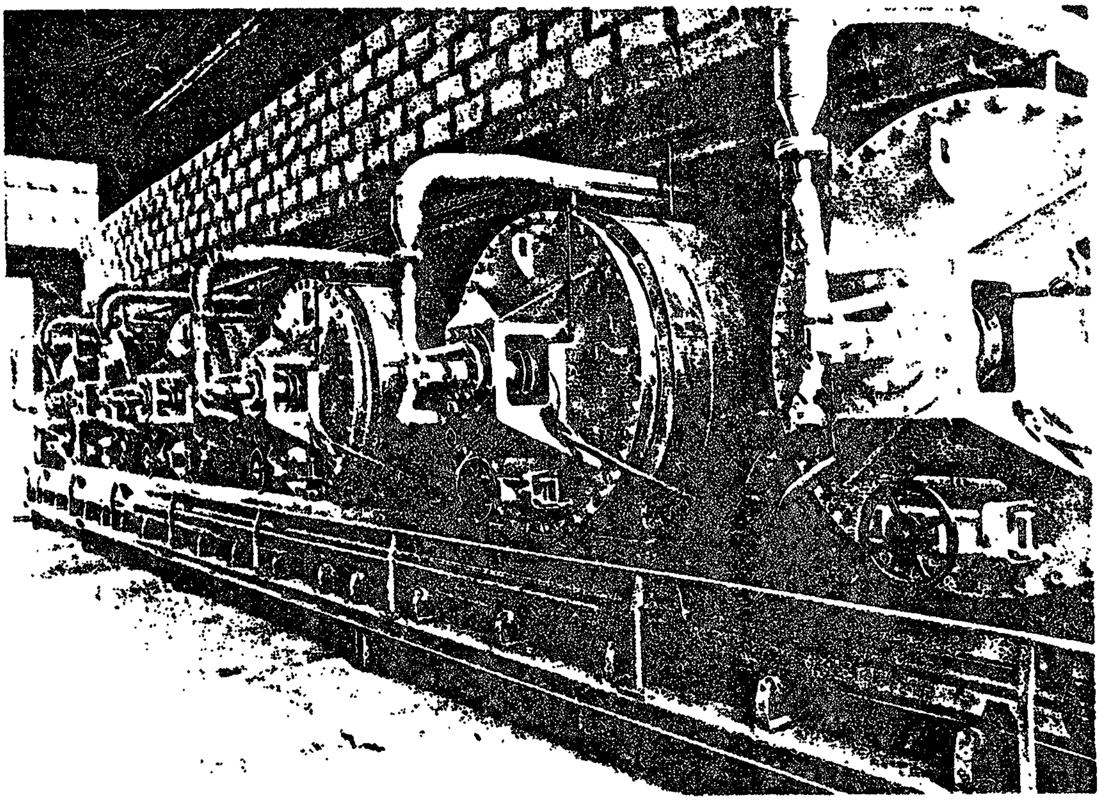
At the present time, plants do not exist capable of upgrading paper recovered from waste. whether manually, or through source separation into the above mentioned, de-inked pulp. However, after repeated experimentation in collaboration with other specialized institutions, our Group has carried out and brought to a successful conclusion research directed at the solution of this problem with encouraging results.



Plans are now underway for an industrial plant capable of producing 50 tons per day of "urban" pulp, already treated and ready for the uses men-



tioned. This will be in addition to the pulp presently produced for packaging papers.



ANIMAL FEED

Coarse organic matter obtained from refuse: fruit, vegetables and other food remnants is used to produce animal feed.

The process involved is particularly complex because of the high hygienic and veterinary standards required in the final product.

Briefly, the most important stages are:

— washing
— removal by floatation of coarse inorganic substances still present
— sterilization by means of autoclaves
— drying to 6-8% moisture content
— removal in various stages, of any small inorganic particles still remaining
— pulverizing
— pelletizing
— bagging

The product obtained has a nutritional value equivalent to 70% of corn meal, and contains 14 - 17% proteins and 7 - 9% fats.

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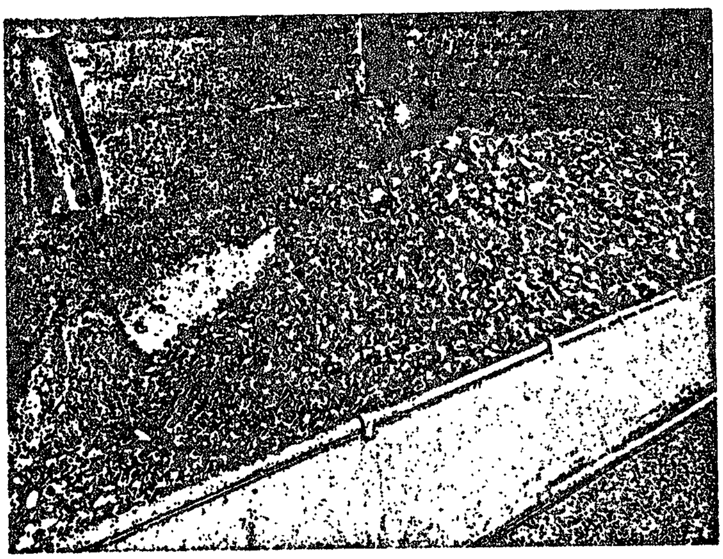
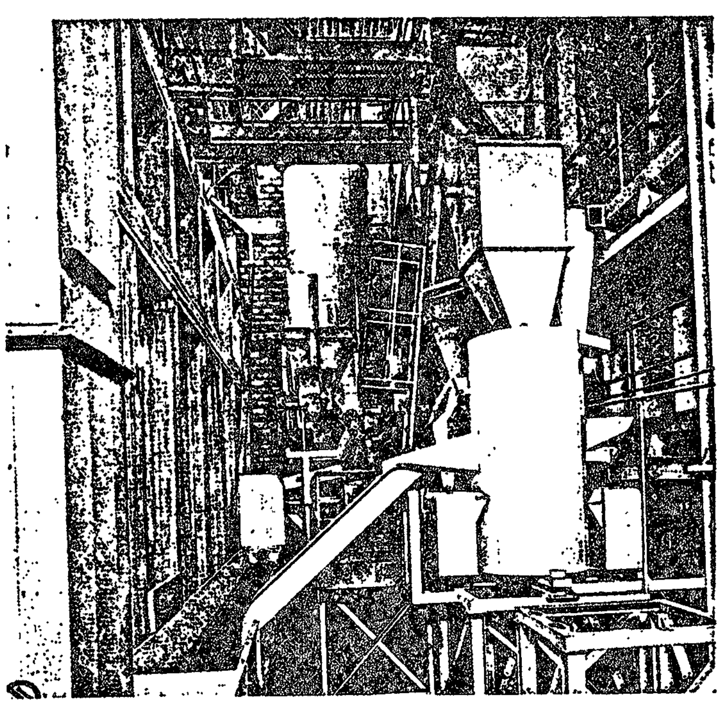
The sterilization and drying processes make use of the steam produced by the incinerator, where contaminants removed in this process are sent. The waters used for washing are purified in a plant which is an annex to the main installations. In six years of experience, there has been a consistency of quality in the product, and there have



been no marketing problems.
The most important and delicate stage of the process is sterilization through the use of modified autoclaves, where the material has to remain for a certain time at a specific pressure and



temperature to complete biological sterilization. Laboratory analyses maintain continuous quality control of the animal feed.

ANIMAL FEED

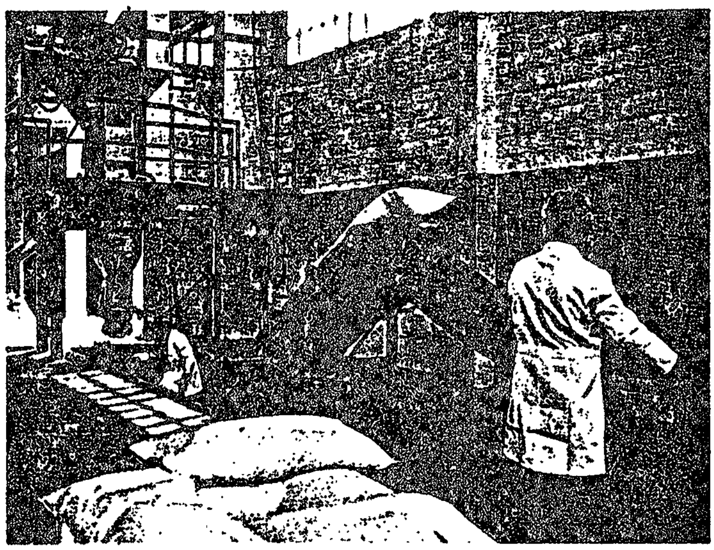
The animal feed obtained from the organic content of Rome's municipal solid waste is directly utilized by livestock breeders.

The percentage fed to the livestock varies depending on the type of animal, the purpose for which they are bred and the size of the individual operation.

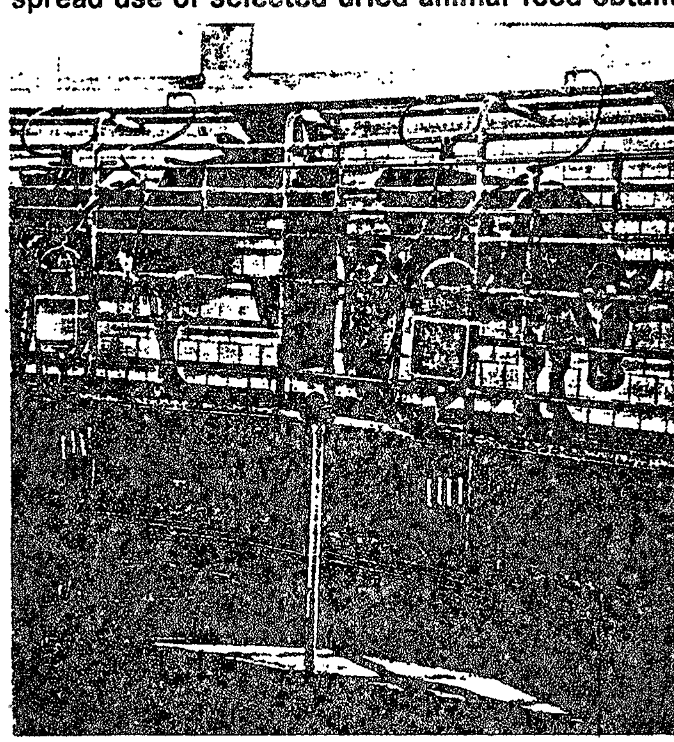
For many years now, because of the successful results obtained, this type of feed has been chiefly used with cattle, both for fattening and for milk production.

One of the fundamental characteristics of this feed is its appetizing smell of fruit and vegetables.

For cattle being fattened, the ratio of conversion is 100 to 15. That is, in order to obtain 15 kgs. of meat, 100 kgs. of this feed has to be given as a fraction of the total food intake.
If the large Italian centres alone (amounting to approximately 15 million inhabitants), were to recover the best organic content of their refuse, it would be possible to manufacture 100 thousand tons annually of animal feed, which would then



produce about 15 thousand tons of meat a year. The lower cost of production, considering it as a part of a disposal process, compared with that of other animal feed, and taking into account the relative nourishment potential, could justify wide-spread use of selected dried animal feed obtained



from refuse, particularly in those countries where it is necessary to import raw materials for feeding livestock.

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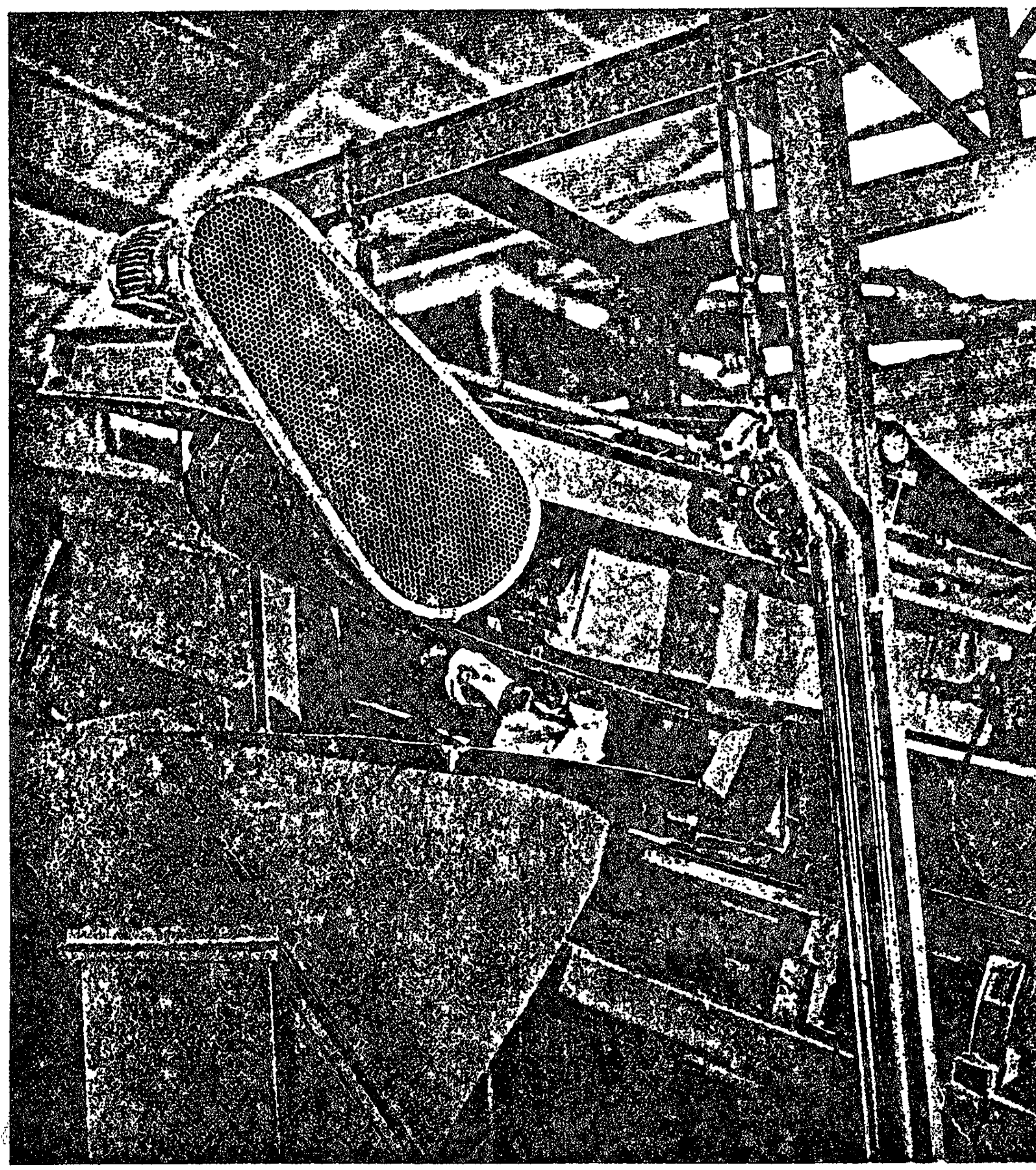
FERROUS METALS

The ferrous metals are extracted from the waste by means of electromagnets which function continuously. The separated materials contain the following impurities:

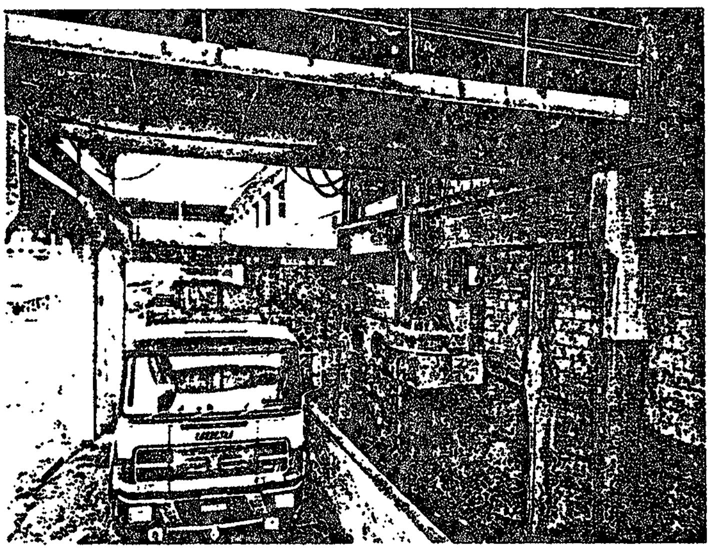
- external labels
- residual internal contaminants
- plastic, paper and rags caught up in the electromagnet selection process



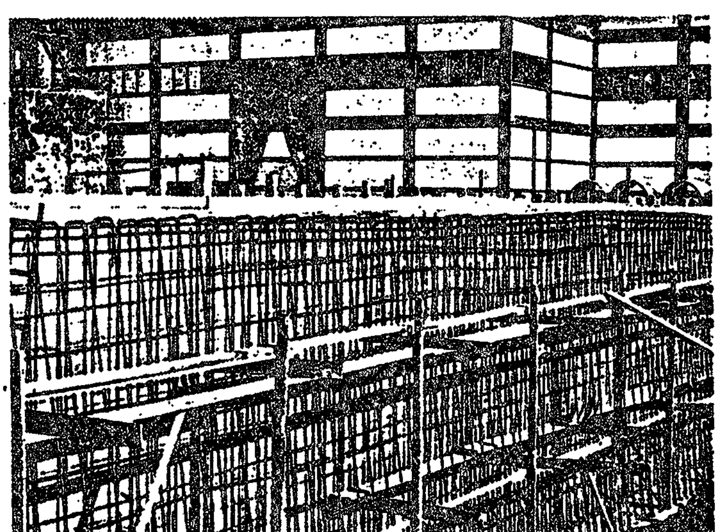
- small percentages of tin, undesirable to the steel mills.

In addition, ferrous metal recovered from refuse poses particular transport problems, due to its volume being made up of 80% cans.

In order to produce a marketable end-product, the SORAIN-CECCHINI plant provides controlled combustion of impurities in a rotary kiln which eliminates labels, remnants and other extraneous matter, and melts a good part of the tin. After emerging from the furnace, the material is subjected to a water cooling process and then enters



a hydraulic press which reduces the total volume. The resulting bales, measuring roughly 50 x 50 x 60 cm, and weighing 150 kgs., are stored in hoppers from which they are loaded into trucks by means of a magnetic disc. The greatest use of the metal is in the production of iron rods for reinforced concrete construction.



Its most important quality is its pliability, and it improves the priming of fusion processes, thus reducing the wear on the furnace.

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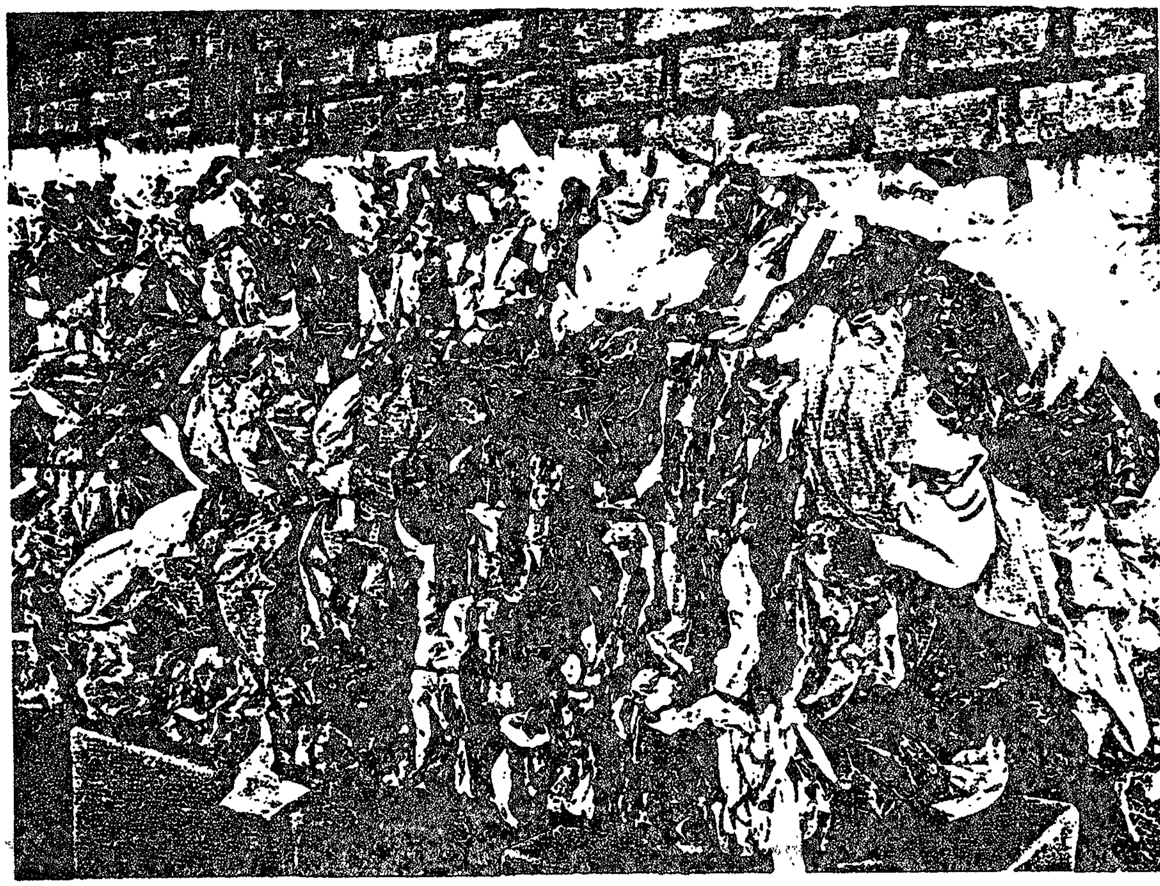

PLASTIC FILM

Salvaged from Rome's solid waste, is a significant percentage of plastic film, made up of low density polyethylene, which is the material used in manufacture of refuse and other plastic bags for commercial use. Other types of plastic, found in smaller quantities, are not recovered. The plastic film, salvaged and baled, is at present sold to the injection and compression moulding plastic industry. This is because at the moment, no other more refined reprocessing is yet available.

After numerous tests made over the past five years in an installation specially designed for obtaining data regarding the upgrading of plastics in general, SORAIN-CECCHINI is planning shortly to build a completely automatic industrial plant, equipped for all the phases of upgrading, including dry and wet processes.

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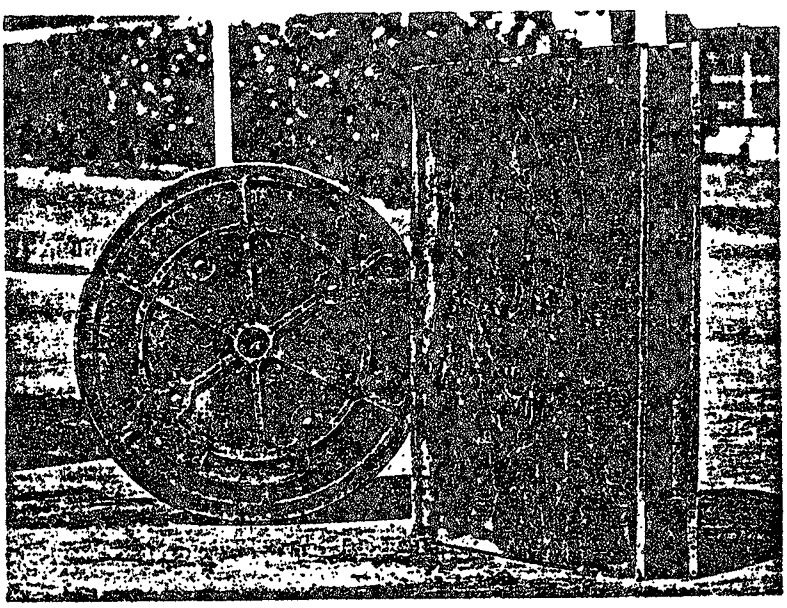
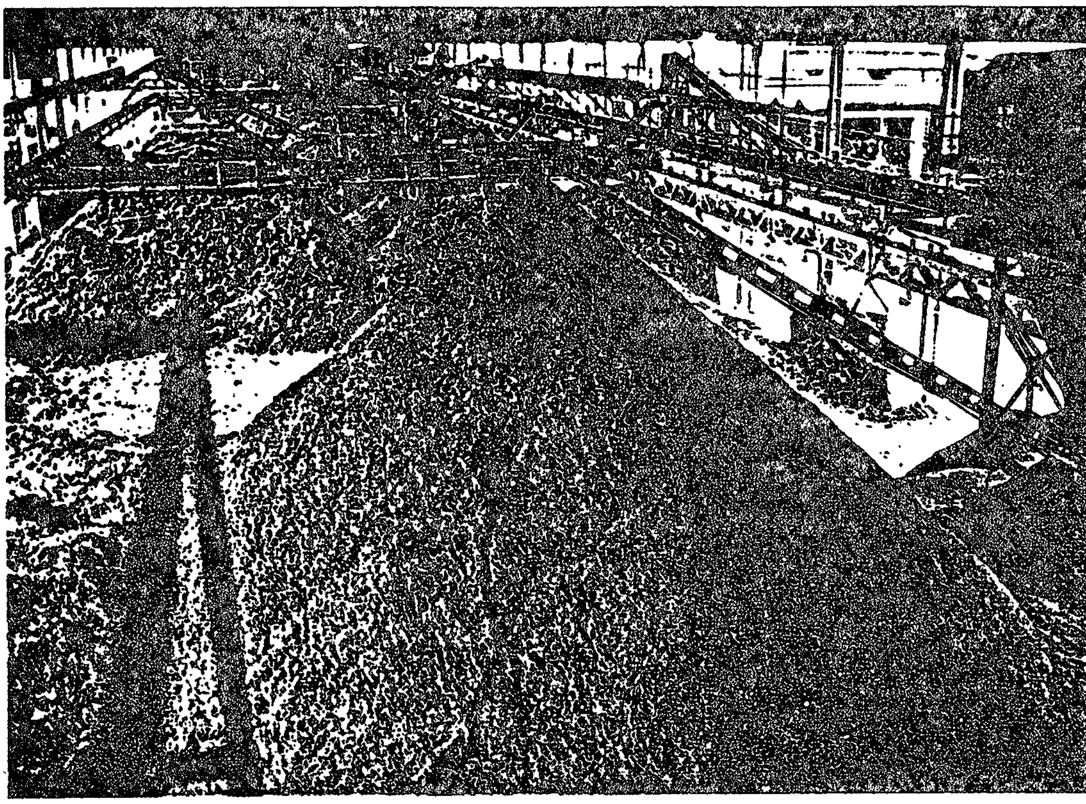
The aim is to convert the plastic film recovered from solid urban waste to granules. The granules will have sufficient purity to allow blending up to 50% with virgin resin for the production of plastic film.



Other types of plastic could be reutilized, but research is still in its initial stages, and the difficulties involved are considerable.
In Italy, and in Rome particularly, these form only 20% of the total plastic in the refuse stream, therefore in terms of quantity, the problem is almost negligible.



COMPOST

Three types of refuse reach the composting section:

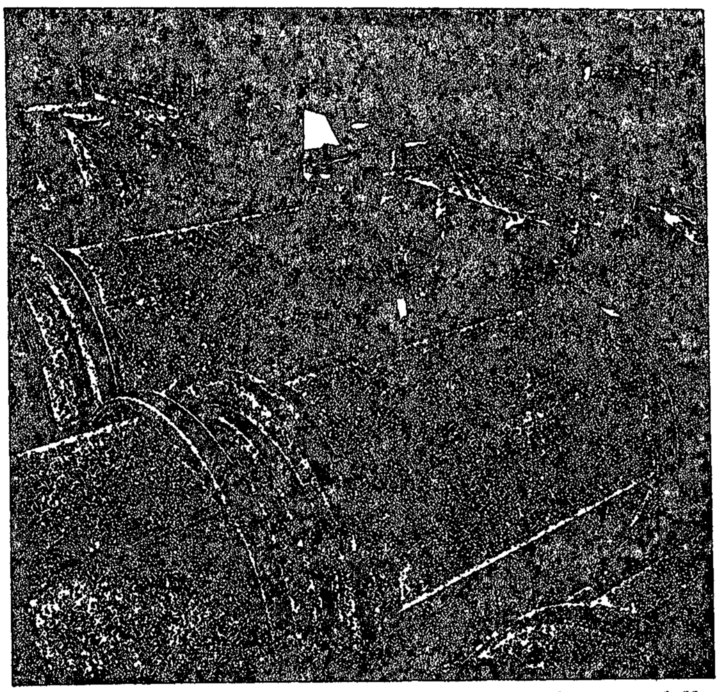
1) that which has not been sent to recovery lines because of its composition: street waste, refuse from the central and local food markets;
2) that collected by vehicles equipped with a shredding mechanism, which, therefore, is indiscriminately mixed and already in a state of deterioration;
3) that which the selection process has assigned to compost.

This section is made up of a series of prefermentor homogenizers operating slowly, in a continuous unit operation.

In these machines, only the organic parts are broken up and begin a process of aerobic fermentation. When it has left the prefermentator homogenizer, the material is screened: that part composed of smaller pieces is sent to the maturing yard, while the coarse fraction goes to the incinerators. After a certain period of maturing, the material, which has a high organic content, is then sold to farmers.

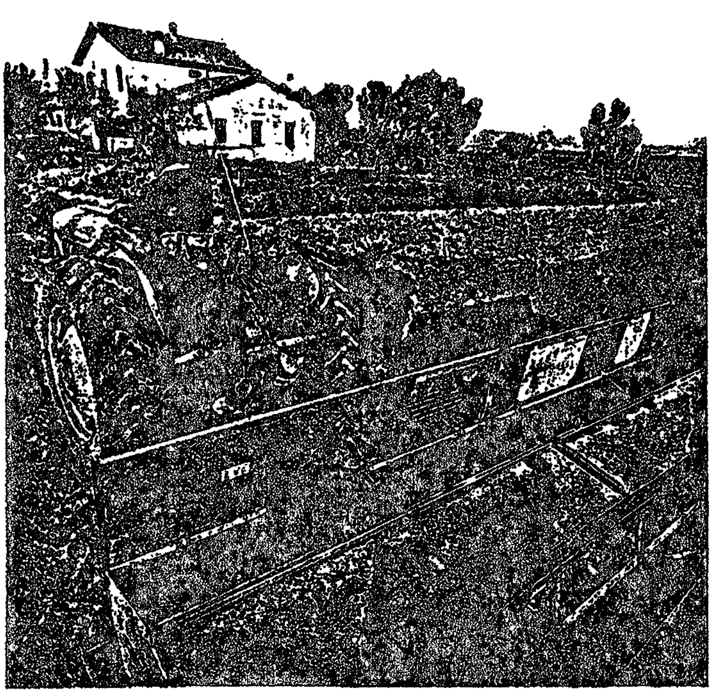
Due to the seasonal nature of compost application, large storage areas are required. The compost obtained through prefermentation in the homogenizors has obvious drawbacks:

— the presence of other materials, such as glass, china, plastic, wood etc.



— the characteristic odour which makes it difficult to use in populated areas.

— cost of transportation, storage and distribution resulting from the low ratio of usable organic content to total weight (1:2.5 including moisture).



Other disadvantages usually encountered in producing compost have been eliminated due to the methods used in our process of recycling.

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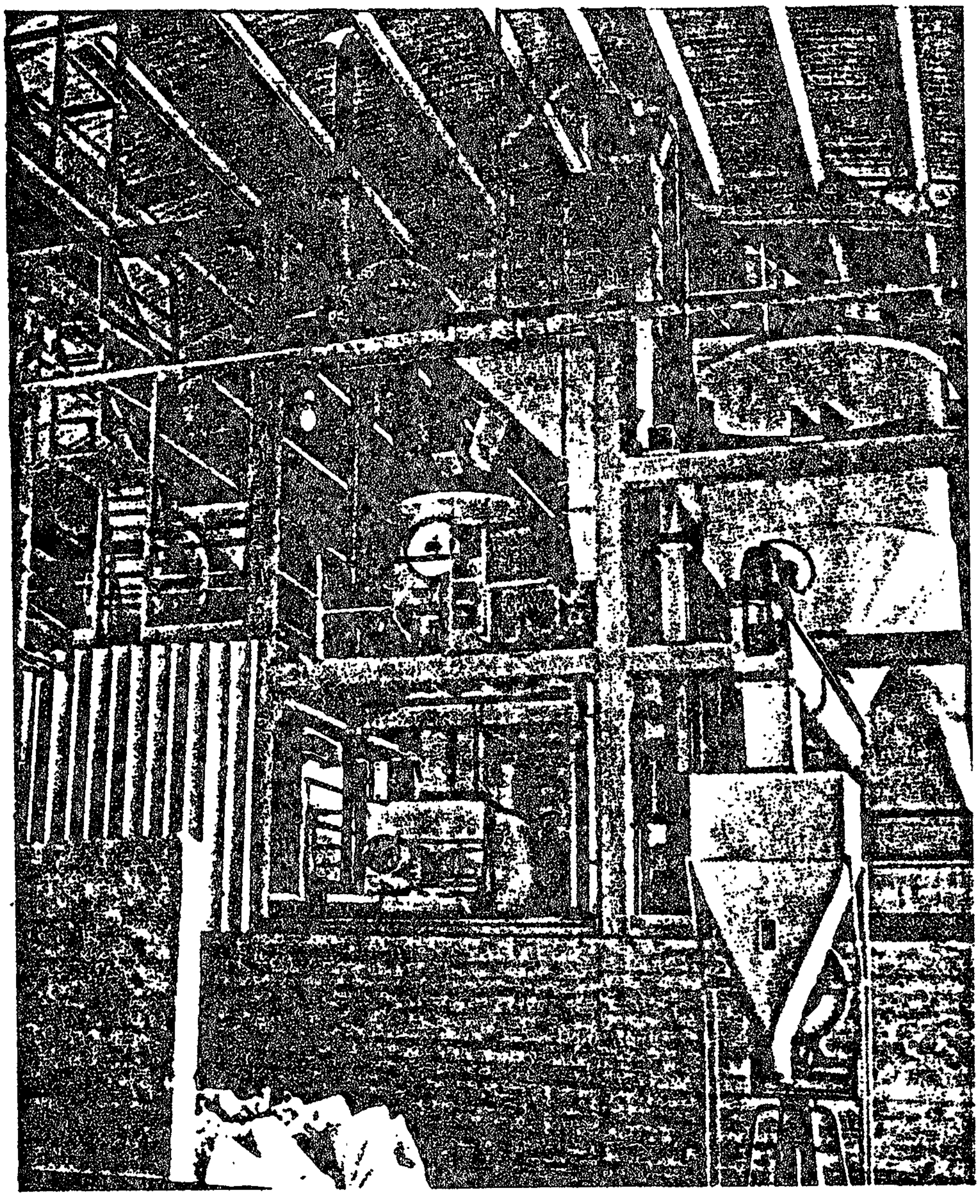
DRY ORGANIC MATTER
After many years of experience, SORAIN - CECCHINI developed a process capable of overcoming



those problems which arise in the conventional production of compost. The plant includes the following processes:

— the product is dried to 10% moisture content, with subsequent sterilization, due to the product remaining for more than an hour in contact with air heated to 110° centigrade
— mechanical screening out of extraneous matter: glass, china, plastic etc.
— optional blending of the product with suitable additives to increase and improve the overall plant nutrient content
— pelletizing and bagging.

While it is still in the experimental stage, this plant is of a commercial size. Excellent results have been obtained from tests made in domestic gardens and greenhouses as well as in large scale market gardening.
Within two years we foresee being able to convert all the material relegated to compost into this new product which is attracting a good deal of interest.

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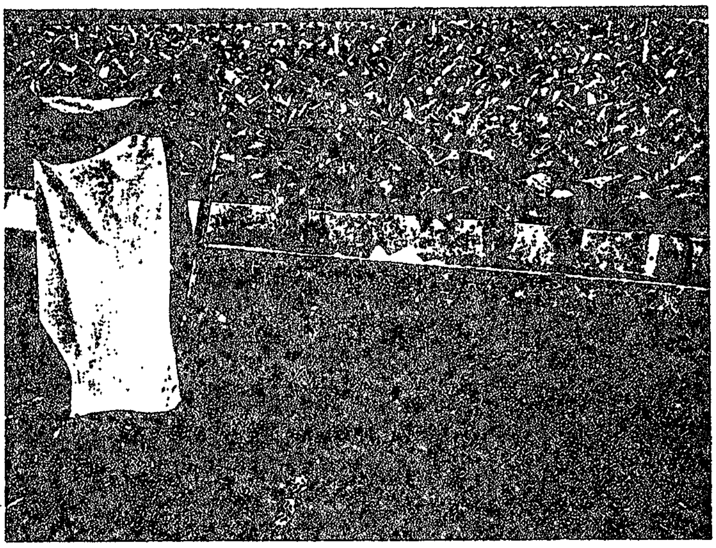
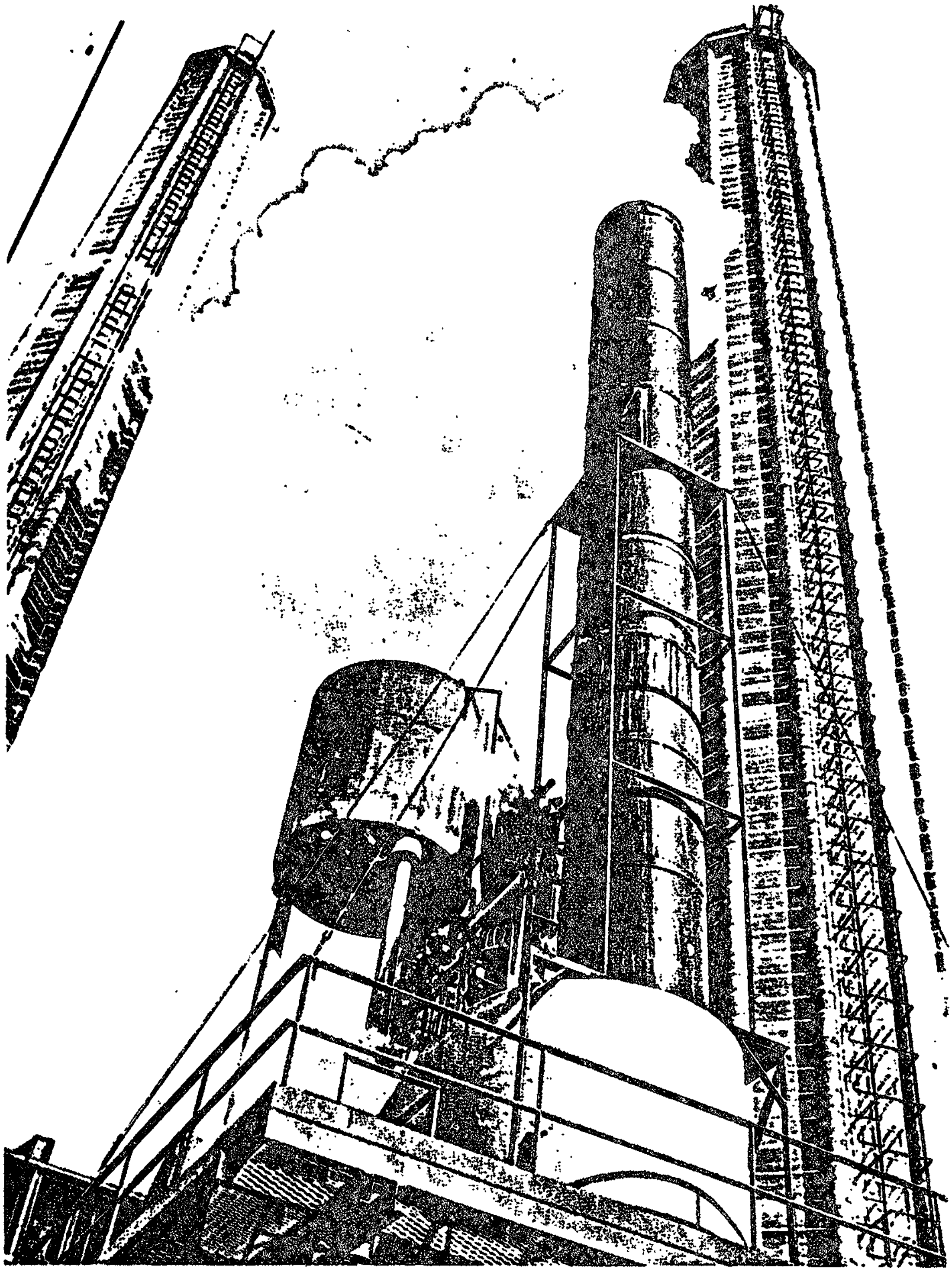


Given its heat value, SORAIN-CECCHINI is also building an experimental plant in which the dried product will be used as fuel. Once ash handling problems are overcome, we believe that this use will be a viable alternative.

The thermic energy value of the product can be used in the generation of hot water, steam, electricity with advantages over the incineration of raw refuse.



INCINERATION SECTION

The incineration section consists of modular units which can burn 100 tons per day each, for a total 6 in the EAST plant and 3 in the WEST. A boiler is attached to each furnace which when combined, produces about 50,000 kgs. per hour of steam at a pressure of 8 atmospheres. The sizing of the individual units is determined by the maximum total steam demand of the plant, as well as providing for a guaranteed steam flow during scheduled shutdowns or during unforeseen breakdowns.Thus two basic functions ensured the incineration section of a recycling plant:

— disposal of the refuse which cannot be recycled
— production of the steam necessary for in-plant use.

Moreover, the incinerators are subjected to less severe conditions than that for which they are designed. In fact, they do not burn "raw refuse", but simply what has been discarded, which is almost completely free from wet organic matter and is homogeneous and well mixed.

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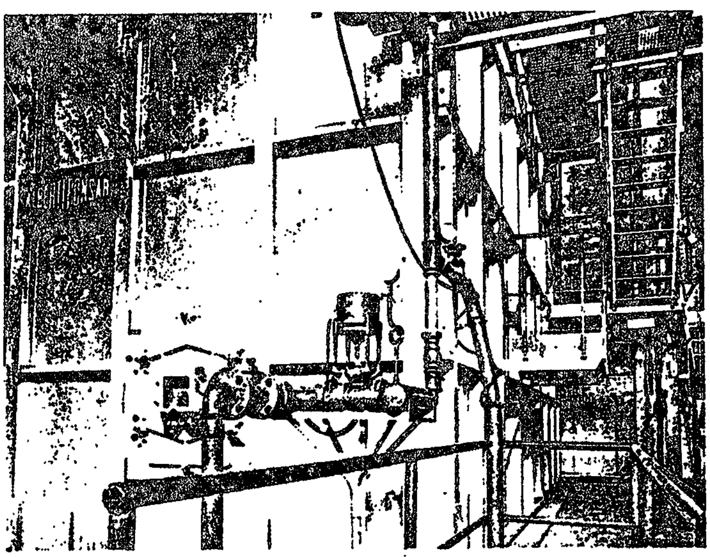
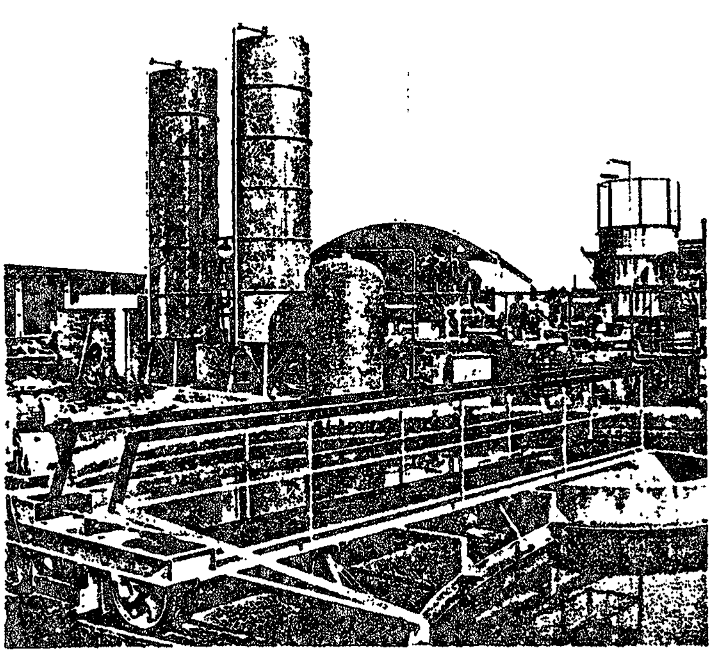


The ash is quenched in water, stored in silos and then taken to a sanitary landfill. The flue-gas is scrubbed with water before entering the atmosphere.

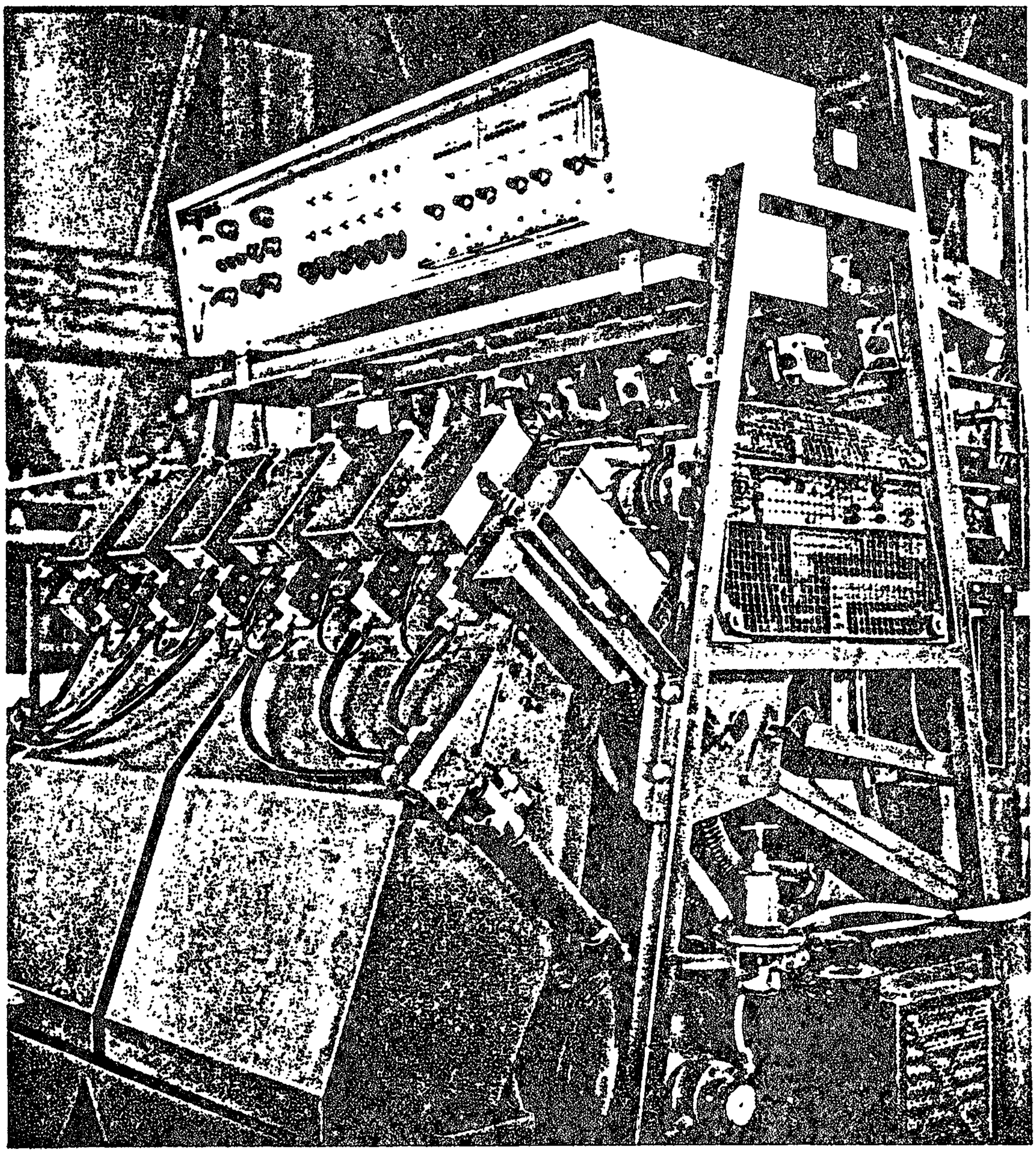
WATER CYCLES

All the water used in the process of the various



sections of the recycling plant receives primary and secondary treatment before reuse in-plant.

GLASS
In the Rome plant, the recovery of glass from urban refuse is still at the experimental stage.



The heart of the plant consists of an optic-pneumatic system to separate the glass from other materials.
The material to be treated, has to be prepared in such a way as to have certain physical characteristics, with glass representing the highest proportion.

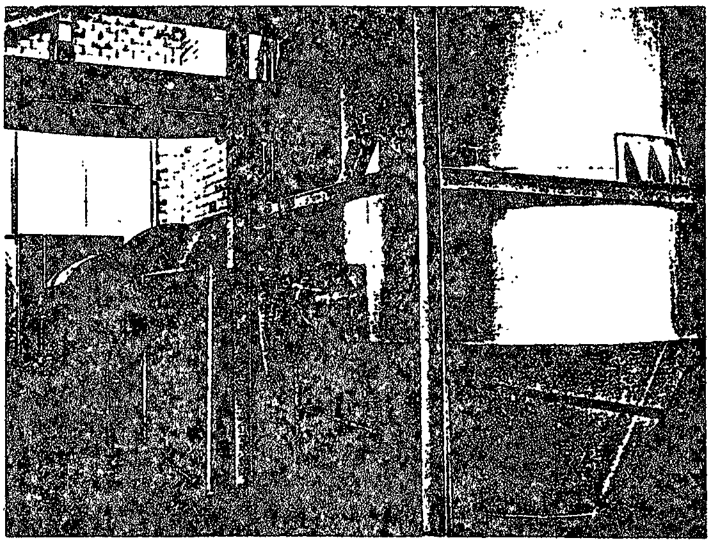
SORAIN CECCHINI S p.a
Via Bruxelles, 53
00198 ROMA
Tel (06) 860192 - 867031
Telex 58251 - SORAIN

The same machine, appropriately adjusted, is then able to sort out the glass into its various colours; clear, green and amber.

After more than a year of experiments, modifications are being made to the system, which will make glass recovery technically and economically viable.

NON-FERROUS METALS

The percentage of non-ferrous metals (aluminium, copper, brass, lead etc.) in refuse collected in



Rome is almost negligible, or at least insufficient to justify its recovery. However, technology is available for the recovery of non-ferrous metals.

NEWS OF THE FIAT RECYCLING PLANT

Wastes produced by the Fiat factories have been analized; the composition of 240 tons per day of collected wastes is shown in the following table:

Kind of waste	tons per day	% on the total	Chemical composition
Working wastes	50	21%	paper (54%) - plastic (12%) - rags (7%) - iron (2%) - various metals (8%) - similar leather (4%) - wood (4%) - various (12%)
Working sludges	75	30%	iron (50%) - oil (12%) - water (28%) - abrasive (5%) - various (5%)
Painting sludges	41	18%	---
Canteen wastes	24	10%	organic substances (44%) - metal container (22%) - plastic (6%) - paper (2%) - humidity (20%) - various (6%)
Oils and solvents	7	2%	solvents (18%) - oils (82%)
Treatment sludges	43	19%	dry material (25%) - humidity (75%)

It has been decided to carry out a treatment plant equal, for the moment, to 1/3 of the total capacity (80 ÷ 100 tons per day) and in accordance with the scheme shown in the enclosed figure 1 which foresees as final disposal:

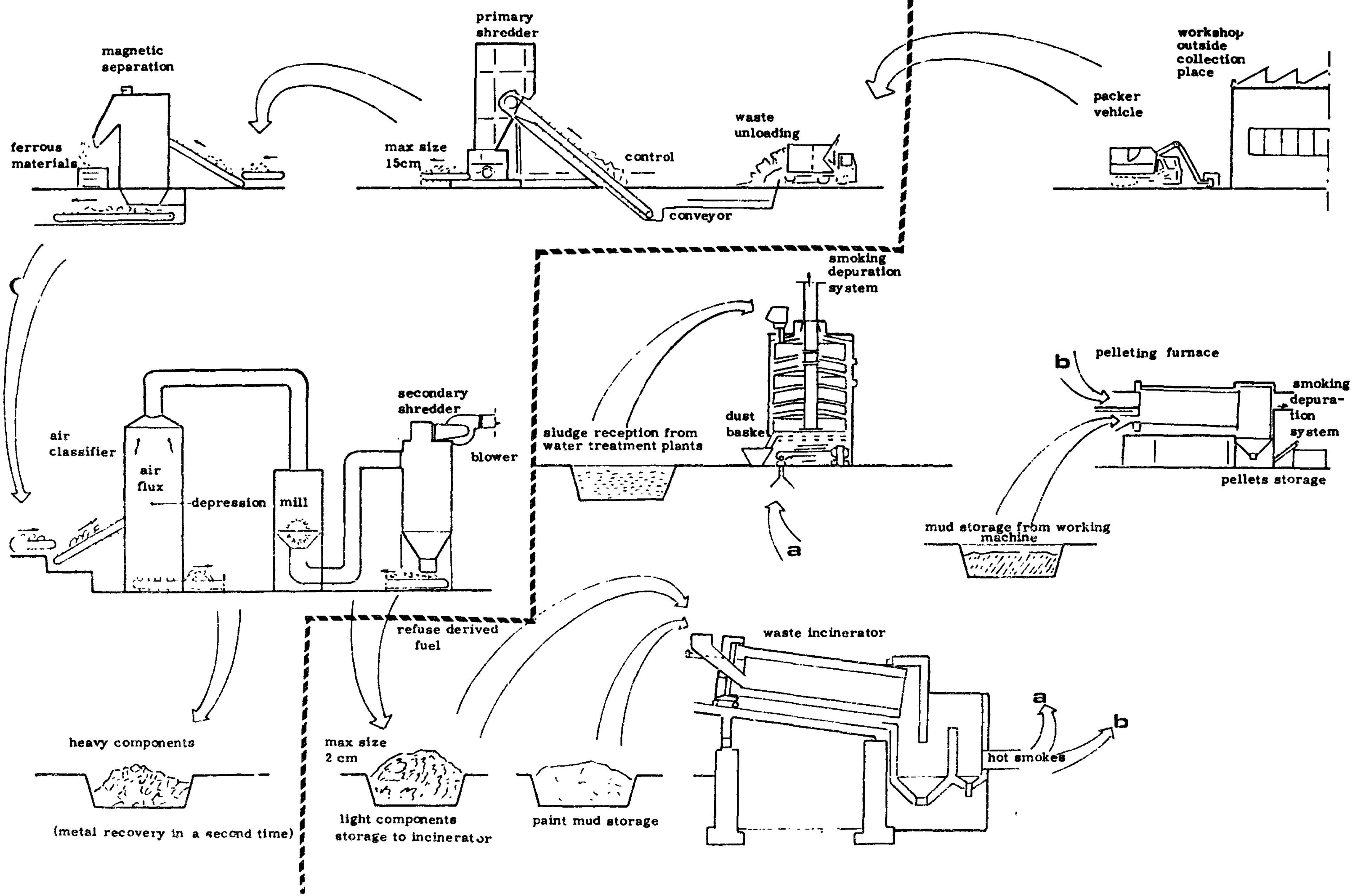
- painting sludges: incineration;
- oven drying and reuse (for iron metallurgy use) for working sludges;
- treatment sludges drying;
- working and canteen wastes treatment with metals recovery and production of refuse derived fuel;
- incineration of oils and solvents not recoverable.

Such a system, although studied for industrial wastes, has the section 'A' of figure 1 that is alike to a treatment line for solid urban wastes. It is foreseen to try the running also with the utilization of urban wastes.

The general design of the plant is carried out by Fiat (Centro Ricerche Fiat and Fiat Engineering) while the main machineries are bought some in Europe and some in the United States of America. The plant will be working in 1978.

Principal data section A		
	Potential:	5 t/h
	Cost: - components for transport, grinding and classification	220 million lire
	- building works, steel structural work, general facilities	200 million lire
	Unit cost (plant operating with 2 shifts)	5 million lire/t/day
	Main machinery:	
	. primary mill - Williams (St. Louis - U.S.A.)	550 Hp; 990 rpm; < 15 cm
	. magnetic separator - Streinert (Köln - Germany)	6 kW
	. integrated grinding and classification unit - Williams (St. Louis - U.S.A.)	317 Hp; <2 cm
	. electric motors (6 in total) Marelli (Italy)	550Hp+220Hp+ 50Hp+ +40Hp+2Hp+6Hp
	Staff (per shifts) - 3 people:	
	. 1 waste handling worker	
	. 1 control room technician	
	. 1 supervisory operative (mechanic)	
	Electrical energy consumption: (installed power 870Hp):	130 kWh/t waste
	Other consumption: no water or auxiliary fuels used in section A	

:GUI



magnetic separation
ferrous materials
primary shredder
max size 15cm
control
conveyor
waste unloading
workshop outside collection place
packer vehicle
air classifier
air flux
depression
mill
secondary shredder
blower
smoking depuration system
dust basket
sludge reception from water treatment plants
a
b
pelleting furnace
smoking depura- tion system
pellets storage
mud storage from working machine
refuse derived fuel
waste incinerator
hot smokes
a
b
heavy components
(metal recovery in a second time)
max size 2 cm
light components storage to incinerator
paint mud storage

9 NEWS OF OTHER RECYCLING PLANT RESEARCH ACTIVITY IN ITALY AND INDUSTRIAL CAPABILITIES

Numerous Italian Companies are interested in problems of recycling solid urban waste, perfecting integral recovery cycles, creating partial recovery cycles or building machinery suitable for the recycling of waste.

The first group includes the De Bartolomeis Company which at Ambivere (Bergamo) has set up the prototype of a 10 t/hour plant.

The second includes SIET/Tecneco, Worthington, etc.

Finally, equipment manufacturers include De Bartolomeis, Impresa Cecchini and Sorain-Cecchini who build most of their own plant equipment themselves, and the Fratelli Ferrero Company of Vado Ligure.

9.1 SOLID WASTE RECYCLING: AN OPERATING RESOURCE RECOVERY PLANT DESIGNED BY THE DE BARTOLOMEIS COMPANY - MILAN (ITALY)

Research began in 1973 with a laboratory and study phase, involving pilot equipment. Early in 1974 the machines required for the experimental plant were designed, built and installed; the results of the operation are illustrated below.

The objectives which were set as basis for the research project and which characterize the 'DB' resource recovery system to-day, are the following:

a) to create a solid waste separation and reclamation plant, on a fully dry operation basis;

b) to obtain the separation of five basic materials:

   a) ferrous metal;
   b) organic fraction;
   c) cellulose products (paper and board);
   d) plastics;
   e) glass;

c) to carry out the separation in a fully mechanical way, thus excluding any manual intervention on the waste;

d) to provide the plant with the highest processing flexibility, to allow for the considerable variations frequently occuring in the composition of municipal wastes and, at the same time, the eventual need of improving the purity characteristics of the reclaimed materials.

In September 1974, an operating unit with a processing capacity of 10 t/h raw waste (thus capable of handling, on a continuous operation basis, the waste generated in European Communities of some 300.000 inhabitants) was set up.

Initially, the operating unit obeyed the following process-scheme:

- constant flow feed;
- elimination of electrostatic charges from film plastic;
- electromagnetic separation of ferrous metal;
- pre-crushing of the in-fed raw waste and tearing of garbage-bags;
- separation and screening of the organic fraction;
- aerodynamic separation of glass cullet from the organic fraction;
- granulometric refining of the organic fraction;
- aerodynamic separation of paper and plastics.

Initially, in other words, only the operation of the basic process-line was perfected, since industrial scale and laboratory experiments had already been carried out on secondary processing of the reclaimed products.

The waste separation plant discussed in this presentation, thus represents the basic part of the diagram (fig. 1) which illustrates the whole of the 'DB' resource recovery system.

Examination of the diagram shows that:

- the system consistes of different sections, designed for different purposes. Some sections may or may not be made operative, depending on objectives; however, they can be bought in at any later stage to complete the process and/or to carry out secondary processing of the reclaimed materials;
- two sections have not been experimented (Nos. 16 and 25); these represent highly sophisticated points of the recovery process and are not necessary to the operation of the system, which will only rarely be endowed with them.

During the two years the plant has been in operation, the process-line has always been fed with unsorted municipal solid waste, such as collected from various urban communities in Northern Italy, which were chosen on purpose, in order to obtain a series of responses, according to the type of waste processed.
Il should be noted that more than 95% of the waste fed into the system was contained in plastic bags, of the special type employed for solid waste collection.
At the end of 1975 some 10,000 tons of waste had been processed.
To guarantee a systematic supply of the waste necessary for the process-tests and a prompt disposal of the reclaimed materials, the research has been done in cooperation with I.G.M. (Impresa Generale Manutenzioni) of Milan.
The results of the analyses carried out on the in-fed waste are summed up in Table I, which shows its composition mean values.

Figure 1 - Diagram of 'DB' Resource Recovery System

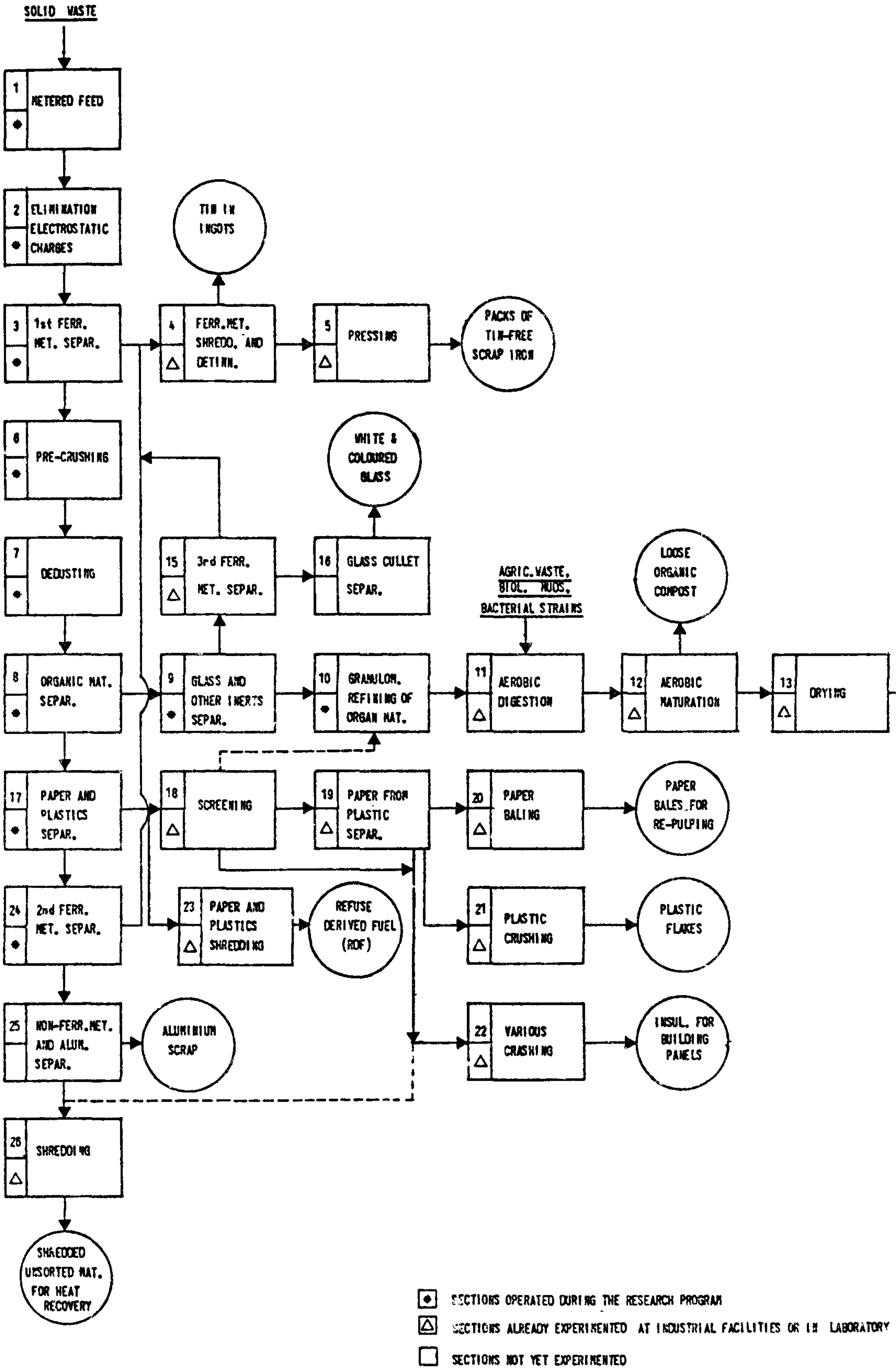


Table I

COMPONENTS	WASTE TYPE 1		WASTE TYPE 2		WASTE TYPE 3		WASTE TYPE 4	
	MEAN	MIN/MAX	MEAN	MIN/MAX	MEAN	MIN/MAX	MEAN	MIN/MAX
MOISTURE	42	38-45	51	47-53	35	34-38	380	-
FERROUS METAL	7	6-8	3	2-3	5	4-7	7	-
PAPER AND CELLULOSE PRODUCTS	31	25-35	22	20-24	41	39-44	50	-
PLASTICS	7	6-10	5	4-6	7	6-8	6	-
VEGETABLES AND PUTRESCIBLES	36	29-42	54	41-58	18	16-25	16	-
FABRICS, WOOD, RUBBER AND LEATHER	6	2-7	4	3-5	5	3-6	6	-
GLASS	3	2-6	2	1-5	4	3-5	8	-
INERT MATERIALS	4	3-5	5	4-6	14	11-16	2	-
OTHER UNCLASSIFIED MATERIALS	6	3-8	5	4-7	6	2-8	5	-
No. OF ANALYSES MADE	185		68		45		4	
QUANTITY OF WASTE PROCESSED t	6.410		3.600		1.500		250	
	MONZA TYPE WASTE		CINISELLO BALSAMO TYPE WASTE		MILAN TYPE WASTE		RECONSTRUCTED USA TYPE WASTE	

VALUES ARE EXPRESSED IN % BY WEIGHT

Type 1 waste can be considered as typical of the centres of medium sized Northern Italian towns. The analysis shown is the weighted mean of 185 analyses carried out during plant operation.

Type 2 waste is typical of the outlying areas of small or medium towns in the North of Italy. The analysis shown in the Table I derives from the weighted mean of 68 analyses carried out during plant operation.

Type 3 waste is typical of the centres of large Northern Italian towns (including rubbish from the roads). The mean is of 45 analyses.

Type 4 has been constructed artificially, by mixing previously separated waste fractions, so as to simulate the typical waste composition of large North American towns.

The reasons here were to complete certain specific studies on North American waste and to examine the performance of the plant in conditions which may be considered extreme, particularly as regards cellulose product content.

The results of separation obtained are shown in Table II, which gives percentage yield values by weight, with respect to the total quantity of the same product present in the in-fed raw waste.

Table II

SEPARATION YIELDS %	WASTE TYPE 1 CAMPAIGNS 1-7	WASTE TYPE 1 CAMPAIGNS 8-10	WASTE TYPE 2	WASTE TYPE 3	WASTE TYPE 4
FERROUS METALS	96	99	95	94	98
PAPER	63	68	56	66	67
PLASTICS	70	71	66	68	72
ORGANIC SUBSTANCES	86	86	88	82	81
GLASS	82	86	81	83	85
UNSORTED MATERIALS (% OF TOTAL WASTE)	19	16	18	27	25

Examination of the above Table II shows that:

- separation of ferrous metal using the electromagnetic system does not create problems and can be achieved with very high yields;
- separation of paper is decisively affected by the moisture of the waste; the higher the moisture, the more difficult the separation; thus a major part of the very small, light fraction of the non-separated paper is found mixed with the reclaimed organic fraction coming from the kitchen waste;
- variations in the separation yields of plastic material are influenced by the material's characteristics: namely, it is easier to separate film plastics than moulded products;
- the separation of organic kitchen waste is promoted, within limits, by the moisture;
- satisfactory efficiency is achieved in the separation of glass cullet mixed with other inert materials;
- the quantity of the remaining unsorted materials is highly influenced by the level of fabrics, rubber, wood, leather and inert materials of large dimensions, as well as by the separation yields of the other fractions;

it is possible to substantially modify the separation yields and the purity of the reclaimed products by regulating the operating features of the precrusher and the rotating classifier.

These machines have been designed so that operating modifications are easy to carry out.

Finally, for the purpose of providing indications as to the course of research results, table III shows the means of results obtained with type 1 waste, on which the greatest number of tests were carried out, in different campaigns, each with the purpose of improving the results of the previous one, particularly with respect to paper recovery.

Table III

CAMPAIGNS	1	2	3	4	5	6	7	8	9	10
PERIOD	SEPT.OCT. 1974	NOVEMB. 1974	DEC. JAN. 1975	FEB. 1975	MARCH 1975	APRIL 1975	MAY 1975	JULY SEPT. 1975	OCT. MARCH 1976	JUNE JULY 1976
WASTE PROCESSED t	120	270	530	750	720	810	790	810	1.130	480
FERROUS METAL	96	97	95	96	96	97	96	98	99	99
PAPER	17	38	42	56	62	65	64	66	68	72
PLASTICS	42	52	51	52	65	72	71	73	70	72
ORGANIC MATERIALS	88	83	85	83	86	87	88	86	85	87
GLASS	-	-	-	55	76	81	83	85	86	88
REAL UNSORTED MAT. (% OF TOTAL WASTE)	36	26	22	20	21	15	20	16	17	15
THEORETICAL UNSORTED MATERIALS (% OF TOTAL WASTE	46	42	40	36	31	29	29	-	-	-

THE TABLE SHOWS SEPARATION YIELD VARIATIONS IN THE VARIOUS CAMPAIGNS

YIELDS ARE EXPRESSED IN % BY WEIGHT OF THE TOTAL QUANTITY OF PRODUCT IN THE ORIGINAL IN-FED WASTE

As a matter of fact, once satisfactory separation yields with tipe 1 waste were achieved, other campaigns were carried out and a more selective schedule developped, the results of which are summed up in table III.

For comparison purposes, table III also gives the value of the theoretical quantity of the remaining unsorted materials, calculated as a sum of the non-recovered quotas plus the quantities pertaining to fabrics, wood, leather, rubber and large dimension inert matters.

In effect, a marked difference is noted between theoretical and real quantities of unsorted materials; this difference is due to the fact mentioned earlier, i. e. some of the non-recovered paper mixes with the organic fraction, when major variations occur in the moisture and sizing of the waste being processed.

During the research period, some secondary processing tests were also carried out on reclaimed materials:

- shredding, cleaning, detinning and pressing of the ferrous metal;
- granulometric homogenization and aerobic digestion of the organic fraction, with addition of humificating bacterical strains, thus obtaining a high fertilizing power compost;
- further purification and upgrading of the recovered paper and plastic;
- shredding of paper and plastics, thus obtaining a refuse derived fuel (RDF) of high BTU content;
- shredding of the unsorted materials for further processing tests.

The plant lay-out has shown benefits from both the economical and operating points of view, due to the fact that the removal of most of the ferrous metal is accomplished at the initial stage of the process cycle. As a result, the subsequent machinery and equipment in the process-line are substantially protected from many real causes of wear and tear, damage and consequento downtime; explosion hazard is also reduced.

Additional cost sabings and improved operating conditions have been shown by the function of the DB rotating classifier. Brittle materials, such as glass, are salvaged in pieces rather than pulverized, which would make it too small for recovery. Other abrasive materials, such as ceramics, stones and fines are removed prior to any shredding, thus reducing wear and power demand by any shredder. Finally, all the above undesirable materials having been removed together with the organic fraction, the amount of waste feeding the rest of the processing machinery and equipment has been substantially decreased, thus improving their operating conditions, which results in a lowering of operating and maintenance costs.

The plant lay out also shown benefits from the operating point of view with regard to secondary processing of the reclaimed paper and plastic fractions.
In effect, due to the concept of the DB process-cycle, paper and plastics are directly separated from the waste stream in large size pieces, prior to any shredding of the in-fed waste.

Consequently, it is hughly favoured the separation process of the paper from the plastics, as it is required when the recovered products can be marketed as secondary materials to be recycled in the paper-mills and the plastic moulding industries, respectively.

At the same time, paper and plastic directly shredded together only after their separation from the waste stream, consistute the cleanest combustible fraction recoverable from any solid waste processing system for use as refuse derived fuel (RDF).
The advantages of dealing with a fairly homogeneous RDF, consisting of only two fractions, paper and plastic, are clearly understood.

A further considerable advantage shown by the DB waste separation and reclamation process is represented by its fairly limited power demand: the total installed power of the DB 10 t/h line is 250 kW; the power consumption is 15 kWh per ton of waste processed.

The plant has not undergone substantial modifications compared to its original design, although improvements have been made to some of the basic process machines.

To conclude, the research confirmed that:

. it is possible to achieve the mechanical separation by dry process of the basic components of municipal wastes, with satisfactory separation yields;

. reclaimed materials possess amply sufficient purity to gain their position on the market of secondary products;

. the process-line is extremely simple, easy to operate and capable to guarantee costant production results, provided plant operation and maintenance standards are applied;

. operating cost per unit of waste processed taken into account even very modest revenues from the sale of recovered products, are extremely interesting.

The plant was built for a potential of 10 t/h, but a 25 t/h line has also been designed.

A plant consisting of two lines, each of 25 t/h capacity, will process 800 tons of solid waste in 16 hours, on a two shifts per day operation basis.

To complete the composting section of the system, a licence has been obtained from the Fairfield Engineering Company Ohio (U.S.A.) for the digestor.

With regard to paper recovery 'DB' cooperates with Beloit Italiana (Pinerolo), a Company which has designed a damp separation line for paper pulp, capable of operating with recycled paper products, provided plastic content does not exceed 6 ÷ 7%. Appropriate processing of the reclaimed paper into paper-pulp, increases the value of the recovered product, by as much as 8 - 10 times (from 40 to 300 Lit/kg); this 'added value' well covers the cost of the above secondary process.

The entire DB plant is designed with a view to cutting operating costs to a minimum:

a) staff: 2 workers per shift, in addition to the plant head;

b) electrical energy consumption: 15 kWh per ton of waste processed.

Plant of this type have been offered in Canada, Sweden, Italy, etc.

A plant in which compost production predominates has been recently built in Brazil.

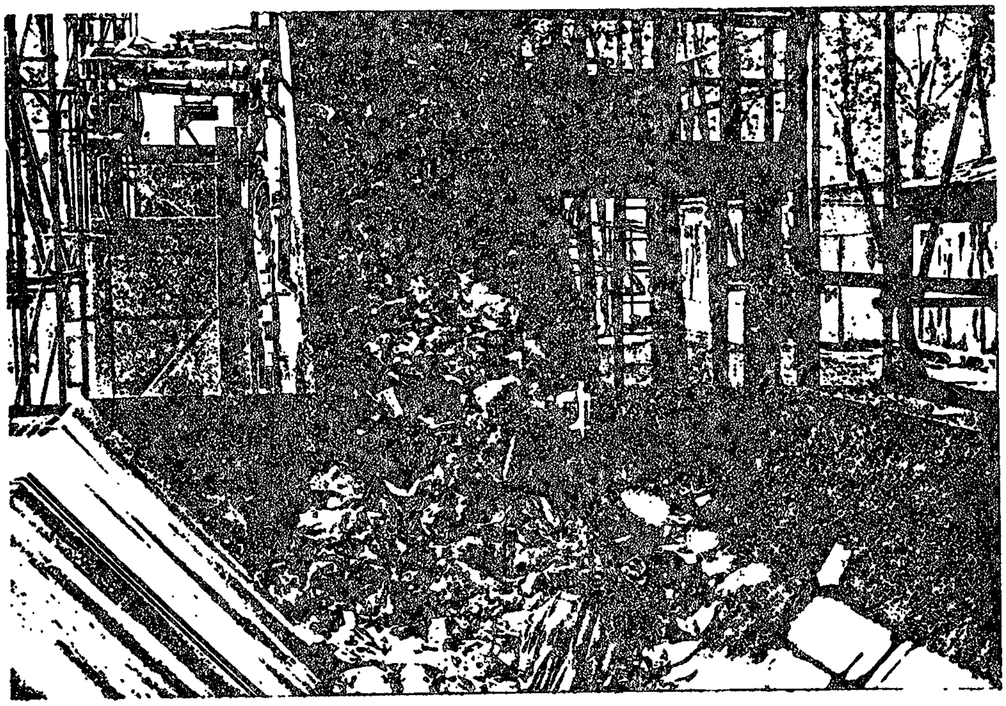
During the study of this contract the plant has been visited by Mr. R. Fox of Fiat Engineering on March 11th, 1977.

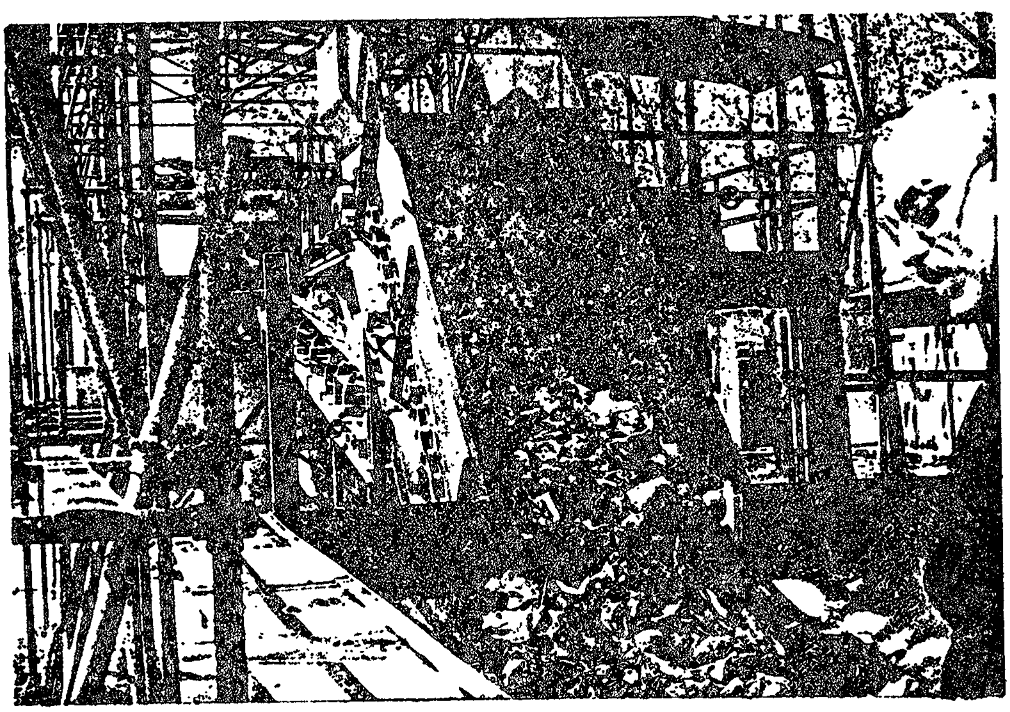
The plant is shown in the enclosed pictures.

Impianto di recupero dei rifiuti solidi da 10 t/h di Ambivere della Società De Bartolomeis - Vista di insieme

Municipal solid waste resource recovery plant - 10 t/h - built in Ambivere by De Bartolomeis Company - General view

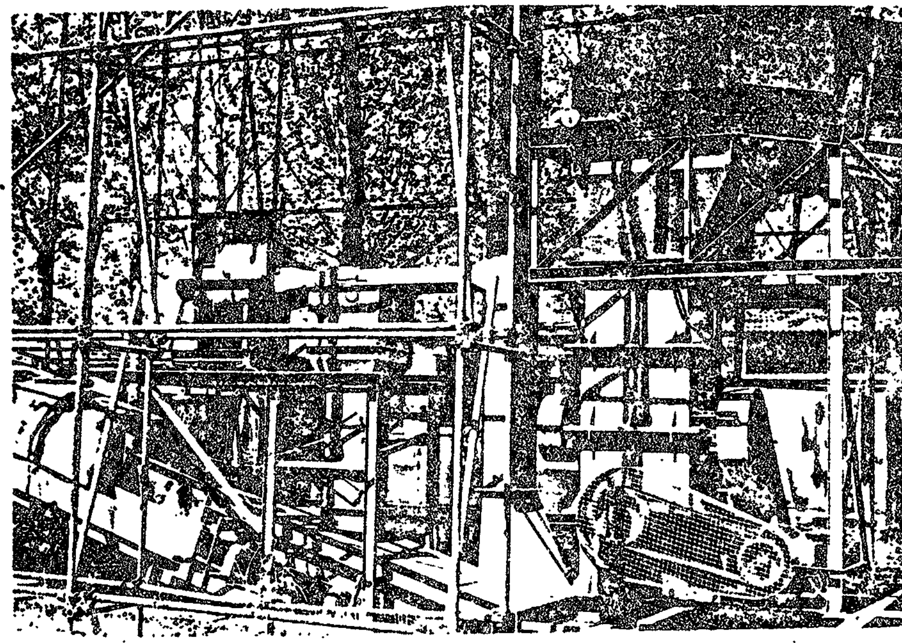
Milan - Italy





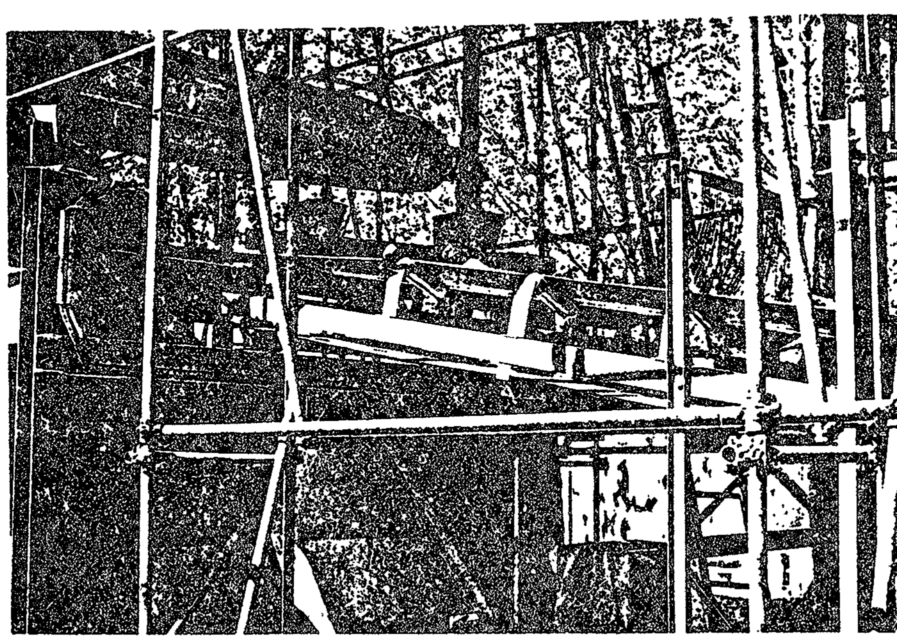
Ricezione ed alimentazione dosata dei rifiuti

Reception and constant flow feed of the solid waste



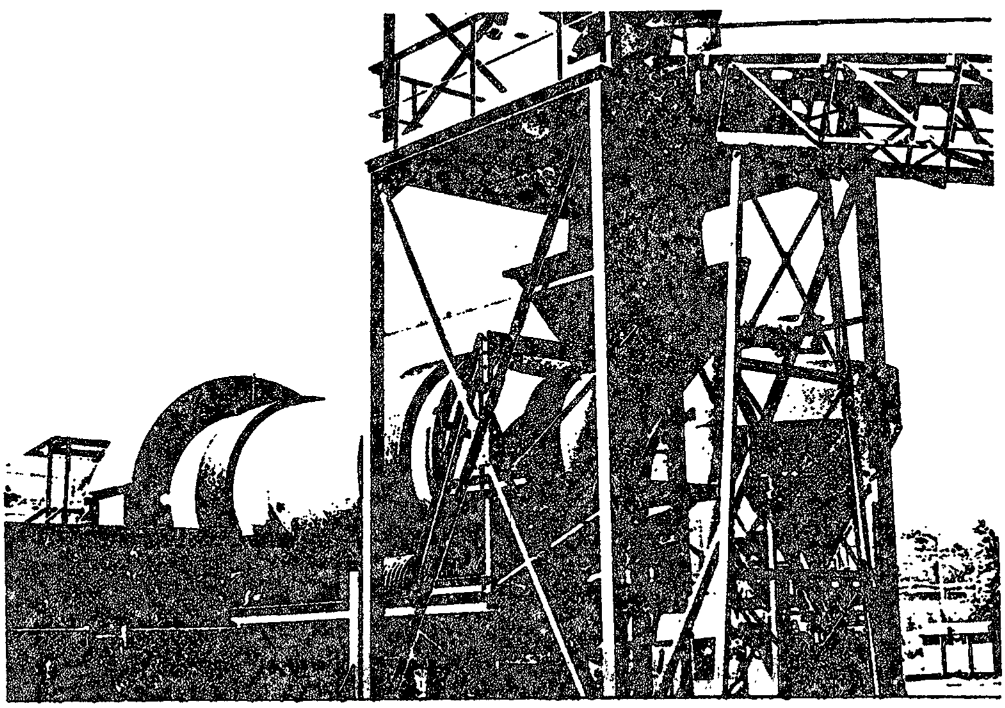
Frantumatore, depolverizzatore

Shredder, depulvarizator



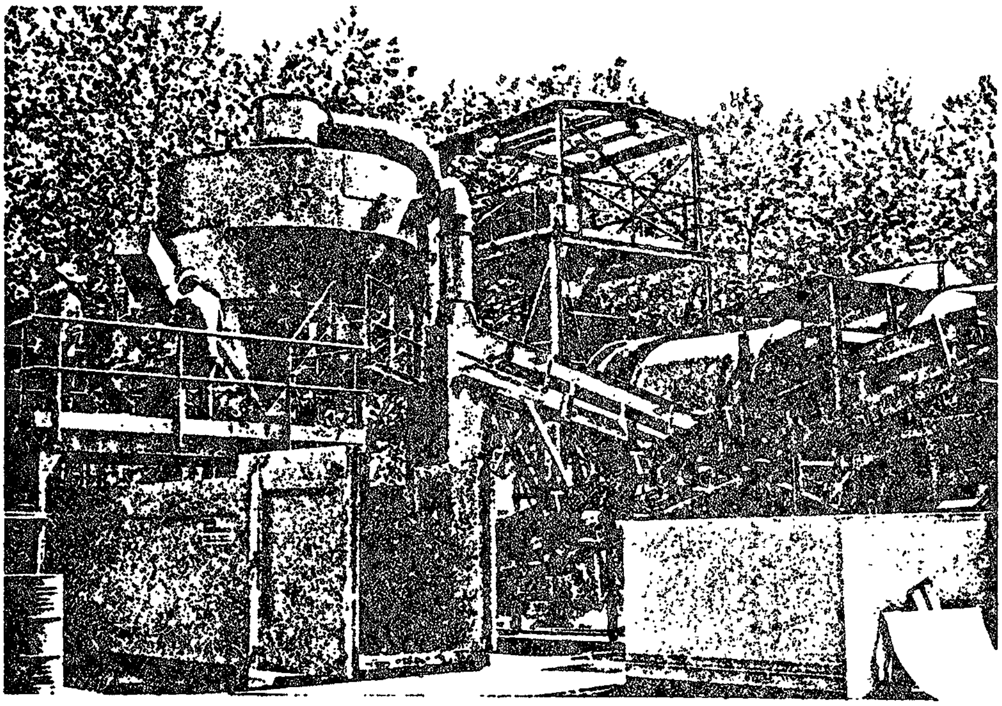
Eliminazione cariche elettrostatiche, rompitura sacchi e separazione elettromagnetica

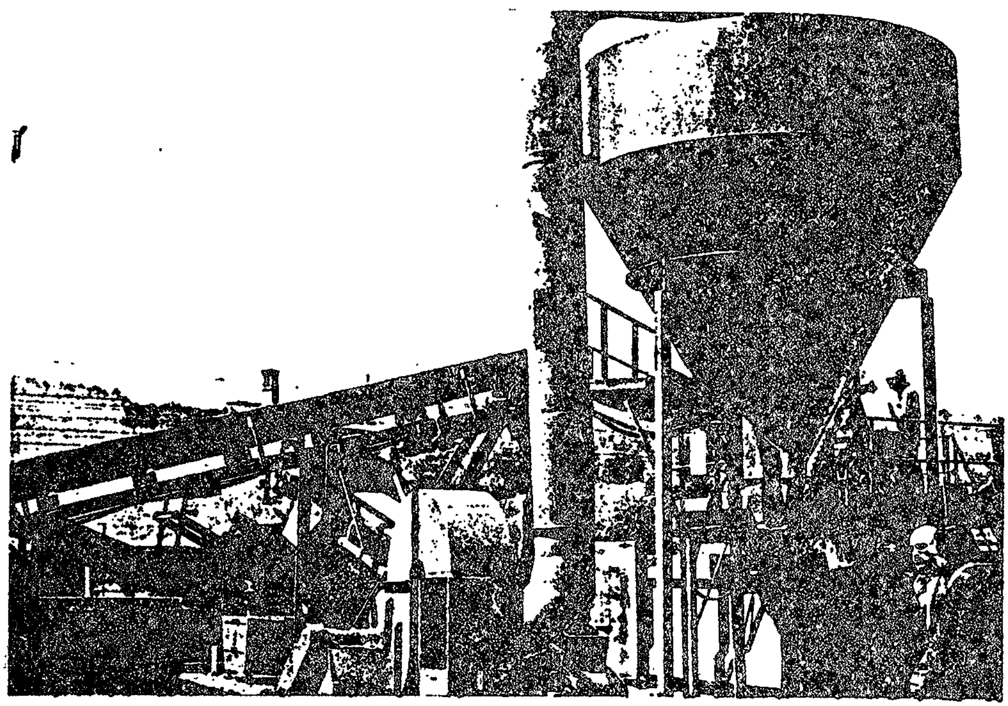
Elimination of electrostatic charges, tearing of bags and ferrous metal electromagnetic separation



Vagliatura e separazione delle sostanze organiche

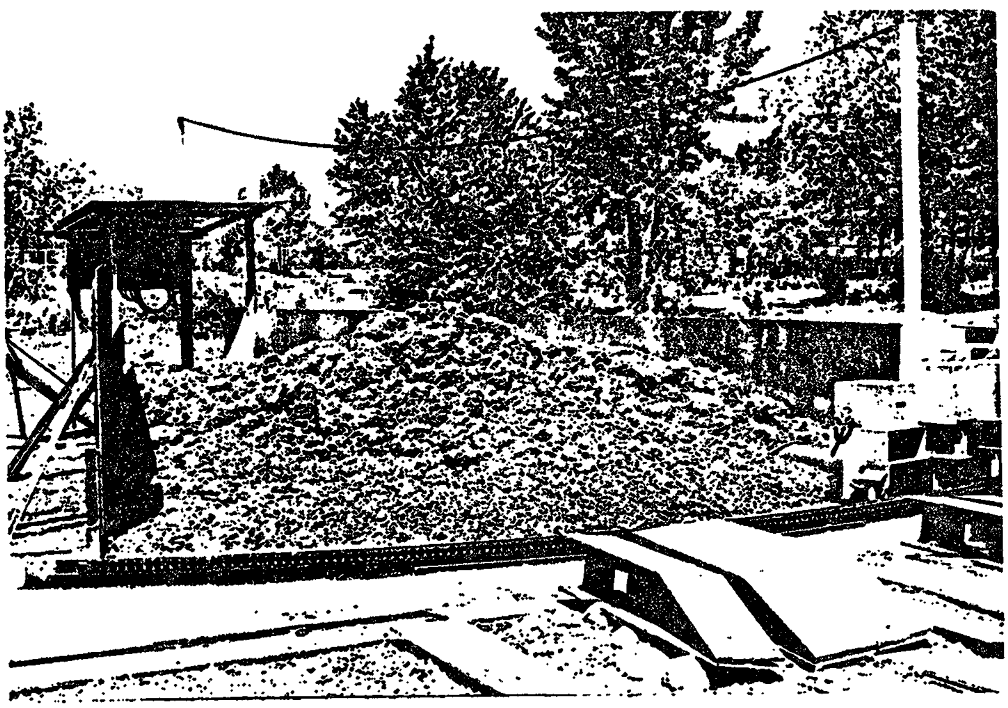
Screening and separation of organic materials





Raffinazione materiale compostabile

Refining of compostable materials

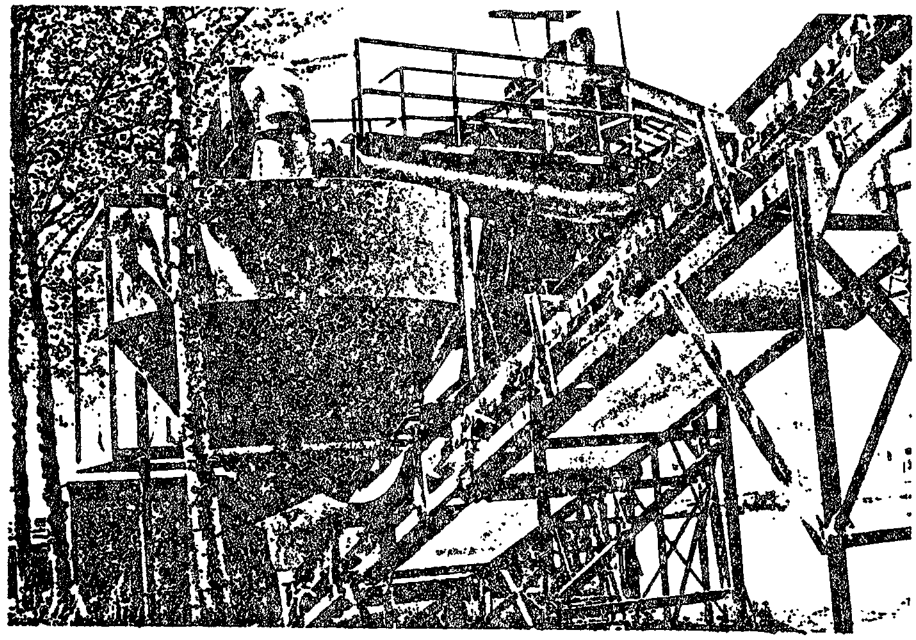


Maturazione aerobica fertilizzante organico

Aerobic maturation of organic compost

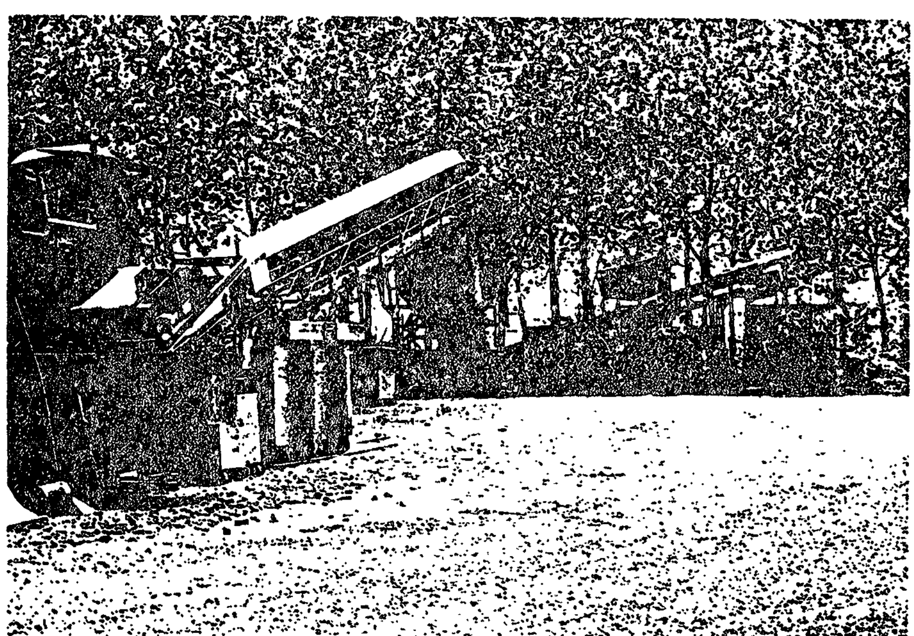
Separazione aerodinamica carta e plastica

Aerodynamic separation of paper and plastic



Deferrizzazione e separa zione combustibile urbano

Ferrous metal second magnetic separation from remaining unsorted materials



9. 2 OTHER STUDIES ON RECYCLING PLANTS

There are a number of Companies in Italy (Siet/Tecneco, Worthington, etc.) operating in the field of solid waste treatment plants (incineration ovens, composting, compacting) which are examining and finalizing partial recycling plants (e. p. paper separation, etc.). None of these plants has been made on an industrial and commercial scale up to the present and we therefore cannot describe them here in detail.

We are now illustrating the principle of the plant studied by Siet/Tecneco.

The combining of various forms of waste recovery into a single integrated facility gives rise to so-called 'recovering' or 'recycling plants' (fig. 1).

Sent to an incinerator are only those wastes which cannot be recycled (between 40 and 45% of the refuse).

Recovery on an industrial scale to day includes:

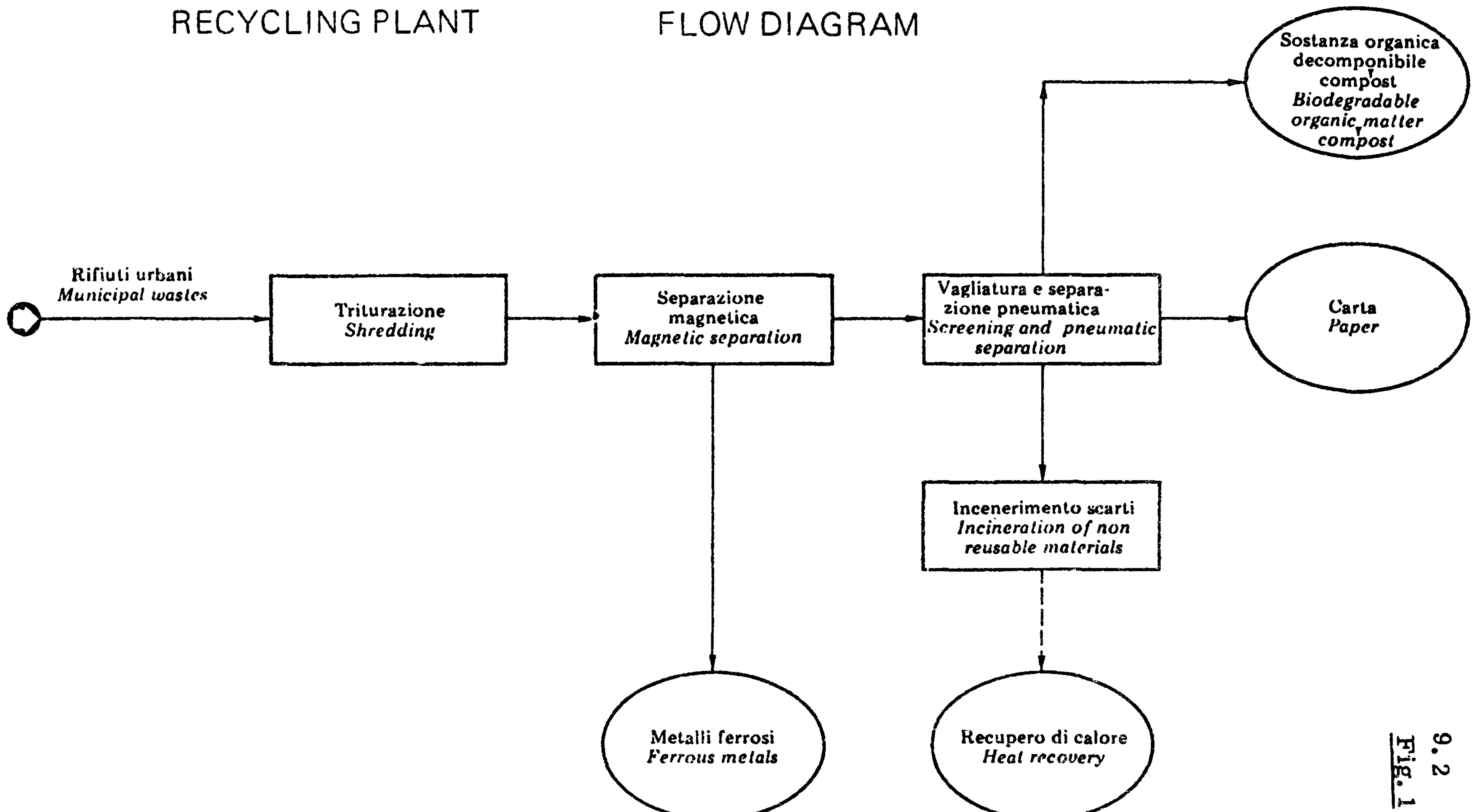
- heat (for heating or energy production);
- biodegradable organic matter;
- paper;
- ferrous metals.

Now under study and to become available in the future are forms of recovery regarding plastics, rubbers, glass and non ferrous metals.

Due to the complexity of plant technologies and problems of organizing markets and selling reclaimed products, facilities for their recovery are feasible only if of large capacities.

IMPIANTI DI RICICLAGGIO — SCHEMA A BLOCCHI

RECYCLING PLANT — FLOW DIAGRAM



9.2
Fig. 1

9.3 ITALIAN MANUFACTURERS OF EQUIPMENT USED IN RECYCLING PLANTS

The Cecchini Company of Perugia, Sorain-Cecchini of Rome and De Bartolomeis make most of their recycling plant equipment in their own workshops.

The Officine Meccaniche Fratelli Ferrero Company of Vado Ligure, manufacturers of equipment for the mining industry, make equipment that is used in recycling plants, e.g.:

- bounce separators for separating glass from compost (15-16 t/h; 7 kW; separation efficiency: 80-90%);
- zymothermal mills for the production of compost 50-120 t/day (power installed 110 hp; diameter 4 metres; length 12.5 m; working volume 120 m^3);
- special screens for waste;
- special paper recovery machines;
- machines for extinguishing and extracting ash from incineration ovens.

There are also a number of mechanical workshops and industries making equipment used in composting and recycling plants.

10 ANALYSIS OF THE COSTS OF OPERATING 10 AND 20 t/h PLANTS BUILT ALONG THE LINES OF THE PERUGIA AND ROME PLANTS

Two 20 t/h plants of Perugia and Rome type have been analysed as was done by the Warren Spring Laboratory in comparing U. S. A. and British plants.

It was assumed that the plants work in two shifts with a 75% utilization factor (thus 2 x 8 x 0.75 = 12 h/day) for 5 days a week and 52 weeks a year, for a total of 3,100 hours/annum.

It was also assumed that the plants are depreciated over 15 years at a rate of 12.5%.

The maintenance cost was assumed to be equal to 4% of the capital.

The staff cost is as indicated in the 1st progress report (manager = 20 million lire/annum; clerk=12 million lire per annum; worker=8 million lire/annum; labourer=6 million lire/annum).

The value of the recovered material was assumed to be equal to that reported to us by the Cecchini Company.

ENCLOSURE I

COST OF RECOVERING URBAN WASTE IN 10 t/h PLANTS - BASIS OF COST EVALUATION (FOR THE ITALIAN PLANT A PROPORTIONAL RATIO HAS BEEN ADOPTED IN FUNCTION OF THE POTENTIAL OF PLANT SIMILAR TO THAT OBSERVED BY THE WARREN SPRING LABORATORY)

PLANT	WARREN SPRING LABORATORY	PERUGIA TYPE
POTENTIAL (75% operation, equal to 12 h/day, 5 days/week, 52 weeks/ /annum, 3.100 h/annum)	10 t/h - 120 t/day - 31000 t/annum	10 t/h - 120 t/day - 31000 t/annum
COST OF THE PLANT (1 pound = 1.500 lire)	1.4 million pounds(2,100 million lire)	4,200 m.lire (20m.lire per t/day for a 300 t/day plant = 25 t/h)
DEPRECIATION OF CAPITAL in 15 years at rate of 12.5%	1.4 m.poundsx 0.1507 = 211,000 pounds (316,5 m. lire)	4.200 m. lire x 0.1507 = 633 million lire
MAINTENANCE (4% of installed capital)	56,000 pounds (84 m.lire)	168 million lire
STAFF - no. & annual cost	12 people excl.management and admin. services; welfare charges excl.: superintendents= 2 x 4420pounds=8840 p. (2 x 6,630 = 13.26 m. lire) shift workers = 8 x 3380pounds = 27040 p (8 x 5,07 = 40.56 m.lire) day workers = 2 x 2860 pounds = 5720 p. (2 x 4,29 = 8,58 m.lire) Total~ 42,000pounds(63 m.lire)	36 people incl. management & admin. services; welfare charges incl.: managers =1x20 m.lire= 20 m.lire clerks = 4x12 m.lire = 48 m.lire shift workers =27 x 8 m.lire=216m.lire day workers = 4 x 6 m.lire = 24 m.lire Total = 308 million lire
ADDITIONAL COSTS (Welfare charges etc.)	38% of wages 16000 pounds/annum (24 m.lire)	Incl. in staff costs " " " "
MANAGEMENT	5000 pounds/annum (7.5 m.lire)	" " " "
ADMINISTRATION	50% staff cost + additional charges 29000 pounds (43.5 m.lire)	" " " "
ELECTRICAL ENERGY	40 kWh/t - 400 kWh/h - 1,24x10^{6}kWh/annum 0.02 pounds/kWh (30 lire/kWh) 25000 pounds/annum (37.5 m.lire/annum)	15 kWh/t - 150 kWh/h - 465000 kWh/annum 30 lire/kWh - 14 m. lire/annum
AUXILIARY FUEL FOR PROCESS	---	160 kg/h - 16 kg/t - 496 t/annum type: fuel oil cost: lire 90000/t = 44.7 m.lire
FUEL FOR HEATING	natural gas: 7042 x 10^6 KJ/annum 2500 pounds/annum (37,5 m.lire/annum)	not indicated-3.75 m.lire/annum assumed
WATER	1000 pounds/annum (1.5 m.lire)	23 m^3/h - 2.3 m^3/t - 71300 m^3/annum 1.8 m.lire/annum (25 lire/m^3)
CHEMICAL PRODUCTS	500 pounds/annum (0.75 m.lire)	---
DISPOSAL OF ASH AND RESIDUE	58% of material treated= 18000 t/annum 1.5 ponds/t - 27.000 pounds/annum (2250 lire - 40,5 m.lire/annum)	30% of the material is incinerated, 10% ash remains for dumping = 3100 t/annum 2250 lire/t - 7 m.lire

ENCLOSURE I

<u>RECOVERIES</u>		
- Urban fuel	30% - 9300 t/annum - 6 pounds/t (9000 lire/t) 56000 pounds/annum (84 m.lire)	---
- Glass	5% - 1550 t/annum - 8 pounds/t (12000 lire/t) 12000 pounds/annum (18 m.lire)	---
- Ferrous material	7% - 2170 t/annum - 12 pounds/t (18000 lire/t) 26000 pounds/annum (39 m.lire)	3.5% - 1085 t/annum - 60000 lire/t 65.1 m. lire/annum
- Paper pulp	---	12% - 3720 t/annum - 80000 lire/t 297.6 m. lire/annum
- Animal feed	---	5% - 1550 t/annum - 60000 lire/t 93 m. lire/annum
- Compost	---	15% - 4650 t/annum - 4000 lire/t 18.6 m. lire/annum
- Plastic	---	3.5% - 1085 t/annum - 100000 lire/t 108.5 m. lire/annum
<u>TOTAL REVENUES</u>	94000 pounds/annum (141 m.lire)	582.8 million lire/annum

ENCLOSURE I

ANNUAL BALANCE SHEET

CAPITAL COST	211,000 pounds (316.5 million lire)	633 million lire
MAINTENANCE COST	56,000 " (84 " ")	168 " "
STAFF COST	42,000 " (63 " ")	308 " "
ADDITIONAL COSTS	16,000 " (24 " ")	incl. with staff
MANAGEMENT	5,000 " (7.5 " ")	" " "
ADMINISTRATION	29,000 " (43.5 " ")	" " "
ELECTRICAL ENERGY	25,000 " (37.5 " ")	14 million lire
AUXILIARY FUEL	— —	44.7 " "
HEATING	2,500 " (3.75 " ")	3.75 " "
WATER	1,000 " (1.5 " ")	1.8 " "
CHEMICAL PRODUCTS	500 " (0.75 " ")	---
DISPOSAL OF RESIDUE	27,000 " (4.05 " ")	7 " "
TOTAL COSTS	415,000 pounds (622.5 million lire)	1180.25 million lire
REVENUES	94,000 " (141 " ")	582.8 " "
NET COST	321,000 " (481.5 " ")	597.45 " "
SPECIFIC COST PER t OF DISPOSED WASTE	10.4 " (15,600 lire)	19,500 lire

ENCLOSURE II

COST OF RECOVERING URBAN WASTE IN 20 t/h PLANTS - BASIS OF COST EVALUATION (FOR THE ITALIAN PLANT A PROPORTIONAL RATIO HAS BEEN ADOPTED IN FUNCTION OF THE POTENTIAL OF PLANT SIMILAT TO THAT OBSERVED BY THE WARREN SPRING LABORATORY)

PLANT	WARREN SPRING LABORATORY	ROMA TYPE
POTENTIAL (75% operation, equal to 12 h/day, 5 days/week, 52 weeks/ /annum, 3.100 h /annum)	20 t/h - 240 t/day - 62000 t/annum	20 t/h - 240 t/day - 62000 t/annum
COST OF THE PLANT (1 pound = 1.500 lire)	2.0 m.pounds (3.000 m.lire)	5,400 m.lire (20 m.lire per t/day,plant = 300 t/day = 25 t/ h)
DEPRECIATION OF CAPITAL in 15 years at rate of 12.5%	2.0 m.pounds x 0.1507 = 302,000 pounds (453 m.lire)	5.400 m.lire x 0.1507 = 813.8 m.lire
MAINTENANCE (4% of installed capital)	80,000 pounds (120 m.lire)	216 million lire
STAFF - no. & annual cost	16 people excl. management and admin. services; welfare charges excl.: superintendents = 2x4420 pounds=8840 p. (2x 6,630 = 13.26 m.lire) shift workers = 12x3380 pounds =40560 p. (12x5,07 = 60.84 m.lire) day workers = 2x2860 pounds = 5720 pounds (2x4,29 = 8.58 m.lire) Total ~ 55,000 pounds (82,5 m.lire)	47 people incl. management and admin. services; walfare charges incl.: managers = 1x20 m.lire = 20 m.lire shift workers = 25x8 m.lire=280 m.lire day workers = 5x6 m.lire = 30 m.lire Total = 402 million lire
ADDITIONAL COSTS	38% of wages	incl. in staff costs
(welfare charges etc.)	21,000 pounds/annum (31.5 m.lire)	" " " "
MANAGEMENT	9,000 " (13.5 m.lire)	" " " "
ADMINISTRATION	50% staff cost + additional charges 38000 pounds (57 m.lire)	" " " "
ELECTRICAL ENERGY	40 kWh/t ≈ 800 kWh/h - 2,24x10^6 kWh/annum 0.02 pounds/kWh (30 lire/kWh) 50000 pounds/annum (75 m.lire/annum)	27 kWh/t - 540 kWh/h - 1674000 kWh/annum 30 lire/kWh = 50.2 million lire/annum
AUXILIARY FUEL FOR PROCESS	—	30 kg/h - 1,5 kg/t -93,5 t/annum type: fuel oil cost: lire 90000/t - 8.4 m.lire
FUEL FOR HEATING	natural gas: 12676 x 10^6 kJ/annum 4,500pounds/annum (6,75 m.lire/annum)	not indicated - 3,75 m.lire/annum assumed
WATER	1500 pounds/annum (2.25 m.lire/annum)	20 m^3/h - 1m^3/t - 62000 m^3/annum 1.55 million lire/annum (25 lire/m^3)
CHEMICAL PRODUCTS	1000 pounds/annum (1.5 m.lire)	—
DISPOSAL OF ASH AND RESIDUE	58% of material treated = 36000 t/annum 1.5 pounds/t - 54000 pounds/annum (2250 lire - 81 m.lire/annum)	41% of the material is incinerated, 14% ash remains for dumping = 8600 t/annum - 2250 lire/t - 19.3 million lire

ENCLOSURE II

RECOVERIES		
- Urban fuel	30% - 18600 t/annum - 6 pounds/t(9000 lire/t)-112000 pounds/annum (168 m. lire)	---
- Glass	5% -3100 t/annum - 8pounds/t (12000 lire per t) 25000 pounds/annum (37,5 m.lire)	---
- Ferrous material	7% - 4340 t/annum - 12 pounds/t (18000 lire/t) 52000 pounds/annum (78 m.lire)	2.8% - 1735 t/annum - 70000 lire/t 121.5 million lire/annum
- Paper pulp	---	13.5% - 8970 t/annum - 65000 lire/t 544 m. lire/annum
- Animal feed	---	10% - 6200 t/annum - 70000 lire/t 434 m.lire/annum
- Compost	---	24% - 14880 t/annum - 4000 lire/t 59.5 m.lire/annum
- Plastic	---	2% - 1240 t/annum - 210000 lire/t 260.4million lire/annum
TOTAL REVENUES	189000 pounds/annum (283.5 m.lire)	1419.4 million lire/annum

ENCLOSURE II

ANNUAL BALANCE SHEET

CAPITAL COST	302,000 pounds (453 million lire)	813.8 million lire
MAINTENANCE COST	80,000 " (120 " ")	216 " "
STAFF COST	55,000 " (82,5 " ")	402 " "
ADDITIONAL COSTS	21,000 " (31.5 " ")	incl. with staff
MANAGEMENT	9,000 " (13.5 " ")	" " "
ADMINISTRATION	38,000 " (57 " ")	" " "
ELECTRICAL ENERGY	50,000 " (75 " ")	50.2 million lire
AUXILIARY FUEL	--- ---	8.4 " "
HEATING	4,500 " (6.75 million lire)	6.75 " "
WATER	1,500 " (2.25 " ")	1.55 " "
CHEMICAL PRODUCTS	1,000 " (1.5 " ")	---
DISPOSAL OF RESIDUE	54,000 " (80 " ")	19.3 " "
TOTAL COSTS	616,000 pounds (924 million lire)	1518 million lire
REVENUES	189,000 " (283.5 " ")	1419.4 " "
NET COST	427,000 " (640,5 " ")	98.6 " "
SPECIFIC COST PER t OF DISPOSED WASTE	6,9 pounds (10400 lire)	1600 lire

ENCLOSURE III

CONTRIBUTION OF VARIOUS COSTS TO ANNUAL TOTAL OPERATING COST %

COSTS COMPARED TO TOTAL COST	WARREN SPRING LABORATORY		PERUGIA	ROME
	10 t/h	20 t/h	10 t	20 t
CAPITAL EXPENDITURE	50,8	49	53,6	53,6
WAGES AND ADMINISTRATION	22,2	20	26,1	26,4
SERVICES	20,5	22,2	19,7	18,7
DISPOSAL OF RESIDUE	6,5	8,8	0,6	1,3
REVENUES	22,6	30,7	49,3	93,5
COSTS PER t OF TREATED WASTE	10,4 pounds (15600 lire)	6,9 pounds (10400 lire)	19.300 lire	1.600 lire

11 PRELIMINARY PROPOSALS FOR A RESEARCH AND DEVELOPMENT PROGRAM

11. 1 RECOMMENDATIONS FOR CONCERTED ACTION

There are already several major research programmes in progress or planned within several member countries of the Community. The project team is very concerned to avoid recommending duplication of this research. It is felt, however, that there are certain areas where international discussion and co-ordination of this research would enhance its value, both to individual countries and to the Community as a whole. The spirit of international co-operation which has been experienced during the present study has been of great benefit and this could provide a foundation upon which further collaborative work could be built.

It is therefore recommended that a programme of concerted action should be established, provided that the support of national governments can be obtained. It is recognised that in some cases existing R & D is funded by commercial interests and could not be included in a concerted action programme. The programme should be organised to cover the following aspects of household waste sorting technology:

a) Work in progress or planned in member countries (e. g. the Doncaster prototype plant in the U.K., the Bundesmodell Abfallverwertung in Germany) should be monitored, existing links between research groups should be maintained and néw ones encouraged wherever possible. These links should be used to promote comparative investigations of different systems under consistent conditions, and studies of the effect of varying the composition of the feed. It is recognized that different project timescales might give rise to problems in making comparisons, but when the planned new generation of experimental plants working at a realistic scale is in operation co-ordination of research an parallel investigations in different locations would be very valuable.

b) Standard methods should be established for sampling and analysing household wastes, specifying the quality of waste-derived products, and reporting cost and related economic data. Comparison of processes in different locations is very difficult, but the value of such comparisons would be greatly enhanced if better standardisation of feed analysis, process parameters and product specification were achieved. The effect of statutory requirements applying to waste recovery in different member countries on the design and viability of waste sorting processes might also be considered.

c) Potential health hazards arising from the handling, treatment and storage of domestic waste and related products should be investigated. This is an area which would require considerable co-ordination of testwork and data collection.

The method envisaged for implementation of the concerted action programme is a series of meetings of technical experts from the member countries. Because of the wide range of topics for discussion it is suggested that these meetings should take the form of symposia lasting 2-3 days with, say, 20 invited delegates per symposium. The estimated cost of a four year programme of 3 symposia per year is 200,000 units of account.

This sum would not include any funds for specific projects arising from the concerted action programme.

11.2 RECOMMENDATIONS FOR INDIRECT ACTION

It is recommended that the major proportion of the financial resources allocated to R & D in waste sorting should be used in a programme of indirect action. Research is recommended into topics where it is felt that more fundamental studies or the development of new or improved separation techniques are required. The recommended topics for investigation come under three headings:

a) Separation Technology

b) Material Recovery

c) Energy Recovery

) Separation Technology

The possibility of two to three projects in this area is envisaged. The highest priority is placed upon an investigation of air classification, but liberation and comminution of waste is also recommended for study.

1. Air Classification

There are several air classification systems available, but there is a serious lack of the information necessary for scale-up of pilot installations and to enable the best choice for a particular situation to be made. It is therefore recommended that a fundamental investigation of the parameters affecting separation should be carried out prior to larger scale trials in association with the experiments on front-end systems. The main aims of this work should be:

. to compare existing types of air classifier under consistent conditions;
. to investigate the effect of changing design variables and composition of the feed;
. to establish criteria for the design and scale-up of air classification systems to process household wastes.

2. Liberation/Comminution

The coice of a front-end system for a sorting plant is still largely a subjective one. Information in the literature is of limited help because of the varying conditions under which the experiments are carried out. It is therefore proposed that comparative investigations of shredding and sizing systems at a scale of at least 10 tonnes/h should be carried out under consistent conditions with a clearly defined feed. Particular attention should be paid to the following points:

. the suitability of the processed waste for subsequent separation into products;
. elimination of gross oversize materials in sizing plants;
. maintenance and reliability.

The concerted action programme could be of assistance in promoting this research. The cost of purchasing new equipment could be minimised by co-ordination of studies in different research groups using existing equipment as far as possible.

b) Materials Recovery

The two most important topics for further research are paper fibre recovery and plastics recovery. Two projects in each of these topics are envisaged.

1. Paper Recovery

In most locations paper is potentially the most valuable constituent of the waste so there is a strong incentive for its recovery. The importance of household waste as a source of secondary fibre has already been recognised by the CREST Working Party on Paper Recycling, and a number of research topics in this field have been included in a proposal for a research programme on paper and board recycling. It is felt that certain aspects of this earlier programme have been largely achieved in the present study. In particular most of the work recommended in Part A of the programme has been done in the present study e. g. classification of urban wastes, the technical feasibility of separating paper fibre from household wastes and economics of process ing to obtain a fibre product. Further effort should concentrate on the recommendations in Part B anc C which relate to the use of urban fibre by the paper industry and health problems which might arise from its use. In addition it is considered very important that support should be given for further R & D on paper separation technology, an aspect which was not included in the earlier recommendations by the Working Party:

- most existing paper fibre recovery systems are based in part on air classification to provide a paper-rich concentrate for further upgrading. There is a requirement for research into the design and operation of air classification systems to produce a better paper-rich product;
- further work is needed on methods of separating plastics film from paper which are less costly in terms of capital equipment and energy consumption than existing ones;
- the development of other novel methods of paper recovery should be encourages. These might be based, for example, on the selective ditection and removal of specific contraries from a paper-rich concentrate;
- as an alternative to dry separation of a paper fibre product, wet processing at the front-end of the paper mill should be investigated in co-operation with the paper industry.

2. Plastics Recovery

Recovery of paper fibre will normally result in the production of a by-product which is rich in plastic film. In some member countries plastic bottles are a significant constituent of household wastes and these can also be separated as a product. Research paying particular attention to the following aspects:

- the indications are that the size and nature of the potential market for plastics products recovered from household wastes varies considerably between the member countries. In some locations it might be possible to sell a mixed plastic product, while in others segregation of polymer types will be necessary. Similarly, requirements for reclaimed polymer for use in moulding or film blowing applications will vary. A community-wide market study is therefore recommended to determine where R&D effort might be most profitably applied;

- there are several processes available for the manufacture of products from mixed waste polymer. Although perhaps the main problem to be solved in this field is the creation of new markets for the products, there is scope for further work on the feedstock formulations required for specific end-products, and the effect of additives on product quality;

  the potential for developing technology for separation and cleaning of mixed and contaminated polymer waste merits investigation. The nature and level of contaminants which inhibit the use of reclaimed polymer in standard moulding or film blowing equipment should be studied, taking into account the possibility of developing new chemical additives to counteract the degradation of secondary polymers during moulding.

c) Energy Recovery

The project team is aware that an EEC Energy Research Programme was adopted by the Council of Ministers in 1975. One of the main subject areas in Energy Conservation and project proposals have already been received which relate to the use of the energy content of wastes. This is therefore, another area where close co-ordination of projects by the Commission is essential. It is considered that further work is needed on the use of both shredded and densified waste-derived fuels, and the following project areas are suggested for consideration:

- Community support should be given to encourage an investigation of the use of shredded waste-derived fuel (for example, in the generation of electricity); shredding, handling and firingsystems for suspension-fired boilers will need to be developed, but there is much relevant experience in the U.S.A. which can be drawn upon;

  experience in the U.K. suggests that for industrial use a densified fuel product is most likely to have adeguate storage and handling characteristics. A great deal of work is required on the continuous production of fuel pellets or briquettes. Most work carried out to date has used machines designed for agricultural purposes and many problems have been encountered. Pilot-scale tests to measure specific power consumption, die wear and throughputs are needed't enable suitable equipment to be designed. Methods of handling densified waste--derived fuel are needed and extended firing trials are necessary to determine the effect of firing waste-derived fuel on corrosion, fouling of boiler tubes and atmospheric emissions. Possible additives to the fuel from the point of view of increasing its calorific value, prolonging its storage life, reducing its susceptibility to water and inhibiting biological activity should be examined.

) Funding

In making suggestions for the allocation of funds to the three project areas the project team has taken into account the close inter-relationship between these areas and the fact that results of the work on separation technology will support and benefit research into materials and energy recovery. Nevertheless, materials recovery is regarded to be of primary importance and the largest share of the funding should be directed to this area. With these considerations in mind the following allocations of funds for indirect action over a period of 4 years are suggested:

. separation technology	(3 projects)	0. 8 - 1. 0 mua
. materials recovery	(4 projects)	1. 9 - 3. 0 mua
. energy recovery	(2-3 projects)	0. 8 - 1, 2 mua
	total	3, 5 - 5, 2 mua

It is expected that the indirect action programme would attract a 50% contribution from the Commission i. e. a sum of 1. 75 - 2. 6 mua.

A total budget requirement of 3. 7 - 5. 4 million units of account over a period of 4 years is suggested for the combined concerted and indirect action programmes.

11.3 SPECIFIC RESEARCH AND DEVELOPMENT PROGRAMME RECOMMENDED FOR ITALY

In Italy, research into solid waste recycling is aimed at improving recycled products rather than perfecting recycling techniques.

A number of plants have in fact been amply proven commercially (Perugia and Rome), while others have been tested at prototype level (DB plant of Ambivere).

Ongoing research thus concerns the improvement of recycled products or the perfecting of new ones.

At the Rome plant, for example, Sorain is experimenting:

- the separation of glass by means of a 'Sortex' apparatus (see par. 2 - enclosure II);
- the making of 'urban fuel' bricks from organic material earmarked for compost (this research is part of the N. R. C. programme aimed at energy saving).

Fiat Engineering is engaged in research into the utilization for energy purposes of solid industrial waste similar to urban waste.

Waste of industrial origin consists of a great variety of materials of different physical and chemical properties.

Fiat has tackled the problem as described in chapter 3.

The composition typical of the waste from which the secondary fuel is derived is shown in table I.

This class of waste is to all intents and purposes the same as urban waste. Thus the research in hand will also offer indications for the use of urban waste as a source of secondary fuel.

Table I - Mean percentage composition of waste from mechanical processes and from company offices and canteens

MATERIAL	PROCESS WASTE	WASTE FROM OFFICES AND CANTEENS
PAPER	51	2
PLASTIC	12	6
RAGS	7	-
IRON	2	-
METALS	8	22
LEATHERCLOTH	4	-
WOOD	4	-
ORGANIC SUBSTANCES	-	44
VARIOUS	12	6
HUMIDITY	-	20

The purpose of the research is to experiment the use of secondary fuel in the production of energy, as an aid or partial alternative to traditional solid, liquid or gaseous fuels.

Experiments are intended to:

- lay down the modifications required for a thermal plant to make it suitable for feeding with secondary fuel;
- establish optimal modalities for feeding or supplementing traditional fuels for the purpose of guaranteeing constant thermal plant performance;
- assess the contribution of secondary fuel to the unit's energy balance;
- assess the ecological impact of the use of secondary fuel from the viewpoint of atmospheric emissions, in different feed conditions.

The research will therefore be broken down into the following stages:

1. Modification of a steam producing boiler, currently used for the supply of liquid fuel, and setting up of ash feed and extraction apparatus.

2. Operating tests using secondary and traditional fuels, under different operating conditions, with relative percentages varying from 10 - 90% to 50 - 50%.

3. Technical and economic appraisal of the use of solid fuel under different operating conditions.

4. Evaluation of atmospheric emissions consequent on the use of varying percentages of secondary fuel.

5. Identification of optimal operating parameters.

6. Processing of final reports.

The research will last two years.

Similar research will have to do with the utilization cf 'urban fuel' to feed cement work ovens. The urban fuel could be used in the form of pellets or else pulverized and put into the ovens directly.

The ash of urban fuel contains elements (Si, Al, Ca, Fe, Mg) which are normal constituents of cement; they can thus be added directly to the cement.

One sector which is the subject of special attention is that of the improvement of the quality of paper pulp and plastic-paper separation. Here, however, researches are closely connected with the recycling plant and, for prudential reasons, are being carried out directly by the Companies as part of its own research programmes.

Some researches are recommended in the field of plastic recovery.

In the solid urban waste the presence of plastic is revealed in prevalence with light plastics (bags for waste collection, bags for supermarket and so on).

Such plastics may have a possible placing in the market as interest the reclaiming activities.

The mix of light plastics recovered from a recycling plant can be sold to the reclaimer with values that vary from a minimum of 50 Italian Lire per kg to a maximum of 100 Italian Lire per kg.

The following reclaiming and transformation in granulate brings to a product marketable at:

. 300 Italian Lire per kg if granulate for pressing;
. 400 " " " " " " " refilming.

In the granulate production for refilming the claimer uses homogeneus rejects of plastics and this is with the same 'meltidex' degree, then the mix of plastics recovered from the wastes could present some disadvantages.

A deepen analysis of the regeneration techniques is needed.

A P P E N D I X

Comments on the U.S.A. and European systems
visited in the course of the study, and comparisons
with Italian systems

1

EXISTING PLANTS VISITED BY THE WORKING GROUP E. E. C. /C. R. E. S. T. OR KNOWN

NATION	ORGANIZATION	LOCATION OF THE PLANT
U.S.A.	RAYTHEON (V) UNION ELECTRIC Co. BLACK CLAWSON (V) TELEDYNE (V) U.S.BUREAU OF MINE (V) NCRR (V) CITY OF AMES (V) PEARSON OCCIDENTALE (V)	MONROE COUNTY (N.Y.) ST.LOUIS (MISSOURI) FRANKLIN (OHIO) BALTIMORE COUNTY WASHINGTON NEW ORLEANS AMES (IOWA) CHICAGO EL CAJON (St. DIEGO)
CANADA	ONTARIO CENTRE FOR RECOVER RESOURCE (V)	TORONTO
ENGLAND	WARREN SPRING LAB. (VF) W.S.L. SYSTEM	STEVENAGE DONCASTER NEWCASTLE
SWEDEN	FLAKT (V)	STOCKHOLM
HOLLAND	TNO (VF)	HAARLEM
GERMANY	IAKB - AACHEN UNIV. (VF) KRAUSS-MAFFEI	AACHEN MUNICH
SPAIN	ADARO (V)	MADRID
ITALY	FIAT CECCHINI COMPANY (VF) SORAIN-CECCHINI (VF) DE BARTOLOMEIS Co. (VF)	TURIN PERUGIA ROME AMBIVERE (BERGAMO)
FRANCE	COMBOR (V) BRGM (V)	PARIS ORLEANS

(V) PLANT VISITED
(VF) PLANT VISITED ALSO BY FIAT ENGINEERING REPRESENTATIVES

2

EXISTING EUROPEAN TECHNOLOGIES

The following technologies are preferred depending on the importance attributed to the materials to be recovered and the make-up of the waste (*):

a) Cecchini system: paper pulp, animal feed, compost, plastic;

b) W. S. L. system: paper, urban fuel (possibly non-ferrous metal and glass);

c) TNO system: paper in bales, plastic (possibly compost or brick-making material);

d) systems deriving from the U. S. Bureau of Mines project (Fiat, Madrid, Paris, etc.): urban fuel;

e) De Bartolomeis system: paper pulp, compost, urban fuel.

The cost of the Cecchini system for 300-400 t per day plants is about 20 million lire per tonne of waste treated per day.

The W. S. L. and TNO systems appear to be less costly as investments (10-12 million lire/t/day) but the material they recover is more limited, being centred prevalently on paper, recovered in bales and not in pulp form (like the Cecchini System).

The USBM type systems also cost little (12 million lire/t per day for the Madrid plant) but they can only offer more limited (urban fuel 3,000 kcal/kg) and less valuable recoveries.

Worth of recoveries is in fact:

- USBM system (Madrid) = 4,350 lire/t of waste treated
- W.S.L. system = 5,000 " " " "
- Cecchini system = 18,800 " " " "

From a technical standpoint, the following remarks can be made about the European systems visited by Fiat Engin. representatives:

- Perugia plant : sound plant, very well designed and built with considerable thoroughness;
- Rome South plant: similar to the Perugia plant, what we saw left a good impression;

(*) All the systems recover scrap iron and so we will not mention the fact again

- Ambivere plant: fine plant at prototype level, no accompanying lines (paper, compost working etc.);
- TNO plant at Haarlem: similar to our impression about Ambivere;
- Aachen plant: this is still at laboratory level; before it becomes operative it will require thorough design and a lengthy experimentation period;
- W. S. L. plant at Stevenage: see our comment about Ambivere and Haarlem.

3

SITUATION OF THE ITALIAN RECYCLING PLANT INDUSTRY

Thanks to Cecchini technology, Italy is the only country in Europe where experimental plant has been operating for some ten years and is now on a commercial basis; the De Bartolomeis plants are also now operating at industrial level.

In addition to Impresa Cecchini of Perugia and the Sorain-Cecchini Company of Rome which design, build and sell or operate such plant, a number of other companies are also operating in the recycling sector:

- the De Bartolomeis Company which produces a composting and incineration line and has come out with a 10 t/hour plant for compost, paper pulp, scrap iron and, if necessary, urban fuel;
- Fiat, which is setting up its own 75 t/day industrial waste recycling plant (USBM type technology);
- Ferrero of Vado Ligure, which is capable of building recovery plant equipment (ballistic separators for glass, compost equipment, etc.);
- Siet/Tecneco, a Company which builds incineration ovens and can also offer paper separation systems,etc.

In Europe generally and in Italy in particular, the vital problem in our opinion is the sale of recovered material and thus plant management.

In effect, there recycling plants (which are never economically self-sufficient but require a subsidy from the authorities for each tonne of waste treated *) are more or less economical depending on the price of the materials sold.

The price of materials fluctuates enormously and is conditioned by a market that is difficult to control.

If the plant management is able to use, by way of side activities, the products it has recovered, it is more likely to do well (examples are Cecchini of Perugia for feed and compost, Sorain-Cecchini in Rome for feed and plastic, and Fiat in Turin which uses urban fuel within its industrial waste disposal centre and the scrap iron within its production cycles).

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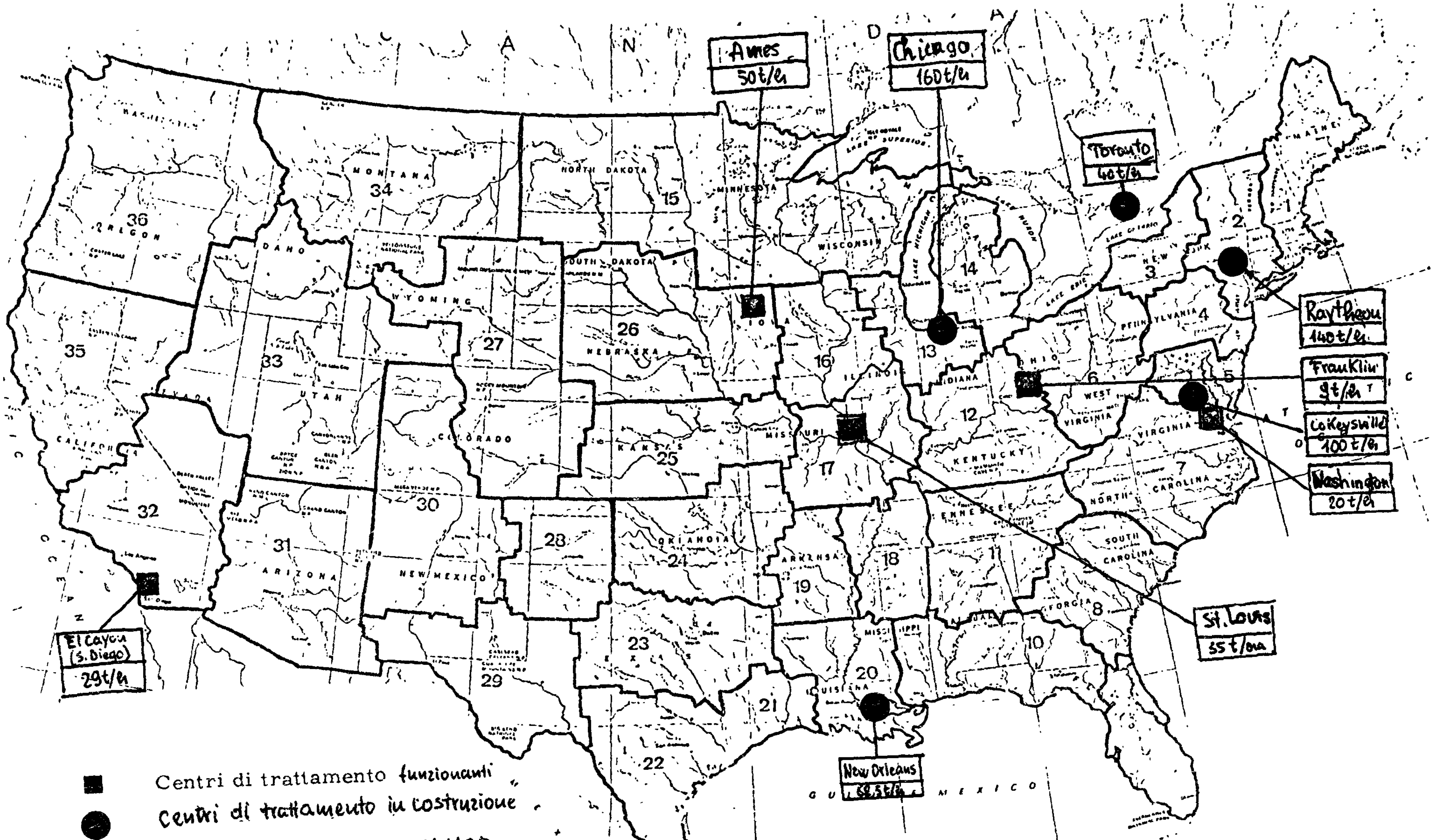
* In Rome, the Town Council pays some 5,000 lire/t of waste treated; according to W.S.L. studies, a USBM type plant of 20 t/h x 16 h/day would require a subsidy of 11.5 Lst./t, i. e. about 17,000 lire/t, while a W.S.L. type plant of 20 t/h x 16 h/d would need a subsidy of 6.9 Lst./t, i. e. about 12,000 lire/t.

The choice of the most appropriate system is thus bound up with individual situations downstream from the plant (paper mills prepared to take recovered paper, heating plants prepared to burn urban fuel, etc.).

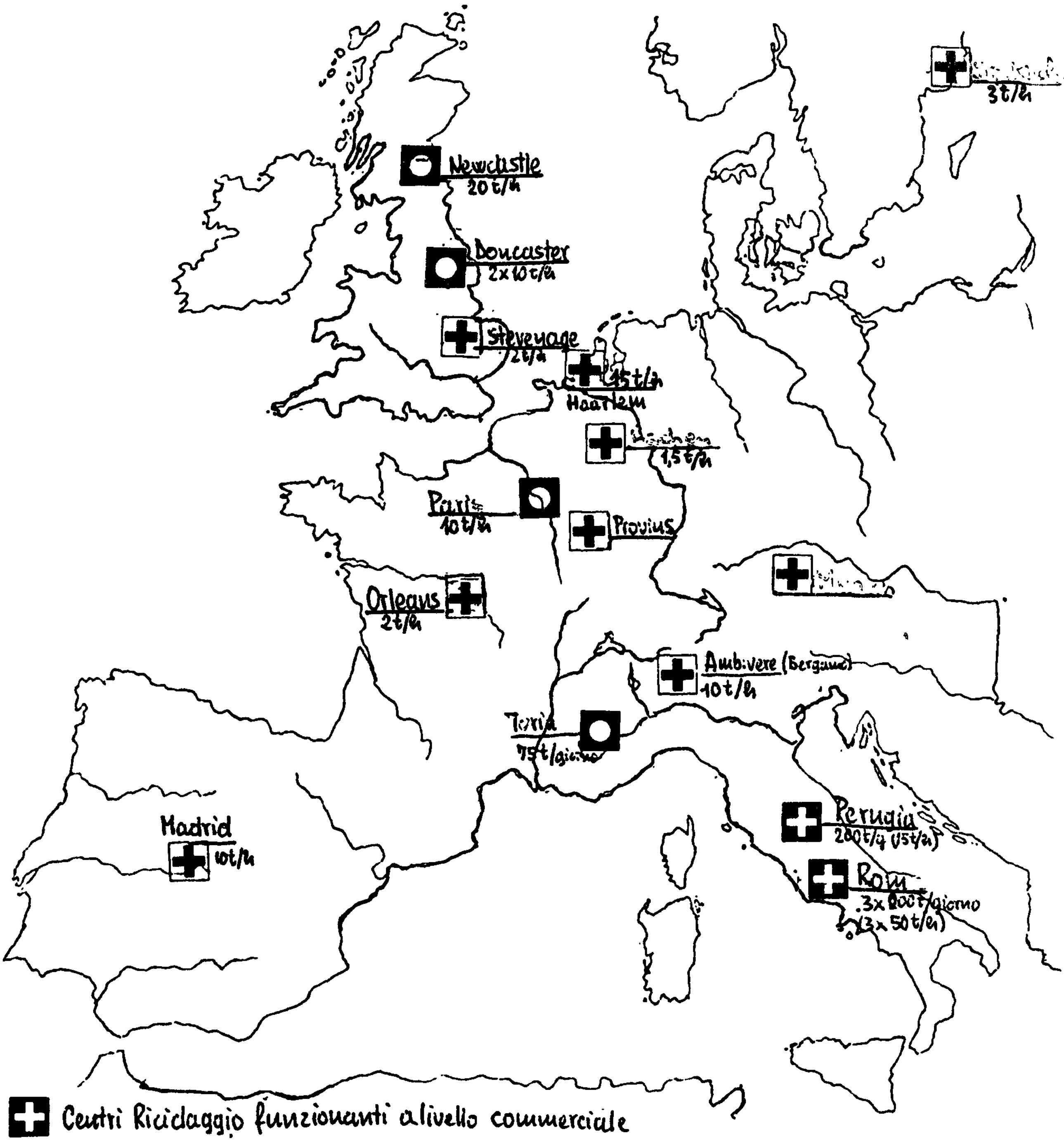


Impianti di Riciclaggio negli USA

Recycling plants in the U.S.A.

Impianti di Riciclaggio in Europa

(Recycling plants in Europe)



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COMMISSION OF THE EUROPEAN COMMUNITIES
(Directorate General XII - Research, Science, Education)

HOUSEHOLD WASTE SORTING SYSTEMS IN THE FEDERAL REPUBLIC OF GERMANY

A report from the Umweltbundesamt

November 1977

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CONTENTS

1. Introduction

In the Federal Republic of Germany, there is a strong interest in the recovery of useful products from household wastes. Government and municipalities as well as science and industry are aiming at three main goals:

- Reducing the quantities of household wastes that have to be landfilled or incinerated
- Exploiting alternative sources of raw materials and saving the natural resources
- Developing an economic, environmentally-safe disposal system

Two different approaches towards resource recovery have been investigated in the last years:

- Sorting at source
- Mechanical sorting systems

Both systems have their own justification. While sorting at source, especially for glass recovery, is already used in many communities only two mechanical sorting systems were developed in the last five years and have been tested in pilot-plants. Because of the great interest in such plants and - on the other hand - the uncertainty about their practicability the Federal Minister for Science and Technology and the State of Baden-Württemberg have agreed to support a full-scale household waste mechanical sorting plant in the Landkreise Reutlingen and Tübingen. This is referred to as "Bundesmodell Abfallverwertung" (Federal Resource Recovery model).

This report gives a summary of quantities and qualities of household waste in Germany, describes the so far developed mechanical sorting systems and the planned Federal Resource Recovery Model. Finally a comparison and evaluation model for mechanical sorting systems and recommendations for further R & D programmes are suggested.

2. Household Waste Disposal Statistics

2.1 Quantities of Waste for Disposal

In 1975 the consumer waste production (i.e. household waste including bulky wastes) was estimated to be within the range of 17o - 330 kg per capita per year. The total production was about 18 · 10^6 tons per year.

The annual increase in consumer wastes is expected to be 3 - 6 %. The projected total for 198o is 2o to 25 · $1o^6$ tons per year, the per capita rates will be within the range of 25o to 4oo kg per year. In general a degressive rather than a progressive development is expected.

2.2 Waste Collection and Disposal

Presently more than 9o % of the wastes are collected by regular mostly weekly municipal or private services. The distribution among the three common disposal methods landfill, incineration and composting is shown in table 1:

Disposal Method	No. of Plants	Population served Mio.	% of Total	Annual Waste Disposal x $1o^6$t
Landfill		47,1	75,9	13
Incineration	39+	13,4	21,7	4,5
Composting	19	1,5	2,4	0,5
		62,00	1oo,o	18,o

Table 1: Waste disposal in the Federal Republic of Germany (+ in 1975)

2.3 The Composition of Household Waste

Recent information on household waste composition is available from Heidelberg (1976), Stuttgart (1974), Reutlingen and Tübingen (1974/1975), Hamburg (1975) and Aachen (1974) as shown in table 2:

	Aachen 1974	Heidelberg 1976	Stuttgart 1974	Reutlingen 1974/75	Hamburg 1975	Bundesmodell Abfallverwertung
Glass	13,5	13,8	9,9	13,4	22,7	9,o
Paper, Board	3o,8	23,4	14,7	13,1	23,1	28,o
Metal	6,9	5,2	5,2	4,4	4,5	5,5
Textiles, Plastics	4,5⁺	8,4	6,2	8,2	4,6⁺	4,0⁺
Wood, Leather, Rubber, Bones		1o,4	4,1	5,6	3,7	3,o
Other Organic Components	16,4	29,6	52,4	45,8	3o,o	22,5
Unidentified	27,9	9,2	7,4	9,5	11,4	28,o

⁺ = plastics only

<u>Table 2</u>: Household Waste Composition (% by weight)

There is only preliminary information on the composition of bulky waste (Sperrmüll) as collected separately by special vehicles.

Within a feasibilty study some 5o tons of bulky waste were hand - sorted in Landkreis Ludwigsburg in Baden-Württemberg. The results as shown in table 3 suggest that bulky wastes would be more attractive raw materials for resource recovery activities than normal household wastes.

Components	Waste Composition (% by Weight) Test 1	Test 2
Metal	5,1o	8,66
Glass	5,75	4,o7
Ceramics	1,55	2,17
Textiles	3,o9	3,15
Plastics	6,78	7,4o
Paper	3o,39	27,28
Cardboard	18,67	15,91
Wood	23,32	26,99
Unidentified	5,35	4,37
	100,00	100,00

Table 3: Bulky Waste Composition in Landkreis Ludwigsburg 1975/1976

A further analysis program for household waste and bulky waste composition is just being performed in the Reutlingen- and Tübingen - area. The results of this program will be available in 1978 and will give special information about the interplay of household waste composition and bulky waste composition under defined waste disposal conditions.

Component	Sweden	Italy (Rome)	Netherlands	U S A	Federal Republic of Germany
Paper	5o	25	25	5o	28
Glass	1o	6	11	9	9
Metal (total)	7	3,5	3,2	9	5
Fe	6	3,1	3,1	7,5	4,5
Al	o,5			o,8	o,2
Nonferrous (total)	1,o	o,35	o,1	1,5	
Plastics	9	8	5	1	4
Other Organic Components	22	45	46	23	35

<u>Table 4</u> : Recoverable Materials Contents (% by weight) - International Comparison

2.4 Materials Recoverable from Household Wastes

The following main components are subject to materials recovery activities:

paper and board
glass
metal (ferrous metal and Aluminium)
plastics
organic components (raw material for composting)

In table 4 a rough international comparison of the contents of these components is given. It shows clearly that the content of paper and board in household waste of the United States of America and of Sweden is twice as high as in Germany, Italy and the Netherland, wheras the content of glass is nearly everywhere the same. In contrary the household waste of Italy and of the Netherlands show a very high content of biodegradable organics.

According to presently available experience only a portion of the recoverable materials can be separated by mechanical sorting as indicated in table 5:

Component	Content (% by weight)	Yield (% by weight)	Recoverable (% by weight)
Paper and Board	28	7o	2o
Glass	9	8o	7
Ferrous Metal	4,5	9o	4
Mixed Plastics	4	5o	2
Total	45,5		33

Table 5: Yield of recoverable materials from household waste

Preliminary information on the expected benefits of materials recovery is compiled in table 6. In this table the columns give information on:

- Amount of recoverable materials (% by weight)
- Demand of tipping space (% by volume)
- Gross revenue (in DM) obtainable for recovered materials from household wastes. "Minimum revenue" (1) refers to revenue under unfavourable economic conditions. "Maximum revenue" (2) shown in brackets, relates to revenue under optimistic market assumptions.
- Energy consumption for the conversion of raw materials in semi-processed raw material and of recovered materials in semi-processed raw materials (in Gcal/t)
- Transport conditions for the recovered materials
- Justifiable transport-distance to customer ,that is the distance at which the "minimum revenue is absorbed by the transport costs.

Table 6 shows that it should be possible to achieve á gross revenue of DM 12,44 (minimum) to DM 23,65 (maximum) per ton of processed household waste.

Table 6. Summary of the Most Important Data on Products

	Yield % by weight	Tipping space required % by volume	Minimum Revenue 1) (Maximum Revenue) 2) DM/t Material	 DM/t Refuse	Energy required for conversion Semi-processed raw material Gcal/t (kWh/t)	 Semi-processed waste Gcal/t (kWh/t)	Transport conditions	Justifiable Transport Distance to Customer
Ferrous metal	4	8	35.- (70.-)	1.40 (2.80)	6 (6,900)	0.5 (600)	compacted (rough cleaned)	indeterminate
Paper	20	30	30.- (60.-)	6.00 (12.00)	2 (2,300)	0.17 (200)	bales	Up to 50 km
Glass	6	13	20.- (25.-)	1.20 (1.50)	2.8 (3,200)	0.3 (350)	cullet (washed)	Up to 40 km
Residual Inert Matter	7		2.- (5.-)	0.14 (0.35)	-	-	in bulk	Up to 20 km
Compost Raw Material	30	20	5.- (10.-)	1.50 (3.00)	-	-	in bulk (sucks)	Up to 30 km
Plastics	2	4	110.- (200.-)	2.20 (4.00)	7 (8,000)	0.2 (250)	bales (washed)	indeterminate
Other	31	25	-	-	-	-	in bulk	-
Σ	100	100	-	12.44 (23.65)	-	-	-	-

3. Products of Waste Sorting Plants

At the moment it is a difficult task to describe the market possibilities for waste derived products. Still there are several psychologic prejudices against all products produced out of household waste. Besides that there is little knowledge about the obtainable product qualities which makes it impossible for the reusing industry to name prices and specify product qualities. This is one of the reasons why it is indispensable to build up a full-scale mechanical sorting plant accompanied by research and development programs for reusing the produced materials.

Products of such a plant would be: paper and board, glass, ferrous metals, plastics and composting material.

3.1 Paper

German household wastes contain approx. 2o - 3o % by weight of paper and board. Because of this high content and the technological possibilities to sort the paper by air-classification all mechanical sorting systems produce a paper product at the first stage. As many different types of air-classifiers are installed and tested it seems impossible with the present technics to recover waste-paper of higher, satisfactory to paper industry quality. The light product of most air-classifiers contains between 1o and 25 % by weight plastics, light textiles and other contaminations and has a high water content.
Waste paper from mechanical sorting plants is competing with mixed waste papers of lower quality which are obtained by sorting at source. The price for mechanical sorted waste paper will be half the price of the lowest quality separated at source waste paper. That means that a price of 35,-- - 4o,-- DM/t will be available.

Using the mechanicly sorted waste paper for production of pressed articles the price will be around 5o,-- DM/t. If the paper will be converted to paper fibres inside the mechanical sorting plant a price of 1oo,-- - 15o,-- DM/t will be realistic.

3.2 Ferrous Metals

The content of ferrous metals in German household wastes lies between 4 an 5 % by weight. 8o - 9o % of this material are tin plate cans which can be sorted easily by magnetic separators. Therefore the most German composting and incineration plants have been separating ferrous scrap since quite a number of years.

The greatest obstacle to processing in the steel industry has been the big content of copper and tin and has made the detinning of tinned scrap necessary. Detinning of not baled tin plate cans in keeping with the latest technological development is economical for quantities above 1oooo t/a. These quantities in connection with reasonable transport costs are available at a few places in Germany only. Therefore a R & D programme for the development of a detinning system by hydro- and pyrometallurgy is financed by the Ministery of Science and Technology.

In the mean-time the Association of the German Ironworks has agreed to accept all tin scrap sorted in composting, incineration and household waste mechanical sorting plants.

As in the UK the ferrous scrap market is currently in recession. The obtainable prices for baled tin scrap are between 7o,-- and 1oo,-- DM per ton, an average price of 8o,-- DM per ton of cleaned and baled tin scrap seems to be realistic.

3.3 Glass

The production of container glass in the Federal Republic of Germany is about 2 88o ooo tons/year. 29 % of the produced container glass is green glass, 24 % amber glass and 47 % flint glass. 12 of the 34 container glass factories are producing green glass and are therefore able to remelt mixed cullet. For all other glass factories it is necessary to clean the mixed waste glass, that means to take out all ceramic, ferrous metal and aluminium particles and to colour-sort the mixed cullet into the colours flint, green and amber. The purity demands of the German container glass industry are given in the next table (table 7) :

Permissible Impurities	Remelting for the Production of: Green Glass	Amber Glass	Flint Glass
Glass Qualities	Only typical sodium hydroxide-, calcium oxide-, silicic acid-glass is allowed (no lead-, borate-glass)		
Liquids	No acids and alkaline solutions		
Organic Substance	max. o,o1 % by weight	max. o,o1 % by weight	max. o,o1 % by weight
Magnetic Materials	No magnetic materials allowed		
Non-Magnetic Anorganic Materials	max. o,o1 % by weight max. 1 mm Ø	max. o,o1 % by weight max. 1 mm Ø	max. o,o1 % by weight max. 1 mm Ø
Non-Magnetic Metals	max. o,o1 % by weight no Lead max.5 mm Ø	max.o,o1 % by weight no Lead max.5 mm Ø	max. o,o1 % by weight no Lead max.5 mm Ø
Waste Glass of Other Colours:			
Green Cullet		max.o,2 % by weight	max.o,o1 % by weight
Amber Cullet	max.15 % by weight		max.o,o1 % by weight
Flint Cullet	max.1o % by weight	max. 5 % by weight	

Table 7 : Purity Demands on Waste Glass for Remelting in the Container Glass-Industry (Preliminary Standard)

In 1976 26o ooo t of waste glass have been sorted at source using centrally located glass recycling containers. The German container glass-industry has estimated that nearly 1o % of the whole of glass in household wastes can be recycled and remelted. One of the reasons for the great interest of the container glass-industry is that o,2 per cent energy saving is possible for each per cent of reused cullet.

The average price for colour-mixed glass is approx. 5o,-- DM per ton, for colour-sorted amber glass 6o,-- DM/t, for colour-sorted flint glass 7o-75,-- DM/t. The highest price is available for absolute clean ready for furnace glass.

3.4 Plastics

There is no technical or economic difficulty to reuse clean sorted waste plastics. But at the moment no technology is available for sorting the mixed heterogeneous plastic packaging materials out of household wastes. Therefore there is a need for new technologies which allow to extrude washed but mixed plastics. Because only a few firms are working in this field there is no demand for mixed waste plastics and no realistic price can yet be determined. Theoretically a minimum revenue of about 1oo DM/t could make separation of mixed plastics from household wastes feasible.

3.5 Compost

In contrast to the UK there are working several composting plants in the Federal Republic of Germany. Nevertheless the total production of compost is only 2oo ooo t/year. The market for compost is rather difficult because of the varying compost qualities.

It is expected that combinations of composting and household waste mechanical sorting plants lead to good conditions for the production of high quality compost. After sorting metals, glass and plastics a valuable organic material is obtainable that gives the opportunity for optimising the composting plant.
Despite this optimistic vision it is realistic to expect no higher price for compost than 5,-- - 1o,-- DM per each ton.

4. Waste Sorting Processes under Development in the Federal Republic of Germany

Two sorting processes for municipal wastes have been developed in the Federal Republic of Germany during the last five years; one comes from the firm of Krauss-Maffei AG, which is a private company wishing to market its process as rapidly as possible; the other comes from a college institute. In both cases, it is extremely difficult to obtain sufficient and comparable information. For both processes, this is primarily because they have not yet been practically proven in commercial scale operation, so that operation experience and precise data on operating costs do not yet exist. Furthermore, only very imprecise data exist on the actual investment costs of each process. In addition, the firm of Krauss-Maffei AG is very careful about releasing detailed data to parties with whom they are not engaged in sales negotiations. This is very understandable and is true also for those processes from the Netherlands, Italy and Sweden. The pilot plant of Institute for Processing of the Rhine-Westphalia Technical College, Aachen will be taken over initially for commercial operation by an industrial firm; here again there are currently no exact data available as to whether, and in which form, the process can be technically established. Thus, in this report, the processes can only be described. However, it is accepted that all the processes will require modifications in their technical set-up to suit operating conditions, e.g. to meet local circumstances. On investment costs and particularly operating costs, only inexact and barely comparable information is available.

4.1 R 80 - PROCESS FROM THE FIRM OF KRAUSS-MAFFEI AG, MÜNCHEN-ALLACH.

4.1.1 General

In October 1974, the R-80 domestic refuse treatment process was introduced by the firm of Krauss-Maffei AG, which was developed by them with financial support from the Bavarian State Ministry for Land Development and Environmental Affairs. This process is aimed firstly at the recovery of waste paper and ferrous scrap, and secondly at the recovery of plastics and glass, but in any case delivers a raw material suitable for composting. The firm proceeded on the assumption that its process would be installed in combination with convential waste disposal processes rather than in isolation; so one would consider an installation alongside an incinerator in a large city or incorporated with a composting plant or a large landfill.

The trial plant is installed at the premises of Krauss-Maffei AG in München-Allach and was tested with original household refuse from the City of Munich.

4.1.2 Composition of Waste from the City of Munich

In Autumn 1974, the composition of household refuse from the City of Munich was investigated in four city districts. The results are presented in Table 8.

Table 8: Composition of Household Refuse in the City of Munich, (Autumn 1974)

Material Group	Content (% by weight)
Ferrous metals	5.8
Non-ferrous metals	0.3
Glass	6.9
Stones, brick, porcelain	1.5
Fines	23.9
Paper	28.3
Cardboard	12.3
Wood	0.9
Leather, bones	1.4
Rubber	0.5
Plastics	7.5
Textiles	3.2
Animal and Vegetable Wastes	7.5

4.1.3 Process Description

The R 80 process has been tested in Munich with a throughput of ca. 3 t/h and is currently being offered to interested cities and municipalities as a plant with a throughput of up to 20 t/h. The process description is directed predominantly at the test plant, but this corresponds extensively in arrangement to the type of plant being offered. The process flowsheet is presented in figure 1.

The domestic refuse is dumped from the collection vehicle into an underground bunker and placed onto a metering plate-conveyor by grab crane. In the trial plant, the bunker has a capacity of 35 - 40 m^3, and the refuse is moved mechanically onto the plate-conveyor by grabarms. The process is subsequently arranged so that the refuse in general is not pulverised, but bundles of refuse are merely broken up and the materials to be sorted retain a typical particle form and size. For this reason, all bulky waste components must be separated by sieving prior to, or directly after, bunkering, and conveyed for separate bulky waste reduction.

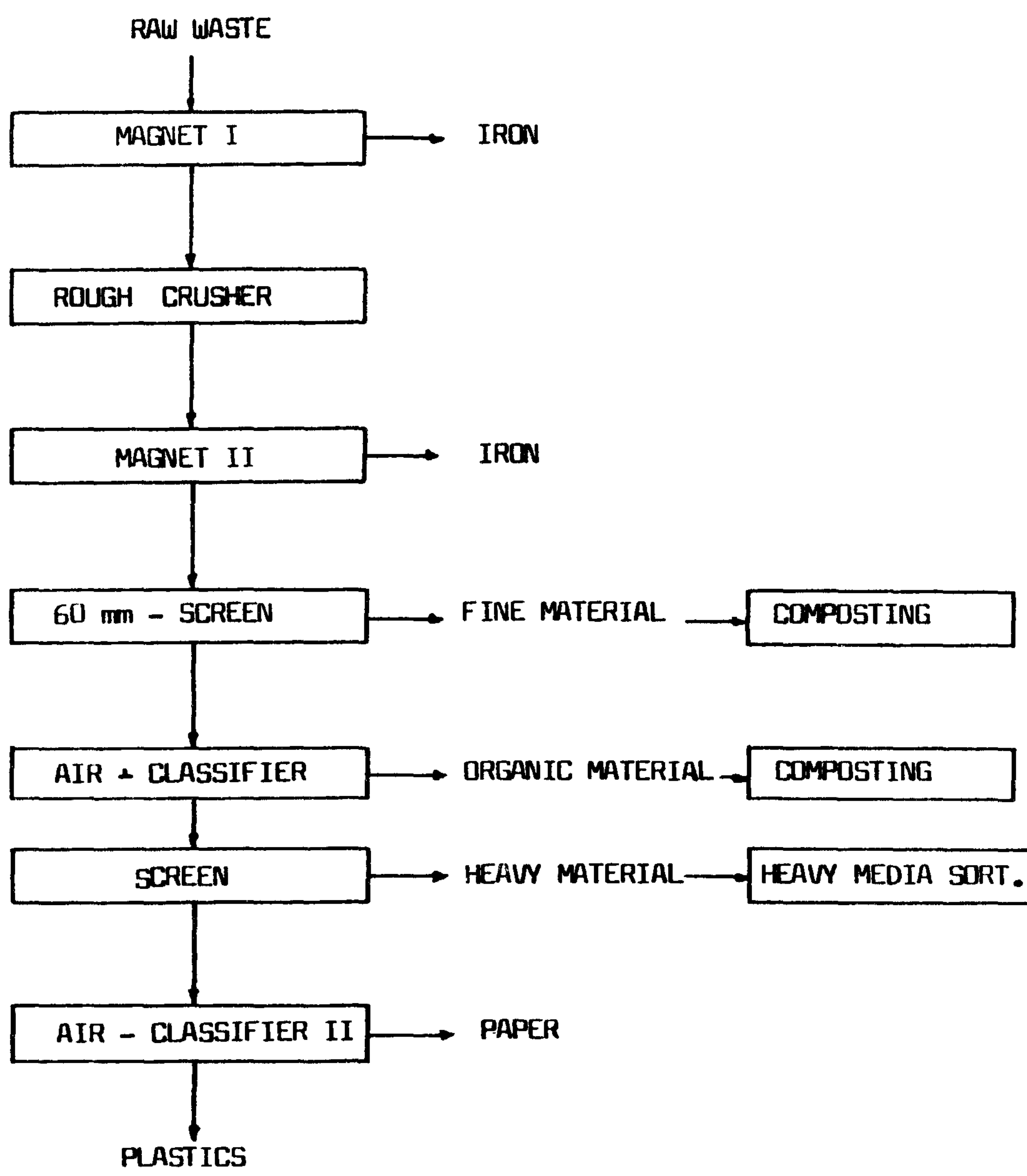

Fig. 1 : Flowsheet of the R 8U of Krauss-Maffei AG, München

The raw refuse is transported on a high speed conveyor which leads to the first and, for the time being, only reduction stage. A large part of the loose ferromagnetic fragments are separated by means of an over-band magnet. Those ferromagnetic components which are locked in composite form, in particular tin cans, closures, etc. are freed during size reduction and separated afterwards by a magnetic separator. In general, 80-90% of total ferrous metal is recovered. Heavy, compact materials e.g. stones, concrete fragments, large metal items, are thrown off ballistically at the end of the high speed conveyor and are not size-reduced.

For the reduction stage, a cutting machine of the type 'Unicrex' was chosen, which was originally conceived for the reduction of truck tyres. Small pieces fall through unaltered; glass bottles are relatively coarsely reduced. The coarsest particle delivered lies at around 30 cm, and the average particle size at 12 cm. This ensures that, above all, paper, cardboard and plastics arrive at the air classifier in large pieces and recovery can be carried out. Through this careful size reduction, the sorting of plastic/paper and the separation of glass is decisively assisted. Figures on wear and tear for the size reduction equipment naturally cannot yet be given out by the company. This is also true of all subsequent units. The size reduction equipment is designed for a throughput of 20 t/h.

At a later stage, the R 80 process is designed with two streams, as it was doubtful whether a single air-classifier would be capable of processing a volume of 15-20 t/h.

The first screening stage after size reduction consists of two stressed, undulating screens of the Hein Lehmann type, each with a throughput of 10 t/h. The particle separation size has been specially chosen at 60 mm for Munich domestic refuse; for other locations it should be adapted to the respective refuse composition. The screened material consists of fine inorganic material and mainly organic kitchen wastes; it is therefore regarded, at least in Munich, as ideal raw material for composting.

The screen overrun (60 mm) is conveyed to a horizontal air classifier with three-product separation. The choice of this apparatus distinguishes the entire process from most European domestic refuse treatment processes, which operate exclusively with zig-zag classifiers. The horizontal air classifier is more sensitive to fluctuations in the refuse composition than the zig-zag classifier which leads in part to clearly discernible impurities in the individual fractions. It was nevertheless selected as the primary screening stage because it was believed that greater throughput quantities could be obtained.

In the first fraction (heavy fraction), predominantly heavy fragments such as wood, rubber, stones and ceramic, non-ferrous metals and organic materials are found. This fraction can be used primarily for recovery, but with a somewhat different raw refuse composition, can also be used as an input for composting.

The second fraction (intermediate fraction) contains heavy paper, cartons, newsprint, textiles, heavy plastic film and lumps of light plastic. This fraction is delivered by the second screening stage.

The third fraction (light product) contains, apart from the light papers, plastic films and light textiles. It can either be introduced directly into a pulper and processed to fibre pulp or be pre-cleaned by removing the plastic film. For the separation of plastic/paper, flotation and electrostatic processes have already been tested by Krauss-Maffei; as both units gave unsatisfactory results, further investigations with new processes will be initiated this year.

In the intermediate fraction, there occurs a portion made up of varying quantities of paper and board, from which the large surface-area components can be separated out on an undulating screen with a particle separation size of 100 mm. The screened material always still contains pieces of paper and, as the company aims to achieve maximum paper yield, the entire material is fed into a zig-zag classifier. The light product from this is added to the paper fraction. The light products from the horizontal air classifier and the zig-zag classifier, as well as the overrun from the 100 mm screen, are compressed and then processed in the paper industry.

Glass bottles and other glass containers are relatively coarsely broken up in the Unicrex pulveriser and arise mainly in the overrun from the first screening stage together with most of the kitchen wastes. As processing of this fraction into compost is envisaged, the glass must firstly be sorted out from the raw compost. Direct sorting by means of density separation and subsequent sorting of coloured glass with the aid of an electronic/optical process can be carried out. The sorting of glass from household refuse in the Federal Republic of Germany is not regarded as very attractive by Krauss-Maffei AG, as the process costs are higher than current revenues.

For a complete plant of 20 t/h throughput, the following installed power ratings for the individual items of equipment are given.

	Throughput (t/h)	Installed Power Rating (kW)
Magnetic separator I	20	9
Pulveriser	20	45
Magnetic separator II	2 x 10	14
Screen I	2 x 10	44
Horizontal air classifier	2 x 6	220
Textile separator (envisaged)	5	10
Screen II	4	22
Zig-zag classifier	2	35
Screen III (planned)	4	22
Conveyors		100
Bulky waste shears	30	126
Sundries		55
		702

Table 9: Installed Power Rating of the Process Stages of a 20 t/h Plant

The installed rating thus amounts in total to ca 700 kW, and the effective consumption would lie at about 500 kW.

From this overview, it is evident that the horizontal air classifier represents the most energy-intensive unit. Hence, the question arises whether a zig-zag classifier should not also be employed in the first screening stage.

4.1.4 Recovery of Valuable Materials

The quality and yield of valuable materials from the R 80 process depends also to a great extent on the respective refuse composition and on the collection and transport system. As a result of experience with Munich domestic refuse, the following yields for valuable materials are given:

Material Group	Material Yield
Ferrous Scrap	80 - 90 %
Paper and Board	60 - 80 %
Plastic Film	60 - 80 %
Glass	50 - 70 %

Table 10: Yields of Valuable Materials from the R 80 Process

With the refuse composition given for the City of Munich, 4.6-5.2% by weight of ferro-magnetic materials can be recovered. As this fraction is predominantly made up of tin cans and other tin-plate packages, detinning is required with larger quantities.

24.4 - 32.5% by weight of paper and board together can be recovered. As long as the separation of plastic/paper is not fully satisfactorily resolved, the light fraction will always still contain between 15 and 20% by weight of foreign matter, that is plastic films and light textiles. According to information from the paper industry, these foreign contents should not be viewed negatively if the plastics arise in sufficiently dimensioned fragments; then they can be relatively easily removed from the pulper by means of a screw conveyor. This factor had prompted the choice of a relatively mild size reduction stage.

Under contract from the firm of Krauss-Maffei and Umweltbundesamt (Federal Environment Agency), paper and board has been made in various factories using refuse waste paper from the R 80 plant. A research and development project financed by the Federal Environment Agency

(Umweltbundesamt) investigated in particular the extent to which the processing of waste paper could be regarded as acceptable from the point of view of hygiene. The final report on this will be presented during the summer of 1977.

In the event that plastic film from household refuse can be successfully marketed, Krauss-Maffei is offering a method of thermally separating paper-plastics in a trommel drier. With this process, between 3 - 4% by weight of polyethylene film can be separated out from Munich refuse. However, for simultaneous recovery of the paper/board fraction, this process is rejected, as the paper fibres are damaged by scaling during the thermal process.

Glass sorting has not yet been practically tested by Krauss-Maffei. Until now, the company has relied exclusively on statements from the firm of Sortex, London.

4.1.5 Personnel Requirements

The personnel requirements are given as 3 men per shift, but this refers solely to the actual processing portion. This is justified inasmuch as one proceeds on the basis that the refuse processing plant described is connected with an existing disposal or recovery facility and that the personnel for refuse delivery, bunkering, for peripheral plant functions and, in particular, administration are already in place.

4.1.6 Costs

Until now, Krauss-Maffei have only stated the total investment costs without specifying costs for individual machines or process sections. With these costs, one should take into account that Krauss-Maffei build the air classifier themselves and intend carrying out the steel construction work themselves but that all other equipment must be bought from specialist companies.

The investment costs comprise the entire processing section from the feed bunker:

Machines and electrics	DM 4,965,000.-
Glass sorting	DM 930,000.-
	DM 5,895.000.-
11% VAT	DM 649,000.-
Installation and start-up	DM 690,000.-
11% VAT	DM 76,000.-
TOTAL	DM 7,310,000.-

The energy consumption of the plant described amounts to an average consumption of ca. 500 kW and an average power input of 75% 375 kW. For a double shift, this means a consumption of 375 kW x 16 h/d = 6,000 kW h/d (16 h/d).

For a throughput of 200 t/d, the unit operating requirement thus amounts to 30 kW h/t. The most recent calculations from Krauss-Maffei indicate that this can be reduced to about 24 kW h/t. At a price for power of 0.10 DM/kWh, the annual energy costs amount to 30 kW h/t x 200 t/d x 0.10 DM/kWh x 250 d/a:

150,000 DM/a

The applicable personnel costs for the processing section alone, with 3 men/shift and average labout costs of 40,000 DM/a, amount to:

240,000 DM/a

The maintenance costs are given as follows:

Costs of wear and tear (2-shift operation)	300,000 DM/a
Spares (ca. 2%)	120,000 DM/a
Operating materials (0.8%)	40,000 DM/a
Insurance and other (1.5%)	90,000 DM/a
TOTAL	550,000 DM/a

The total costs without capital servicing, administration, vehicles, trading tax and operation interruption tax amount to:

940,000 DM/a

With 250 d/a and 200 t/d throughput, this means the specific processing costs amount to ca:

18.80 DM/t

4.2 THE PROCESS OF THE INSTITUTE FOR PROCESSING OF THE RHINE-WESTPHALIA TECHNICAL University, Aachen

4.2.1 General

In 1972, the Federal Minister of the Interior commissioned the Institute for Processing, Coking and Briquetting of the Rhine-Westphalia Technical University, Aachen to develop, in the framework of a research project, a complete process for recovering valuable materials from household refuse. In a period of 3 years, a pilot plant has been constructed which makes it possible to recover paper, ferrous metals, non-ferrous metals, glass and a compost raw material from household refuse of varying composition. The plant has been put together using conventional processing stages, in this case, from processes for the preparation of ores and hard coal, whereby individual items of equipment e.g. the air classifier and the up-stream sorter have been constructively adapted to the specific problems of household refuse. The throughput of the pilot plant, which operates continuously with odd interruptions, lies currently at about 1 - 1.5 t/h. As the research project has been concluded and, in the opinion of the Institute Director, the process is ready for operational service, the firm of Siebtechnik GmbH of Mühlheim/Ruhr has been commissioned to bring the plant to an operational scale.

4.2.2. Waste Composition in the City of Aachen

As the assembly of the processing plant, in particular the choice of suitable points of separation in the screening, depends on the composition of the refuse, analyses of Aachen household refuse were undertaken at the beginning of the research project. The results are repeated in Table 11:

Table 11: Composition of Household Refuse in the City of Aachen

Material	Content (% by weight)
Metals	6.9
Glass	13.5
Textiles	1.6
Plastics	4.5
Paper, board	30.8
Fines	22.0
Organic kitchen wastes	16.6
Other	4.1

Unfortunately, there is no detailed information available on the quantities of refuse analysed, from which parts of the City of Aachen the refuse originated, and with which methods this was investigated.

4.2.3 Process Description

The household refuse is transported in the original collection containers to the testing hall of the Institute, and fed here directly into the pilot plant. As there is thus no possibility of homogenisation, the plant must process wastes with relatively large variations within short periods of time.

The process stages described below are not all included in the pilot plant, but are essential for the entire process. The process flow diagram is presented in diagram 2 .

The raw refuse is conveyed in the first instance to a tearing device in which bundles of refuse of every kind are broken up. The design of this tearing device is not specified. After this, the fine product (smaller than 20 mm) is separated in the first screening stage. For this screening stage in the pilot plant, a vibrating sieve is installed; in an operational plant, a Hein-Lehmann sieve or a trommel sieve may be employed.

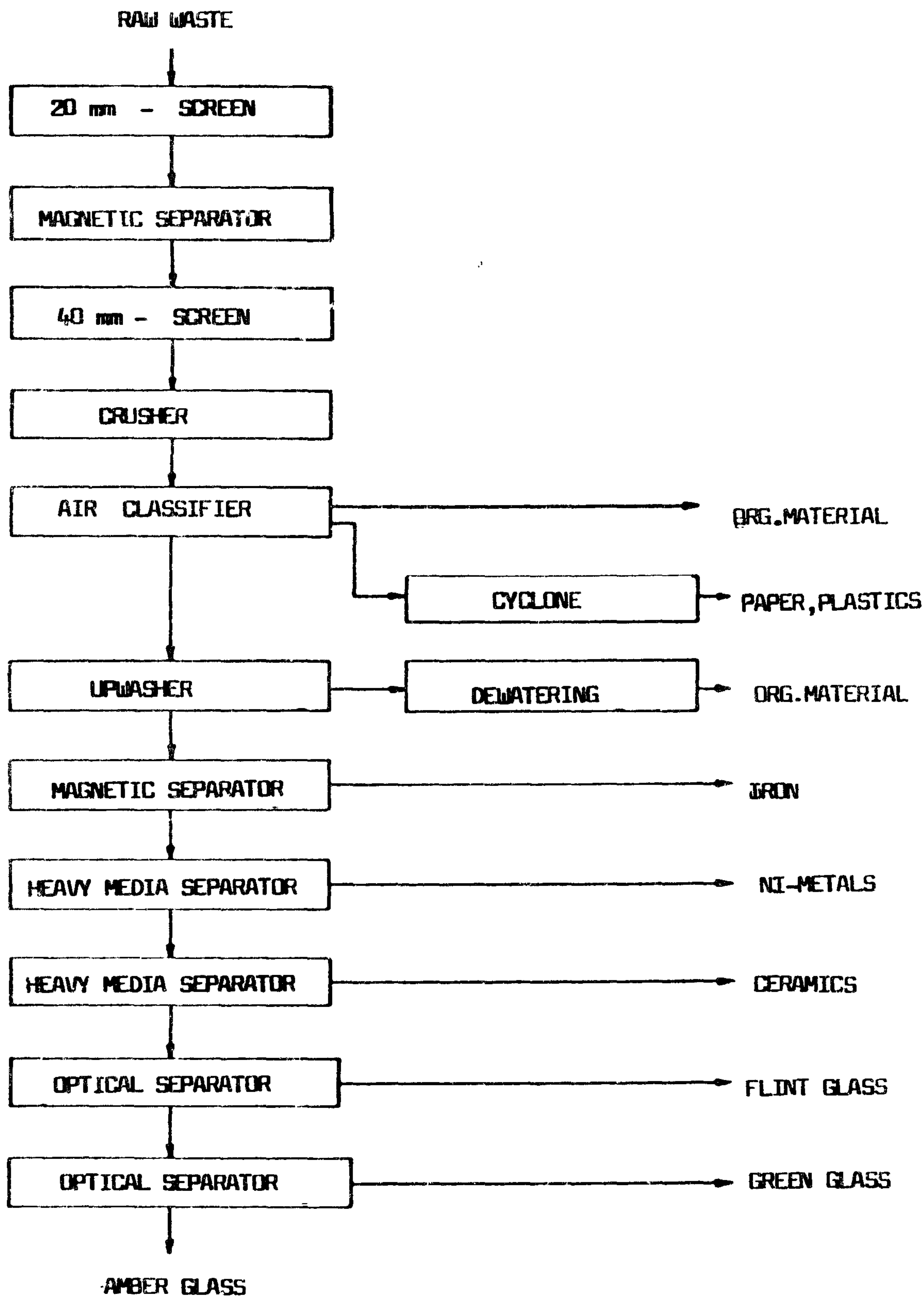

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Fig. 2 : Process of the Institute for Processing of the Rhine-Westphalia Technical University Aachen - Flowsheet -

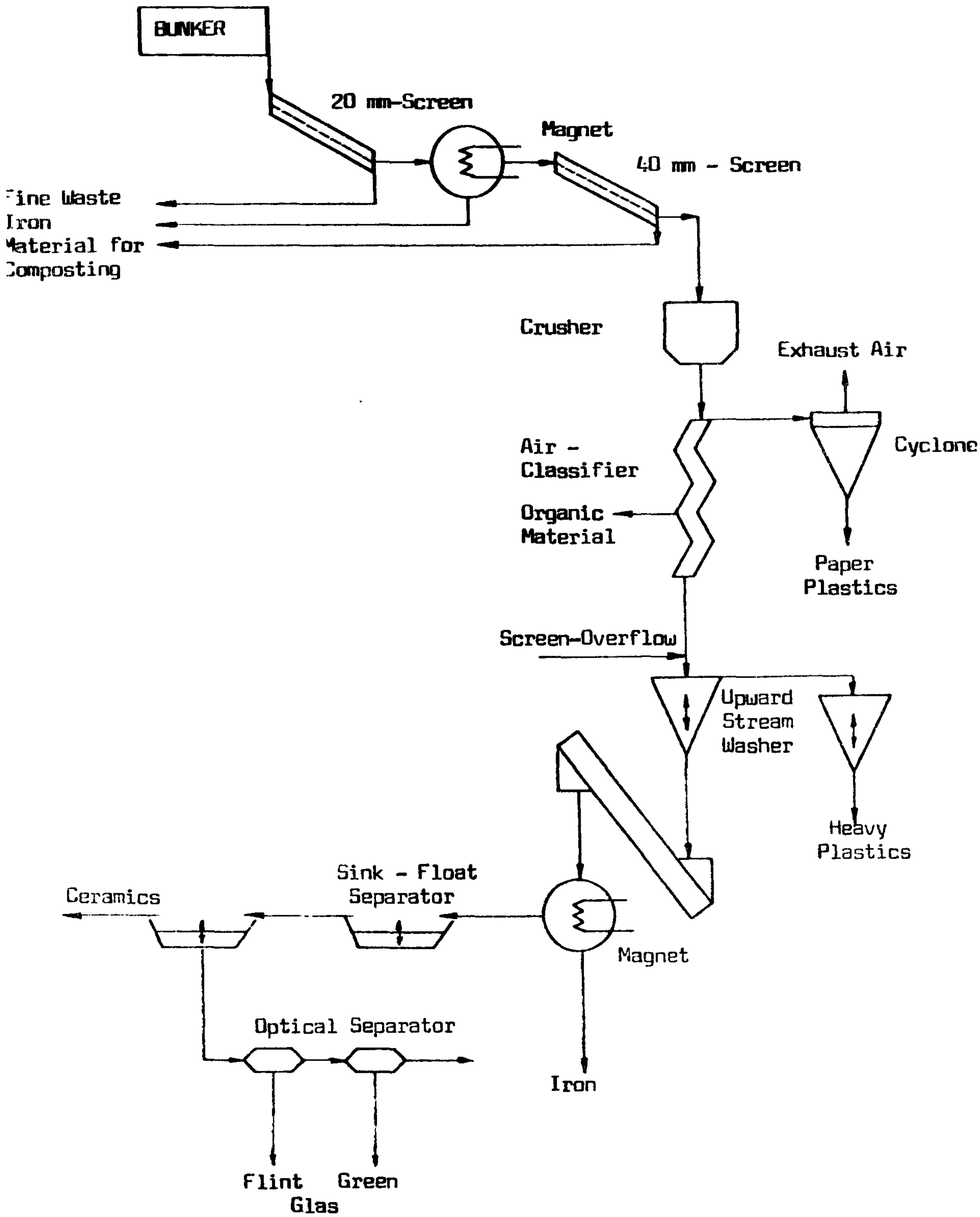

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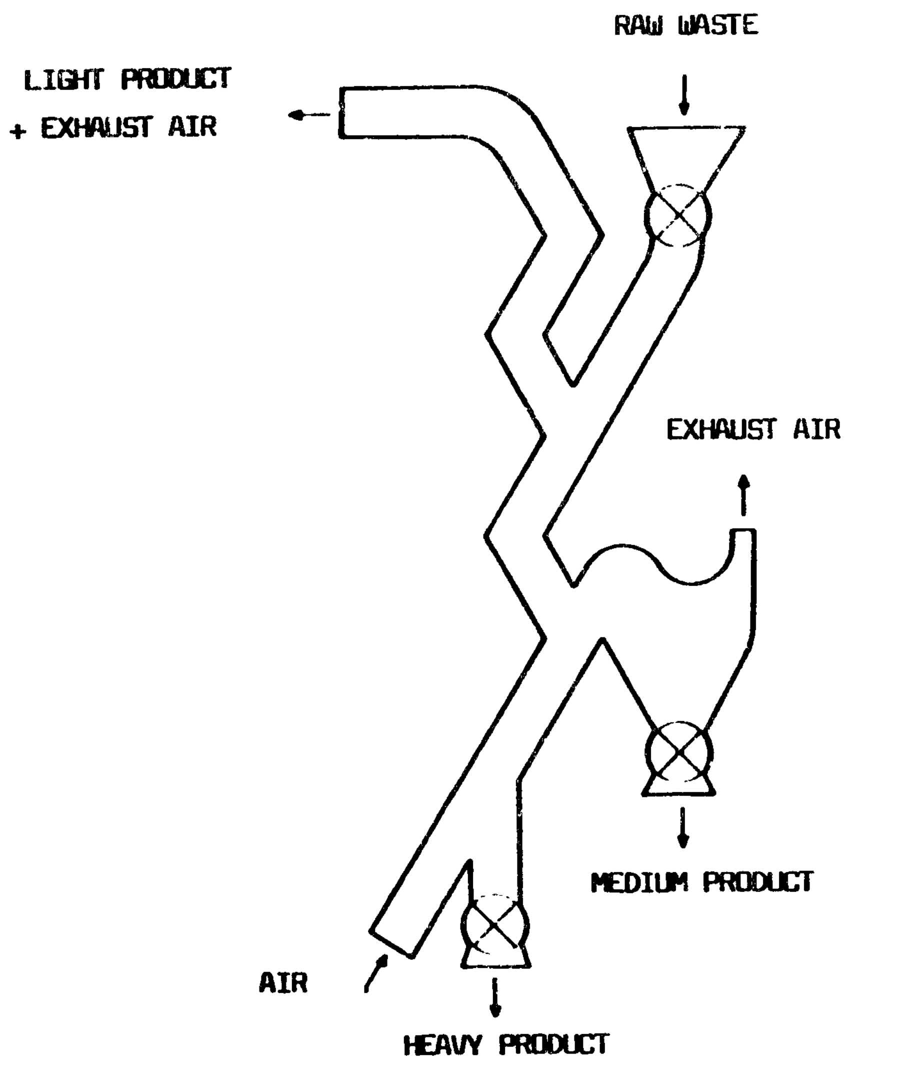
Fig. 3 : Process of the Institute for Processing of the Rhine-Westphalia Technical University Aachen - Flowsheet -

The same applies to the second screening stage, where screening with a 40 mm light mesh occurs. The fine fraction 0-20 mm consists of about 60% by weight ash and sand, 38% organic components and about 2% broken glass and ceramics. This fine material should be tipped during the colder seasons and could, with increasing content of organic components during the summer months, be used as compost raw material. This applies, regardless of the time of year, to the 20-40 mm fraction; this contains 85% by weight organic kitchen wastes and has a smaller content of glass, ceramic and metal fragments. The 20 and 40 mm screening relieves decisively the burden on subsequent process steps (about 30 to 35% by weight) and facilitates particularly the up-stream sorting and air classification. This final item is significant in as much as the separation density is altered by suspended matter and particulates in the air stream of the classifier, and this means that the expected selectivity is impaired and the throughput is reduced. Moreover, this prevents the fine product, in the form of granules adhering to the coarse particles, from contaminating the valuable fractions.

The overrun from the 40 mm screening is fed into a shear-drum pulveriser to break up composite materials and lumps of refuse. Here, reduction is predominantly based on pressure and shearing. This equipment has been selected for the process as the sole reduction device because it would reduce metal components more cleanly whereas these are often only deformed in hammer mills, because glass is ostensibly more gently reduced and because interference for example from textiles is avoided. If bulky material e.g. steel pipes, wooden beams and thick books, blocks the cutting tools, the mill stops, the cutting tools reverse and continue the cutting-shearing operation intermittently until the particles are reduced. This operation can, for example with wooden boards, be repeated as often as 5 times or more. A negative effect is that books, magazines and catalogues are not only reduced but can also be partially compacted by the shear-teeth, so that this material after reduction, possesses a greater apparent density than before and consequently does not go into the light product from the air classifier but rather into the heavy product. In addition, very little can currently be said about the wear and tear on the cutting tools. One can only assume that, with an increasing bulky portion, the cutting edges become worn very quickly.

The screen underrun contains a small proportion of ferro-magnetic material, in particular bottle closures and smaller fragments of tin plate; these are sorted out by means of an overband magnet. The arrangement of the overband magnetic separator at this point does not appear to be entirely well chosen. In choosing two stressed, undulating screens, an arrangement between these would suggest itself. The same applies to the second magnetic separator which is located between the up-stream sorter and the density sorters, but which would be better situated for separating tin cans directly behind the shear-drum; in this way the air classifier would be less burdened. Besides, this would increase the adaptability of the entire process, as it is not certain that the process will always be installed with the wet, density sorting process.

The pulverised raw refuse is fed into a zig-zag classifier with a three-product output, modified at the Institute for Processing, and shown schematically in figure 4 . The installation of an original zig-zag classifier e.g. from the firm of Alpine, Augsburg, was not possible because of insufficient height clearance in the testing hall. In the classification duct, particular flow conditions prevail which enable the extensive cleaning-up of the lightly contaminated kinds of paper, through the loosening of adhesive impurities. But this effect applies to every zig-zag classifier. As the intermediate product output could cause difficulties at operating scale, it can be expected that for scale-up of the pilot plant, a different type of separator will be installed (zig-zag classifier or inclined screen); however, this would not significantly alter the total process. According to the results of investigations, a light fraction can be recovered from Aachen refuse, with the assistance of the classifier, which comprises up to 86% by weight paper, 8% plastic film and 6% textiles. The Institute is in no doubt that this light product must be processed further, if one wants to market it at reasonable prices. For this reason, special investigations of the separation of paper/plastics ought to be carried out.



Fiq. 4 : Simplified Scheme of the Modified Ziq-Zaq-Airclassifier

The yield of paper from the air classifier amounts to 80%. The 20% paper remaining in the refuse would be highly moistened consumer-paper; however, a certain proportion would also consist of magazines and books compacted in the pulveriser.

The classifier light product is refined in a first cyclone stage; a second cyclone stage serves to remove dust from the exhausted air. These two cyclones are not incorporated in the pilot plant but are contained in the process proposals and, as other household refuse treatment plants have shown, are absolutely essential.

The intermediate product output from the air classifier consists mainly of organic components, but would also contain leather, rubber and wood. Assuming that the arrangement of the intermediate product output proves successful, about 15% by weight of the total refuse would be collected here, which can be regarded as ideal composting raw material.

The dense product output from the air classifier contains, depending on refuse composition, ca. 30-46% by weight of the total refuse and comprises metals, glass, ceramics and stones, heavy plastics, and the remainder from leather, rubber, wood and the like, and organic components. Further processing of this dense product is thereupon aimed at recovering the glass, ferrous and non-ferrous metals content. For this reason, all other materials must firstly be separated. To this end, an up-stream sorter has been constructed at the Institute for Processing, as presented in figure 5 . The light product is carried with water as the separating medium, and contains residual organic matter, heavy plastics and materials of a similar density. The dense product is removed by means of a scoop and contains, besides the valuable heavy materials mentioned above, small quantities of ceramics.

The light product is fed to a bow screen for liquid-solid separation. This screen has proved successful for dewatering. Further cleaning of the water has not been installed in the pilot plant, but will however be necessary in an operational plant. Although the installation of wet processing stages should be avoided because of the requisite water treatment, it must be said that the described up-stream sorter represents a robust and effective sorting device; it shows its advantages only when, as in this case, the dense product undergoes further wet-mechanical processing.

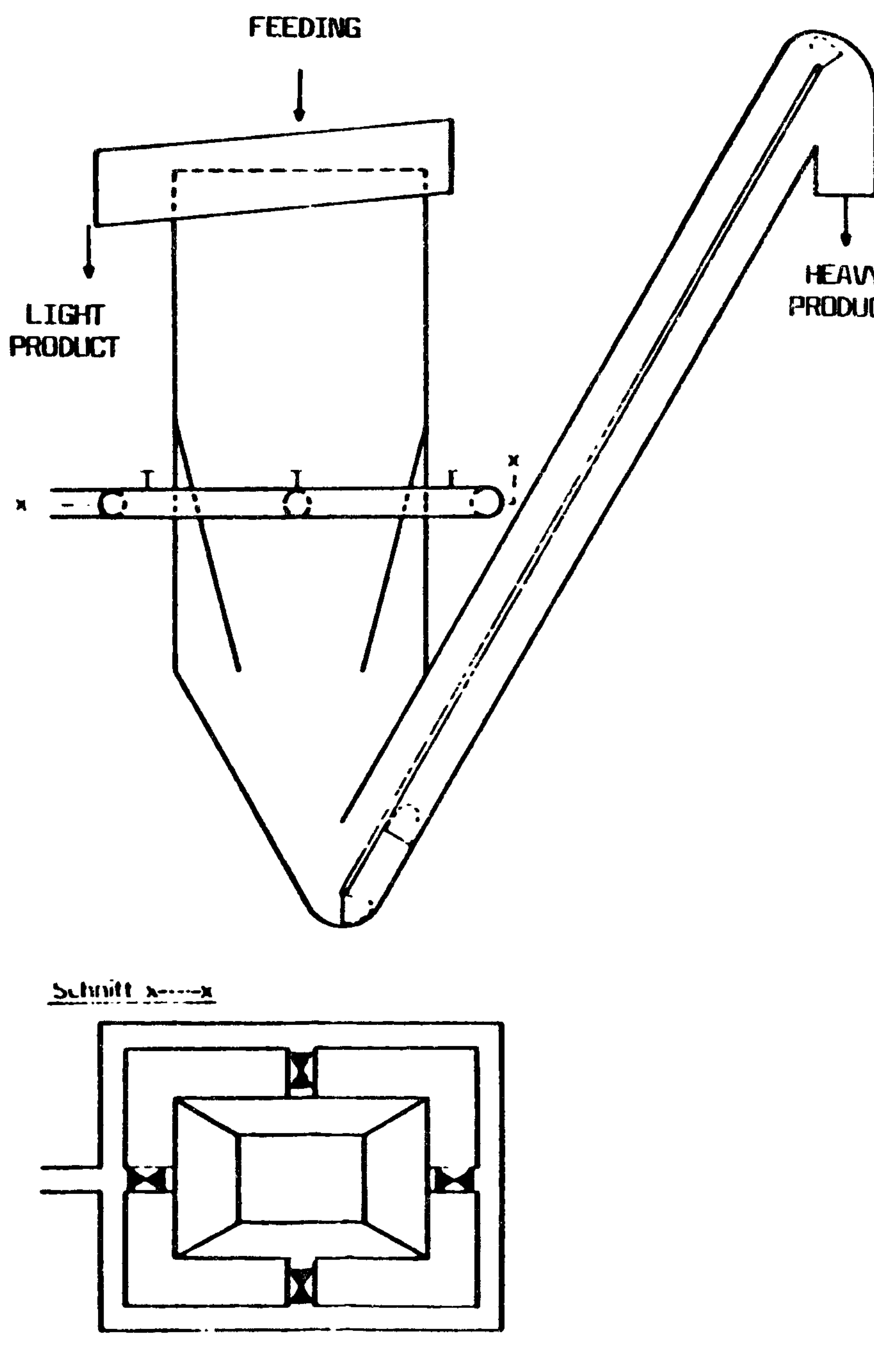
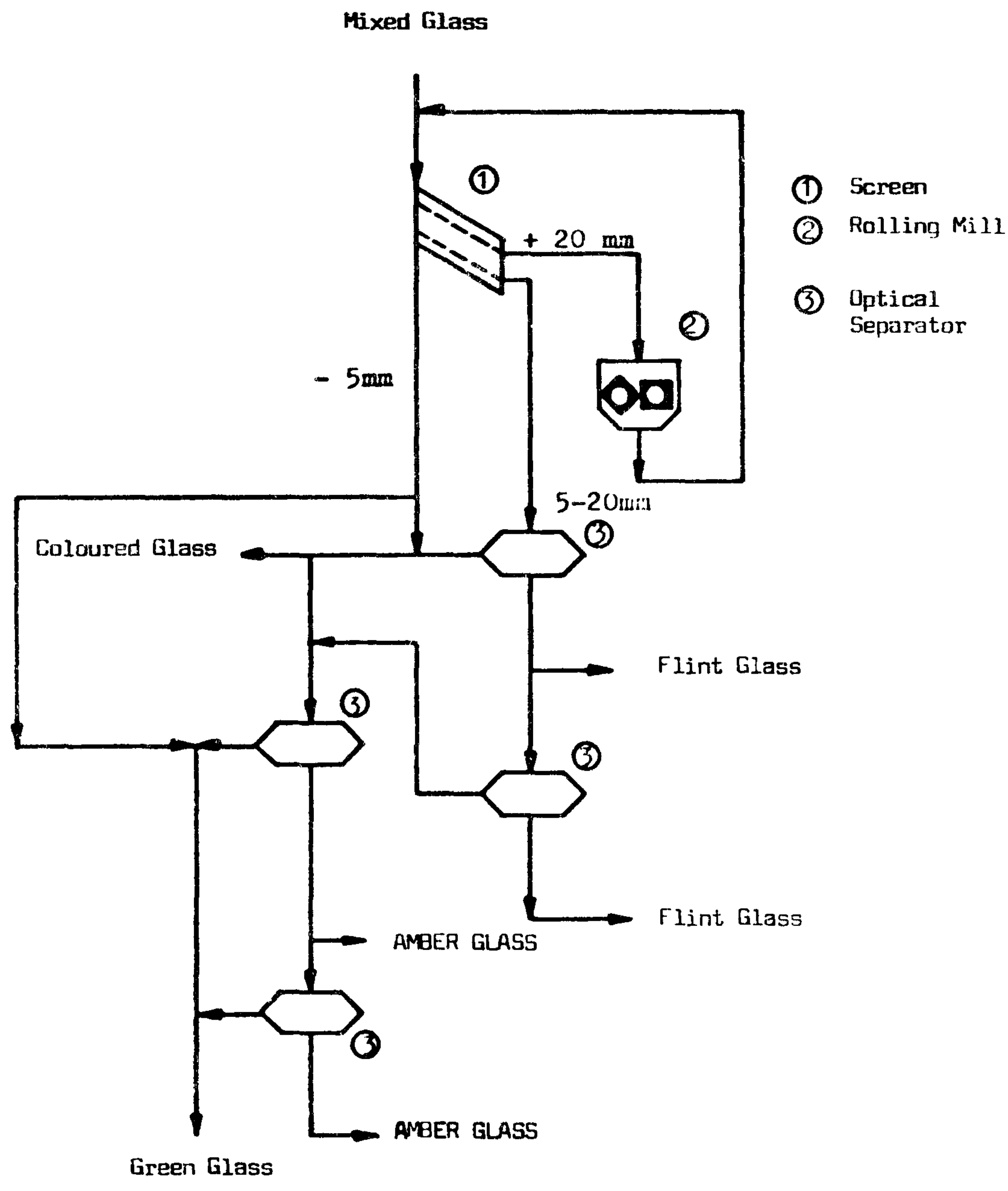


Fig. 5: Simplified Scheme of the Upward Stream Separator

The underrun from the up-stream sorter is conveyed to a drum magnetic separator by means of a bucket conveyor, which would also serve for dewatering, and this sorts out the residual ferro-magnetic components (predominantly tin cans). The residue now remaining comprises exclusively ceramics and porcelain, non-ferrous metals and glass. Should one wish to recover the glass in a sufficiently pure state, the ceramics and porcelain and all non-ferrous metals must be separated out. This is most simply achieved with wet density sorting devices, i.e. suitable sink-float separators. These sorting stages have not been proven in the full process at the Institute for Processing. On the contrary, density sorting tests have been carried out in glass beakers with dense liquids. In addition, operational separation of non-ferrous metals in sink-float separators with the aim of recovering for example, aluminium, copper or zinc, is totally uneconomic because of their low content in German domestic refuse. This would be justified solely on account of the required purity of the glass fraction; however, in this case, the costs of density sorting must be charged to the sorting of the glass. This applies in any case to the separation of ceramics and porcelain.

As output from this second density sorting stage, clean, but colour-mixed glass would be recovered. This glass can be sold as mixed glass; however, at the Institute for Processing, colour sorting with the aid of optical-electronic sorting techniques has been thoroughly tested. A Sortex Type 621M has been used as the sorting apparatus. With single stage sorting, clear glass with 3% by weight of coloured glass could be produced with a yield of more than 88%. With a second stage, the off-colour proportion can be reduced to less than 1% by weight. Corresponding values can be achieved for amber glass. However, it must be stated that these trials were made with moist glass but not with greasy or contaminated glass. Furthermore, the glass was already broken and classified to the optimal particle size for the Sortex device of 20-25mm. As the mixed glass from the density sorting stage arises with about 45% by weight at a size greater than 20 mm, a comminution device and screen supplementary to the process flow diagram in figure 6 , is necessary to achieve the optimal particle sizes.



Flowsheet of the Glass Colour-Sorting

Fig. 6

In order to ascertain the most suitable pulverising equipment for the reduction of glass, tests were made with hammer mills, impact pulverisers, flat roller mills and serrated roller mills. The objective was gentle reduction with as low a proportion as possible of fine particles under 5mm. Of the equipment mentioned, the serrated roller mill ought to come closest to these requirements. In accordance with the tests carried out, the process flowsheet shown in figure was developed for the colour sorting of refuse glass into clear, amber and green colour qualities. It must first of all be investigated whether the expenditure on the process, with the associated investment and operating costs, is justified in comparison to the incremental proceeds from colour-sorted glass. Figures 7 and 8 show the output of clear glass in relation to particle size and throughput.

The installed power requirement for the complete refuse processing plant has been calculated theoretically for a throughput of 15 t/h. For individual items of equipment or process units, the following values were determined:

Table 12: Installed Power Requirement of the Process Stages for the Aachen Process - Throughput 15 t/h

	Throughput (t/h)	Installed Power Rating (kW)
Bridge grab crane	15	48.0
Pre-pulveriser	15	109.5
Screen	15	22.0
Shear drum pulveriser	15	75.0
Air classifier	15	124.0
Conveying equipment	15	32.9
Refuse and product presses	15	110.0
Dense liquid sorting	3-5	60.3
Up-stream sorter	10	55.5
Glass sorting	1.7	37.1
TOTAL		678.3

It should be noted that this list does not yet take water treatment into account. Further uncertainties arise in that it is still not absolutely clear whether the complete process can actually be realised in the form outlined.

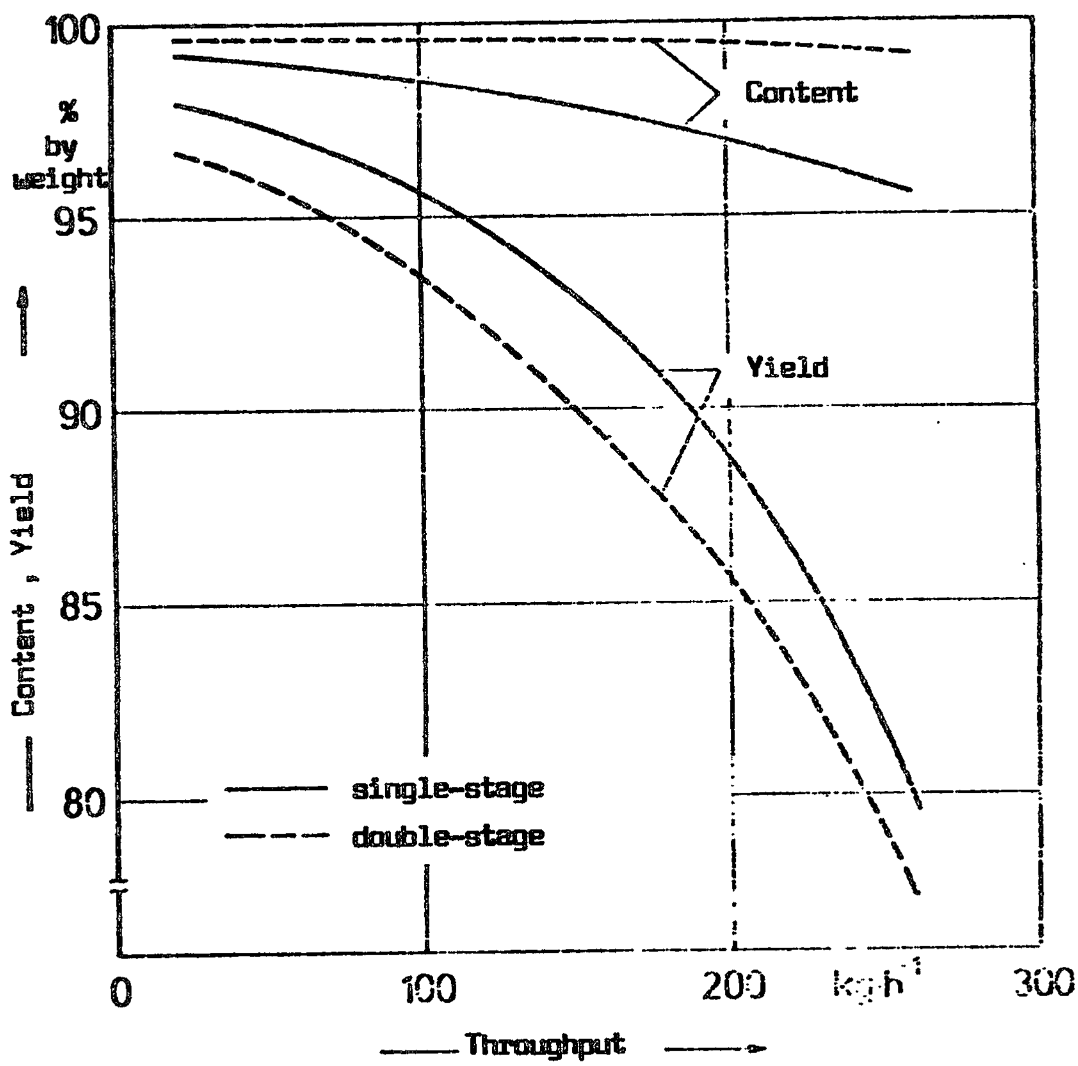


Fig. 7: Content and Yield of Flint Glass

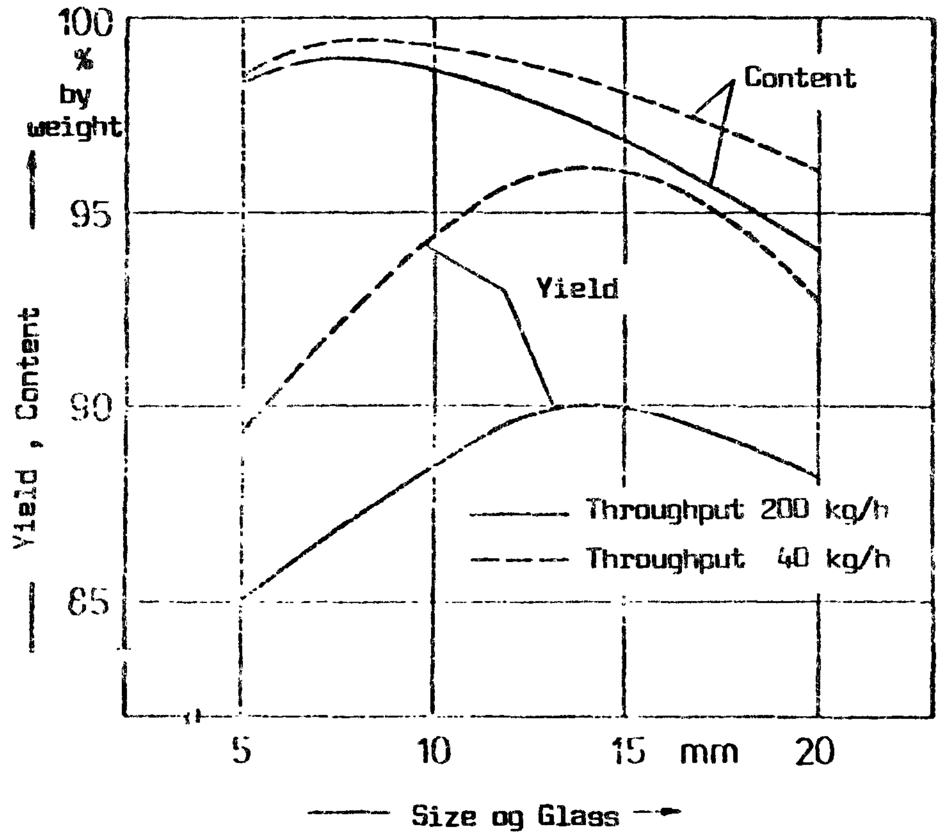


Fig. 8 : Content and Yield of Flint Glass

4.2.4 Recoverable Products

It is assumed in principle that the Aachen process can produce the same products, with the same material yields and the same product qualities. During various visits, the impression was gained that the air classifier at the Institute for Processing in Aachen produces a cleaner light product than the horizontal air classifier in Munich. This can be founded in the fact that the Munich plant processed refuse from collection vehicles of various types while the Aachen plant took refuse directly from household refuse containers. Moreover, the Aachen process is rather more suited to manufacturing products of higher purity, thanks to the wet density sorting stage. In this regard, the question still remains whether it is better from an economic point of view to sort out middle grade products at lower cost or high purity products at high cost.

4.2.5 Personnel Requirements

A personnel requirement of 2 men per shift for a 15 t/h plant is given by the Institute for Processing. Naturally, this does not include refuse delivery, the refuse bunker as well as administration and peripheral parts of the plant. For a sorting plant including up-stream sorting, dense liquid sorting and optical glass sorting, 4 personnel would be more realistic (1 shift foreman, 3 technical assistants).

4.2.6 Costs

The costs given here apply to a 15 t/h plant (15 t/h = 200 t/d = 50,000 t/y) and were determined in connection with the planning of the Federal Waste Recovery Model by the firm of Siebtechnik GmbH, Mülheim/Ruhr.

The investment costs for machinery are divided into:

Dry stage (without bunker)	DM 3,500,000.-
Up-stream sorter	DM 450,000.-
Dense liquid sorter	DM 540,000.-
Glass sorting	DM 400,000.-
TOTAL	DM 4,890,000.-
VAT (11%)	DM 538,000.-
Installation	DM 1,000,000.-
Electrics	DM 400,000.-
VAT	DM 154,000.-
TOTAL	DM 6,538,000.-

In the costs for the dry stage are included, inter alia, the following costs for individual units:

Pre-pulveriser	DM 160,000.-
Screen	DM 135,000.-
Shear drum pulveriser	DM 740,000.-
Air classifier	DM 360,000.-
Presses	DM 900,000.-
Magnetic separator	DM 310,000.-
Plate conveyors	DM 560,000.-

However, these data should be handled very carefully, as it is presently not absolutely clear whether the Aachen process can actually be realised in the form described. Factors of great uncertainty arise particularly with the scale-up of the air classifier to operating scale and with the exact design of the wet-sorting stage. Moreover, with regard to economic viability, it is still questionable whether the optical colour-sorting can be realised.

The energy costs emerge from the installed power rating of ca. 680 kW, a power demand of 80% of the installed requirement and an average power input of 75%:

$$\text{Energy consumption} = 680 \text{ kW} \times 0.8 \times 0.75 \times 16 \text{ h/d}$$
$$= 6{,}528 \text{ kW h/d}$$

$$\text{Unit demand} = \frac{6{,}528 \text{ kW h/d}}{200 \text{ t/d}}$$
$$= 32.64 \text{ kWh/t}$$

The personnel costs (without administration, delivery and bunker), with 3 men/shift and two-shift operation, are given as:

8 men @ 40,000 DM/Year = 320,000.- DM/a

The energy costs, at a price per kWh of DM 0.10, amount to:

32.64 kW h/t x 200 t/d x 0.10 DM/kWh x 250 d/a = 163,200.- DM/a

For maintenance costs, the following values can be assumed:

Costs of wear and tear	ca. 6%	392,280.- DM/a
Spare parts	ca. 2%	130,760.- DM/a
Materials	ca. 0.8%	52,300.- DM/a
Insurance	ca. 1.5%	98,070.- DM/a
TOTAL		673,410.- DM/a

Total costs amount to 1,156.610.- DM/a

Unit processing costs $= \frac{1,156,610.- \text{ DM/a}}{250 \text{ d/a} \times 200 \text{ t/d}}$

= ca. 23.13 DM/t

These costs relate only to the actual processing and so do not include costs for land, buildings, delivery, bunkering, storage of the products, peripheral plant facilities, capital servicing, administration, transport, vehicles etc. These costs shall not be considered here as it is not yet possible to calculate exactly the total operating costs due to the limited state of development of the plant.

4.3 THE FEDERAL WASTE RECOVERY MODEL

4.3.1 Objective of the Federal Waste Recovery Model

The basic objective of the project is the promotion of the recovery of municipal wastes, as is also considered in the Waste Management Programme of the Federal Government:

- as a means for reducing the quantities of waste,
- as a method of exploiting alternative sources of new material,
- as a way of developing an economic, environmentally-safe disposal system.

These aspects can be viewed as having equal importance and are mutually connected. The chances of success in promotion of the goals mentioned can nevertheless be variously assessed.

The 'recycling' of wastes has already attained a positive standing with large groups of the general public, the media and politicians, before it had any opportunity to prove itself successful in terms of general expectations.

The advantage of sympathy, which is guaranteed for 'recycling' in comparison to the conventional processes, is confronted by a deficiency of information and experience which has so far prevented the construction of a first large-scale 'recovery plant'. These circumstances determine the concrete objectives of the model project:

- development and testing of organisational models for the erection and operation of recovery plants and the marketing of the raw materials recovered from wastes. This above all includes questions of responsibility, corporate organisation, financing etc.

- large scale testing of waste treatment techniques, which have already reached an advanced stage in semi-technical test operation, as well as the new and further development of alternative and complementary process steps.

- promotion of the use of secondary raw materials from wastes by the consuming industry, through the placement of research and development contracts and participation of this industry in the operating and trading organisation.

- evaluation and documentation of technological, operational, economic and marketing results and experience to pave the way for general introduction of resource recovery in municipal waste management.

The time factor plays a decisive role in relation to the setting of objectives. The number of municipal "recycling plants" that might be realised in future will depend essentially on the point in time when the new waste recovery process is sufficiently well developed that it is available to cities and rural authorities as a proven, alternative solution. The need for new solutions is beyond doubt. The pressure on the waste disposal authorities created by legislation for the regional reorganisation of waste disposal, has led to a multitude of technical planning tasks. The model project is therefore aimed at advancing the recovery of waste materials as rapidly as possible so that it can be duly considered as an alternative or complement to conventional solutions, before most of the potential opportunities for application are fulfilled by conventional solutions. With a positive outcome from the Model trials, the newly proven plant-type will be applicable in more or less ready form for the following purposes:

- supplementing existing landfill sites to extend site life;

- supplementing existing incinerators as a substitute for further extensions;

- supplementing existing composting plants for processing industrial and commercial wastes;

- for new plants;

- as an alternative to ordinary landfill sites, incinerators or composting plants.

The total number of possible resulting projects in the Federal Republic can be approximately estimated at about 40. Only possible sites in urban areas are considered in this figure.

The promotional impact of the Model project can be illustrated by a worked example, which proceeds on the following assumptions:

20 follow-up projects are realised 2 years earlier than would be possible without execution of a state-promoted test model.

With a plant throughput of 20 x 100,000 t/a = 2,000,000 t/a; corresponding to 4 million t. of waste in 2 years and an achievable monetary advantage in respect of economic aspects and environmental factors of DM 10.- /t waste, gives a total gain, as a result of a 2 year lead, of DM 40 million. This should be cited as a guide for assessing the value of promoting the project.

Moreover, the industry participating in the Model project has the chance to acquire a two-year lead in 'know-how', which can bring about export advantages especially as it is known that other industrial nations are also working on such solutions. This applies both to waste processing technology and to those industries involved in re-utilising secondary raw materials.

4.3.2 Technical Concept

With waste technology, practically usable results from research and development, such as those which the Model project must produce, can only be acquired by several years trials at a large operating scale.

The reasons for this lie in the heterogeneous composition of wastes and the seasonal variations, and the difficulty then follows to produce representative raw material samples and, hence, representative product samples for reuse testing.

Whereas with household refuse, one can, within reasonable margins of error, draw conclusions from samples of the order or a few tonnes, this possibility is ruled out for bulky refuse, and industrial and commercial wastes. With these types of waste, which for resource recovery are more productive than household refuse, the smallest representative sample has the same order of magnitude as the overall quantity. Therefore, until now, details are only available on the composition of household refuse.

Long-term, large-scale operating trials are economically only justifiable when they serve simultaneously the purpose of disposal for a sufficiently large catchment area and aim from the outset at the industrial utilisation of the products recovered from wastes.

Hence, with regard to the objectives stated at the beginning for the project definition, the following basic requirements and provisions emerge:

Operational Combination with a Complementary Plant

In order to ensure continuous, trouble-free disposal, the Model plant should be operated in connection with a complementary facility. Co-ordination with an existing or future landfill site or incinerator with residue disposal site is suitable.

The residues from the Model plant and those types of wastes unsuited to recovery are deposited and handled in the complementary plant. With interruptions to operation and short-term outages for alterations, which will be inevitable in the Model plant, the complementary plant serves to maintain disposal facilities.

Types of Waste

All types of wastes, for which the regional authorities in the catchment area have the disposal responsibility, would be processed by the total, interconnected plant. The Model plant itself is primarily conceived for treating household refuse, bulky refuse and similarly composed industrial and trade wastes. Municipal sewage sludge can be jointly processed in limited quantities in the composting process train. The recovery of certain 'special' (difficult) wastes is not fundamentally excluded.

Preparation of Wastes

The project is confined to the recovery of valuable materials from the mixture of wastes which arises from conventional refuse collection operations. The alternative possibility of accomplishing recycling through the preparation of 'pure materials' at the waste source (see Konstanz or St. Gallen) is not an objective of the trial.

Size and Lay-out of the Catchment Area

For the Model plant, which comprises three process lines set up in parallel, the following lay-out is envisaged corresponding to a technical scale of operation:

Raw refuse throughput of each process line:
ca. 15 t/h = 100 t/d with one-shift operation
200 t/d with two-shift operation

and for three process lines:
300 t/d = 75,000 t/a with one-shift operation
600 t/d = 150,000 t/a with two-shift operation

As a rule, two-shift operation will be aimed for.

The minimum quantities of prepared products required for further industrial processing cannot be achieved at a low throughput.

The proposed lay-out necessitates a catchment area of at least 400,000 to 600,000 inhabitants which, in terms of specific arisings of recoverable waste, corresponds to 250-375 kgs per inhabitant per year.

Total waste arisings to be processed by the Model plant in connection with a complementary plant will lie, for a catchment area of the size mentioned and depending on urban and economic structure, at considerably over 150,000 t/a.

The catchment area must to a certain extent be over-sized so that as large a selection of wastes as possible is available for testing the model and the plant can be employed to capacity.

Land Requirements

Depending on the nature of the site, the land requirements for the model plant amount to 3 - 5 ha. For a complementary landfill site, a land area of at least 20 ha. is necessary.

The further development of existing technologies and research on new technologies for the utilisation of process products from the Model plant shall be promoted on an equal basis. Large-scale testing in this area must nevertheless take place within the industry consuming the products. At all events, small-scale tests for this can be carried out in the Model plant.

Transport System

Combined road and rail transport is aimed for, both for transport of refuse to the plant and shipment of various products to the respective customer locations. The coincidental need for transport to and from the plant makes rail transport appear interesting. Product distribution is thereby facilitated, as greater transport distances can be borne. Direct unloading from rail to refuse bunker requires expensive construction work so that instead of this a container-transfer system is proposed. Whether rail transport can be achieved must be decided after determining the location of the site.

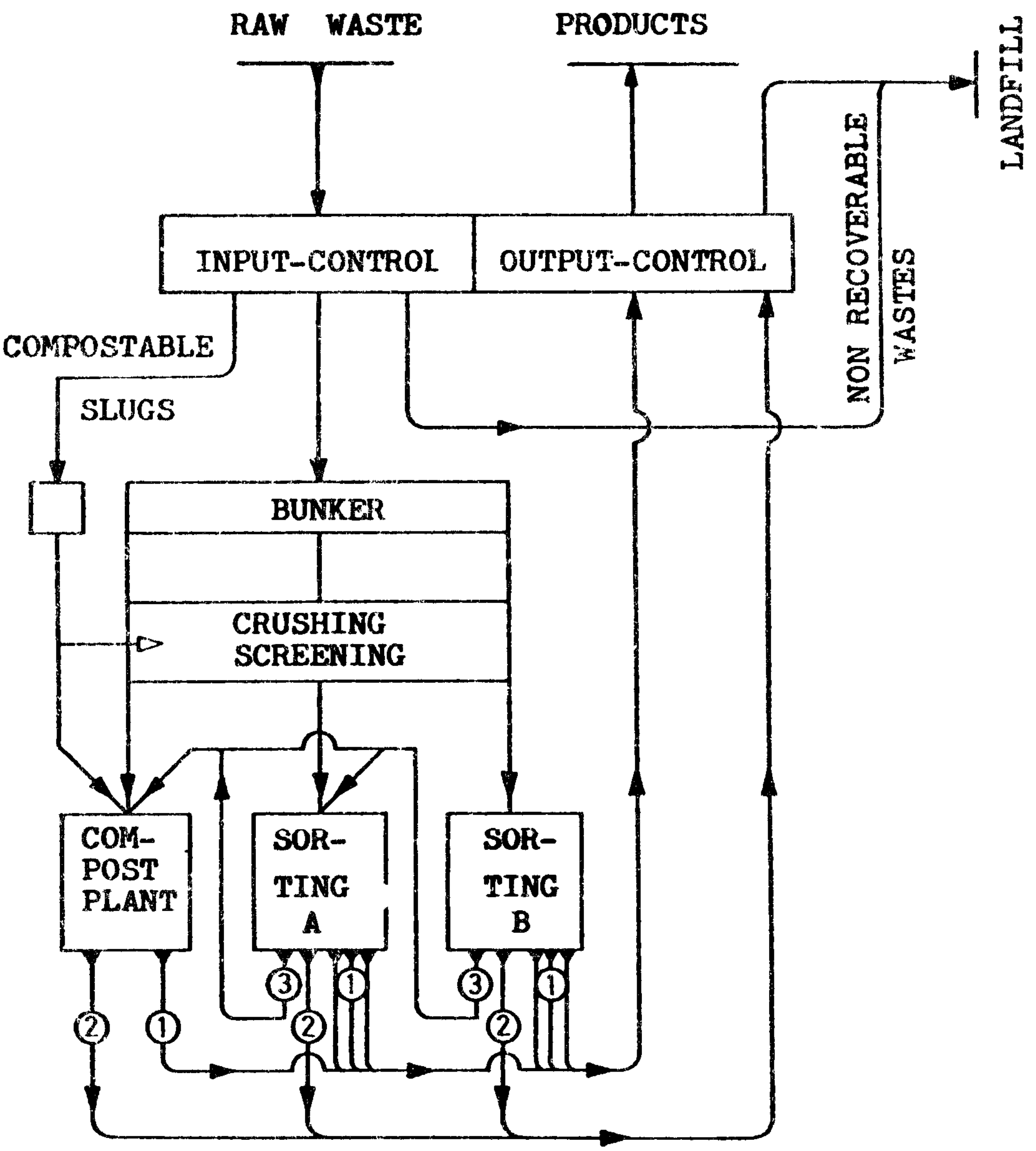
Key Technical Points in the Process

In the Model plant, primarily mechanical treatment processes will be tested. In this regard, one can mention such individual processes as pulverisation, classification, fine and coarse sorting and drying. Composting is included in as much as it is the only process until now which is suitable for exploiting certain groups of organic matter and sewage sludge. The testing of specific, alternative composting processes and thermal recovery processes shall remain the subject of other model projects.

4.3.3 Plant Erection

The sketch given in figure 9 shows the preliminary process scheme for the plant.

All wastes from the catchment area are registered at the central arrivals control point and the weights recorded on a vehicle weigher. Here, the decision is made regarding further handling in the Model plant or the complementary plant. Residual materials and products are likewise recorded and weighed before leaving the plant.



① = Mechanical Sorting Products

③ = Intermediate Products, Organic Materials

② = Non Recoverable Wastes

UBA Berlin	**FEDERAL WASTE RECOVERY MODEL**	**Fig. 9**

In the unloading area of the plant, apart from an underground bunker with grab crane, a parallel, opposing shallow-bunker is envisaged. Here, there follows unloading at ground level of separate boxes against one another in a row. The material is pushed by a wheel loader onto a steel conveyor after which two leading picking conveyors are arranged in parallel.

This combination of a shallow bunker and hand-sorting lines serves various purposes:

- the carrying out of crude refuse and product sorting analyses within the scope of the required operational measurement programme;

- the test recovery of high value materials (e.g. polyethylene film, corrugated board, etc) through hand picking of selected deliveries of industrial and trade wastes;

- the trial hand-selection of foreign matter from products with a view to improving quality (return of product burden to the shallow bunker, separation at back of the picking line by way of a by-pass into a container);

- the visual control of deliveries of unknown composition and, if necessary, removal of large, non-processable items (e.g. from bulky refuse) in the area of the shallow bunker, with the aid of a longitudinal hoist.

The greater proportion of the raw materials is fed as a rule into the process by way of the underground bunker and crane. The technical portion of the process is presented at some length in paragraph 4.3.2 The individual units are relatively well spaced-out and connected with flexible materials handling technology.

Parallel to important individual units (e.g. pulverising), foundations for testing alternative makes are envisaged from the outset. Leaving aside the independantly installed composting trommel, the processing lines are accommodated in a lightweight-construction hall adjacent to the bunker tract.

On the output side, baling and packing presses, loading bunkers and container stacking spaces are set out for the various process products and residues. Depending on requirements at the site, the plant can be additionally furnished with a tyre shredding plant.

In order to allow the interested public to view the Model plant at any time, a rotating observation platform is proposed which covers all the points of interest, but is shielded to the extent that unaccompanied inspections are possible without impeding the operations and without danger to the visitor. For explanation to the visitor, information stands serve along the observation walkway.

The outside of the plant will be attractively arranged with green areas, and the compost and product storage area will be screened with camouflaging vegetation.

The plant concept proposed here is being held open to further suggestions, alternative proposals and amendments, both in respect of the structural design and arrangement, and the equipping of the process.

.3.4 Process Engineering

The process engineering concept provides for the testing of three parallel process lines, which are set out for approximately the same throughput:

Sorting process A: e.g. "Aachen process"
Sorting process B: e.g. "Krauss-Maffei process R-80"
Process C : Composting (e.g. trommel process from the firm of Rheinstahl-Thyssen-Technik).

Each individual process line is tested initially with one-shift operation and a quantity of 100 t/day of crude refuse can be fed through. Hence, a total throughput for the Model plant is given as 300 t/day or 75,000 t/year. After completion of the first phase of testing, 2-shift operation will be adopted, whereby the annual throughput is increased to 150,000 t/year. By extending the daily running periods of individual processes, the periods of down-time for the other processes can eventually be cushioned, so that continuity of refuse disposal is ensured.

In addition to these three process lines, additional units for example for size reduction and sorting, which have been specially developed by industry and research and development institutes for recovery of wastes, are to be fitted in the Model plant and tested.

The final lay-out and process choice as well as the selection of individual machines, means of transport etc, shall remain subject to decision by the holding corporation which is to be established.

Figures 2-5 show the processes envisaged by current plans, with corresponding materials balances.

Process C - Composting

Composting counts as one of the conventional waste treatment processes. Within the framework of the Model plant, this is carried out along conventional technical lines. However, what is novel is the function assigned to composting within the overall operational concept, and the set-up which results from connection with other processes.

A characteristic of refuse composting in the traditional sense is that it is employed for an unsorted waste mixture. The separation of the heterogeneous raw material into product and residue takes place based in the main on particle size and hence, with respect to product quality, is casual rather than sensibly selective. Fine-particled mineral constituents, which have little or no value end up in the product; coarse, valuable materials in the residual fraction.

As a result of this, compost recovery has the inherent defect of being clandestine waste disposal - more or less justified - depending on the proportion of worthless inert material in the compost. The tipping of the residue is in part "disposal of valuable materials"

The quality of the product is ultimately determined by the refuse composition; short-term, e.g. seasonal variations affect the compost quality unless action could be taken to control this in operation.

This fundamental problem has a complicating effect on the marketing of compost. The stipulation and observance of quality standards founders on a lack of operational possibilities for influencing the composition of the compost.

More favourable pre-conditions are presented in the Model plant: composting is operated in connection with a sorting process. Predominantly organic constituents are conveyed to the composting line, which for the time being are not usable elsewhere; these inevitably arise in the parallel-operated A and B processes as "organic residual fractions", after separation of metals, paper, plastics, glass and inert matter. What makes this crucial is that the technical process costs for separation of these 'selected' compost raw materials do not fall on the production of compost, or in other words, this does not need to be justified by the incremental proceeds from compost distribution.

For the production of compost, there are a multitude of raw material constituents to choose from:

- organic residual fraction from sorting processes
- fines fraction from sorting processes
- unsorted household refuse
- sewage sludge
- certain organic industrial wastes

Depending on the quality of product required, these components can be processed in various mixture ratios.

The relationships between "raw material recipe", compost yield and compost quality are to be investigated, with the objective of developing standard products with defined quality characteristics for a variety of applications. Particular significance is attached here to the problem of hazardous material concentration in the compost e.g. heavy metals. It is assumed that the organic residual fraction of household refuse exhibits very small concentrations of hazardous substances. After the specific values of individual components have been determined, it will be possible to observe limits for hazardous substances through controlled selection of the raw material.

Process Engineering Concept for Composting

For the composting, an orthodox rotary trommel plant is envisaged with subsequent mechanical windrowing on a covered compost site. In the trommel, there occurs above all the mixing of the raw material constituents. The pre-retting, i.e. the retention time in the trommel, is limited to ca. 24 hours.

Alternatively, the function of the trommel as a pre-retting unit could be dispensed with. Then a short mixing-trommel with a larger diameter might be considered. The actual composting then takes place solely in the windrows. In each case, particular value is placed on mechanised turning of windrows which enables frequent, intensively-mixed displacement and thereby, extensively odour-free operation. A part of the composting area will be fitted out with equipment for artificially aerating and ventilating the windrows.

By covering over the composting area, the difficult problem of collecting and cleaning-up rainwater drainage is avoided. The composting area remains at all times trafficable and the water balance in the windrows is extensively independant of the weather.

The moisture loss during decomposition is made up through the addition of water or sewage sludge when turning over the windrows.

The higher construction and operating costs for subsequent composting are partially offset by lower costs for composting area preparation and drainage.

Furthermore, equipment arranged after composting enables, depending on market requirements, fine screening, admixing of mineral fertilisers, filling into sacks, as well as production of a compost light fraction for new areas of application, e.g. for brick manufacture.

Possibilities for Extension after the Testing Phase

The carrying out of research and development work in the approximately 7 year testing phase of the Model plant will lead to alterations in equipment and process engineering. After this phase, the correspondingly modified plant should be optimised for the recovery of valuable materials from the available wastes. With this, one can expect that the initial separation of the A and B processes is abandoned and an optimised, complete process line created from these.

By retaining the given structural features, it is possible with this optimised treatment plant to achieve a throughput of 40 t/h (160,000 t/year) in respect of the processing section. Together with the compost line, the total throughput will then lie at 200,000 t/year. This throughput can be still further increased by installing a second composting trommel; this would certainly require structural alterations.

Independant of the alteration of processing technology, the Model plant can be modified after the research and development phase so that special processes for product refinement can be added at plant operating scale (glass cleaning, fibre recovery etc). Moreover, it is conceivable that individual materials would be already processed to end products on the site of the Model plant. This could be worthwhile for plastics and fibre processing.

4.3.5 Products from the Model Plant

General Information

Within the term products, the following sortable fractions from waste are understood; metals, paper, inert material, glass, plastics as well as compost as a processed product. The possibilities for utilising these products are dependant upon such technological factors as sorting precision, purity specifications, and raw material and technical production problems in introducing the products as a new raw material. Nevertheless, the crucial issues for prospects of reutilising the products are not the technological questions, which are basically resolvable, but the economic and organisational factors.

The following tables 13-15 contain data on sorted products and compost from the processing of household refuse, as until now sufficient data and findings from tests are only available for this type of waste. The inclusion of industrial and trade wastes as well as bulky refuse, such as is planned in the Model plant, will lead to substantially better results at least in respect of the quantity and quality of the paper product.

Conclusions drawn from a limited consideration of household refuse as the raw material lie, so to speak, "on the safe side".

The introduction of exploitable raw materials must bring marketing advantages in relation to the raw materials to be replaced, or open up a market for completely new products.

A socio-economic gain, which for example is connected with energy saving through resource recovery (see table 2), is not yet currently considered in a proper manner.

Table 13: Average Contents of Valuable Materials in Domestic Refuse in Different Countries (% by weight)

Material	Sweden	Italy (Rome)	Netherlands	U.S.A.	Federal Republic of Germany
Paper	50	25	25	50	28
Glass	10	6	11	9	9
Metals	7	3,5	3.2	9	5
Ferrous	6	3,1	3.1	7.5	4.5
Aluminium	0.5			0,8	0.2
Non-ferrous (total)	1,0	0.35	0.1	1,5	
Plastics	9	8	5	1	4
Organic components	22	45	46	23	35

Table 14: Resource Recovery from the A and B Processes

Material Content (Refuse) % by weight		Material Yield %	Recoverable Content % by weight	2-shift operation, 16h. 400 t/d	
				t/d	t/a
Paper	28	70	20	80	20,000
Inert Material	15	85	13	52	13,000
of which Glass	9	70	6	24	6,000
Ferrous metal	4.5	90	4	16	4,000
Plastics	4	50	2	8	2,000

Throughput for each process line, 12.5 t/h

250 days/year

Table 15: Compost Production with Different Operating Variants (Process line C
Raw Material Throughput with 2-Shift Operation 200 t/d, 50,000 t/a)

Operating Variant (1)

Crude refuse input (Mainly from compactor lorries)	t/d	200	100	50	50
Input "organic residual fraction from process lines A and B"	t/d	-	50	100	150
Input, sewage sludge	t/d	(2) -	50	50	-
(60% water content)	t/a	-	12,500	12,500	-
Output					
Mature compost: fine / Fresh compost: coarse	% by weight	35-50	45-60	60-70	
Compost production	t/d	70-100	90-120	120-140	
	t/a	17500-25000	22500-30000	30000-35000	

(1) Intermediate variants possible

(2) Increase in sewage sludge processing over and above 12,500 t/a through admixing on the composting site, is possible.

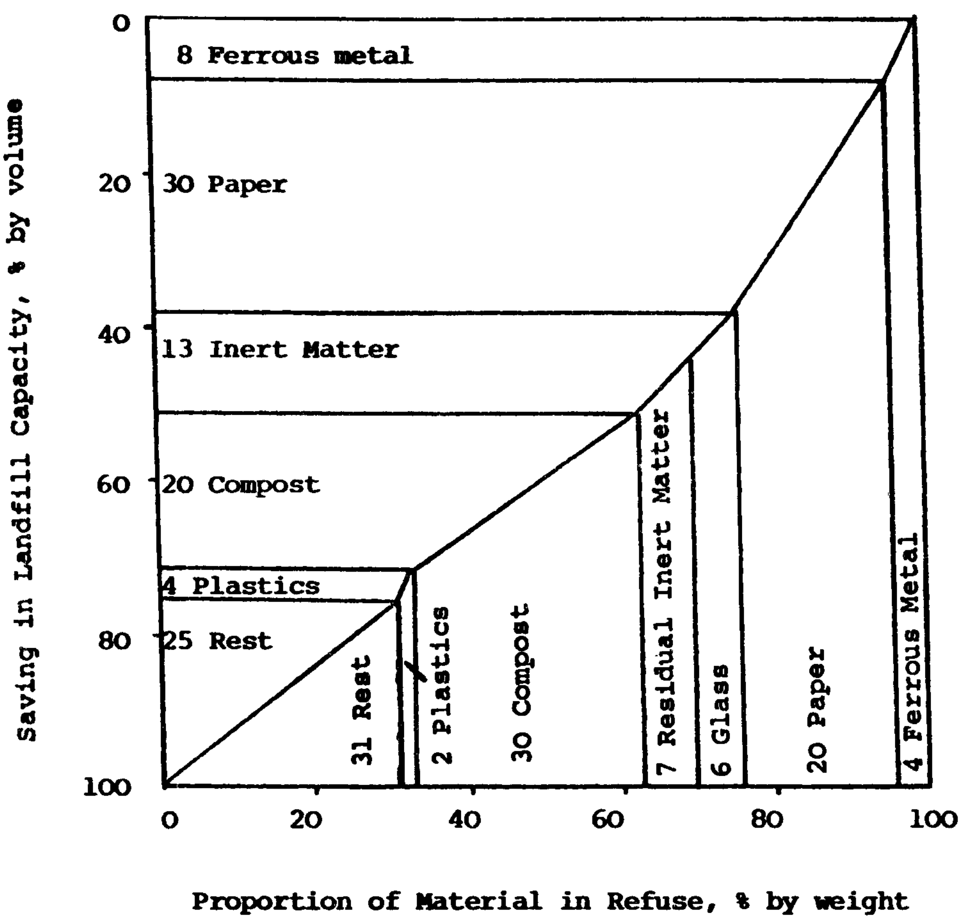


Figure 10: Relationship between the Proportion by Weight of a Material and the Resulting Saving in Landfill Capacity from Recovery

The diagram shows the varying influence which the sorting-out of ferrous metal, paper, inert matter etc. has on the demand for tipping space. The smaller saving in volume in relation to weight through the recovering of compost is due to the fact that residues are screened out in the production of compost which must be landfilled.

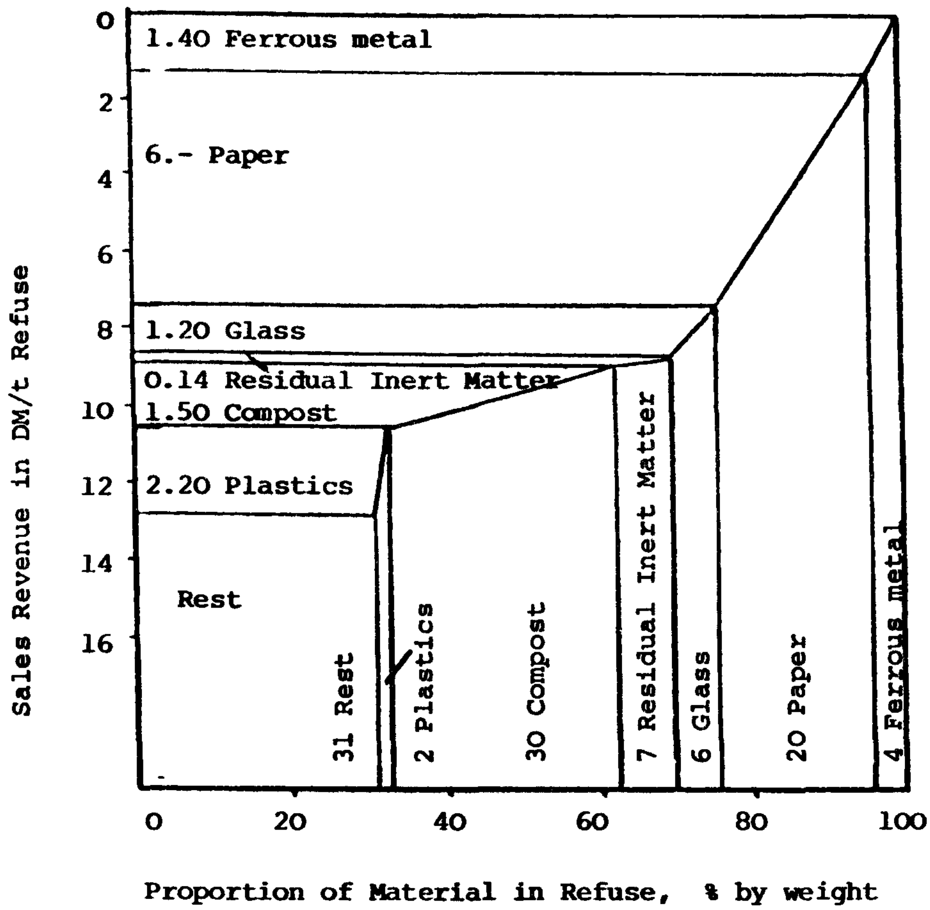


Figure 11: Relationship between the Proportion by weight of a Material and the Revenue from its Sale in respect of 1 tonne of Waste.

From this diagram, one can gather that ferrous metal, paper and glass are the most important products with regard to revenue. Also plastics, the sorting-out of which is aimed for, bring a high revenue with their small proportion by weight.

4.3.6 Estimate of Costs

General

Although no specifically expensive technologies are employed in the Model plant, the costs are relatively high as various processes are tested in parallel, which require expensive construction and process engineering equipment for the research and development work planned. One must also reckon with higher labour costs and additional costs for reconstruction and replacement of individual units as well as for waste analyses, measurement programmes etc.

Investment subsidies from the Federal and State governments shall reduce the costs to the level of conventional "higher value" technologies.

The following estimation of costs is based on firm offers for the process and electrical engineering components of the plant as at April 1975, and an estimate of costs for the structural and other arrangements on the basis of preliminary designs. Appropriate allowances for unforeseen items are taken into consideration. A detailed financial analysis for the planning and testing period can only be compiled once the essential information on project financing is available.

The following simple estimate of costs was not put together according to industrial management principles. Nevertheless, the result enables comparisons to be made with alternative solutions, as this method of computation is customarily employed in waste disposal planning.

Investment Costs

150,000 t/a lay out - 1975 costs.

Purchase of land	400,000
Development and construction	12,800,000
Machines and electrics	27,400,000
Vehicles	800,000
	41,400,000
Incidental costs ca. 8.7% (Planning, building supervision, administration, etc.)	3,600,000
Total Investment Costs	45,000,000

Under the assumption that the deadlines given in paragraph 4.7 for project implementation can be met, the following approximate timing for investment outlay results:

1976	ca.	500,000 DM	(Planning Costs)
1977	ca.	12,000,000 DM	
1978	ca.	17,500,000 DM	
1979	ca.	15,000,000 DM	

In addition, the costs for establishing the holding company would apply in 1976.

Operating Costs

Labour and General Costs	DM/a
Labour (ca. 50 employees) **	1,750,000
Maintenance, repair, etc.	1,651,000
Energy, fuel	850,000
Administration, P.R. other	250,000
Residue disposal (50% residue, 10.- DM/T)	750,000
	5,251,000

** for operation and research.

Specific processing costs at 150,000 t/a = 35.- DM/t

Revenues from the sale of the products and expenditure for special research projects and accompanying research are not included.

Annuities

It is assumed here that a total of DM 30 million in the form of grants are made available. 15 million DM of the investment costs must be obtained on the capital market:

Average annuity ca. 15% p.a.,

15% of 15,000,000	= 2,250,000 DM/a
Thus capital servicing at 150,000 t/a	= 15. - DM/t
Labour and general costs	5,251,000 DM/a
Capital servicing	2,250,000 DM/a
Total Operating Costs	7,501,000 DM/a
Unit costs at 150,000 t/a in total	50. - DM/t

Revenues

From the assumptions made in tables 4 and 5, the following, theoretically possible revenues result from the sale of the 'recycling products', given full employment of plant capacity and successful product marketing (optimistic revenue rates in brackets):

Sorting processes

A and B (without additional revenue from compost)

100,000 t/a x 10.90 DM/t Crude refuse = 1,090,000 DM/a
(x 20.- DM/t Crude refuse = 2,000,000 DM/a)

Process C

Composting

25,000 t/a compost x 10.- DM/t = 250,000 DM/a
(x 20.- DM/t = 500,000 DM/a)

1,340,000 DM/a

(2,500,000 DM/a)

Average revenue per t. crude refuse at a throughput of 150,000 t/a

9.- DM/t

(16.70 DM/t)

One proceeds on the assumption that, during the testing period, the revenues obtained are employed to guarantee product sale and for financing experimental programmes to promote reuse by the consuming industry, or if necessary for repaying subsidies. Using the revenues for reducing waste disposal charges only appears realistic after completion of the test period.

Cost comparison with conventional processes

The costs for the Model plant established above do not permit any valid statements to be made about the economic viability of the plant in comparison to conventional treatment plants. To enable at least a roughly comparable assessment of costs, a hypothetical cost model is employed, taking as a basis a plant concept such as that aspired to as the outcome from the test Model:

standardised process technology; optimised, clean disposal and production unit; lay-out; 200,000 t/a, employed to full capacity.

In ascertaining capital servicing, it is assumed that the total investment requirement is supplied through the capital market.

Using a 1975 cost basis would give investment costs of about 35 million DM. Ranges of costs and average values for unit costs per tonne of waste are indicated in the following tables. The comparative costs for incineration and composting plants are taken from evidence provided by the Institute for Urban Water Development and Water Quality Management of the University of Stuttgart for the rural districts of Reutlingen, Tübingen and Zollernalbkreis in July 1975, and apply to plants of similar size. (The revenues quoted there of DM 10.15 for scrap and heat from an incineration plant are to be considered as optimistic).

The cost comparison shows that the costs for the recovery plant are lower than those for an incinerator, and about equally above and below those for composting, depending on how successfully the products can be marketed. In this regard, it should be noted that a 200,000 t/a composting plant is an unrealistic project for comparison, at least given the current market situation for refuse compost. In a comparative process assessment, one should consider apart from the costs, the varying effect on the need for landfill space (compare figure 6). The percentage values for the remaining tipping space requirement, shown in the botton line of table 5, relate exclusively to those types of waste which are capable of being processed (capacity required for landfilling these types of waste without treatment ≙ 100%). In this context, a feature of "recycling" is that sale of the products is an inalienable pre-condition for operation of this process. Whereas with incineration, reduction in volume (the prime objective) is substantially achieved without product distribution (plants without heat recovery), and with composting where the compost is not successfully sold, an advantage in disposal is at least to some extent achieved as against tipping of crude refuse, a sorting plant without any sale of products is absurd as, apart from material separation, no volume reduction or other advantageous transformation is achieved.

Table 18: Comparison of Processes

	Recovery Plant (hypothetical cost model)			Incineration	Composting
	from	to	average		
	DM/t		DM/t	DM/t	DM/t
Operating costs	40.-	50.-	45.-		
Residual tipping costs	3.-	10.-	6.50		
Total costs	43.-	60.-	51.50	64.-	41.-
Net revenue from product sale	16.-	9.-	12.50	10.15	5.-
Remaining costs	27.-	51.-	38.50	53.25	36.-
Remaining need for tipping space	30%	40%	35%	ca.25%	ca.40%

.3.7 Target Dates and Project Schedule

Figure 8 represents, in the form of a bar diagram, a possible schedule for the Federal Model up until the end of the testing phase. A period from January 1976 to September 1979 is envisaged. Commencement at the appointed time (January 1976) does not preclude shifts in the forward plan of up to a year. The following main activities are presented in the diagram which, for reasons relating to the timing of the whole project, often overlap extensively:

- site selection
- establishment of the holding company and placement of a planning contract
- completion of planning documents
- execution of the process for planning agreement
- completion of the developed plan
- placement of contracts for supply of mechanical plant and structural components
- construction
  delivery
- installation
- test operation
- take-over and commencement of operation

Presentation of the accompanying, parallel-running research programme and the completion of agreements with customers for the products were ignored.

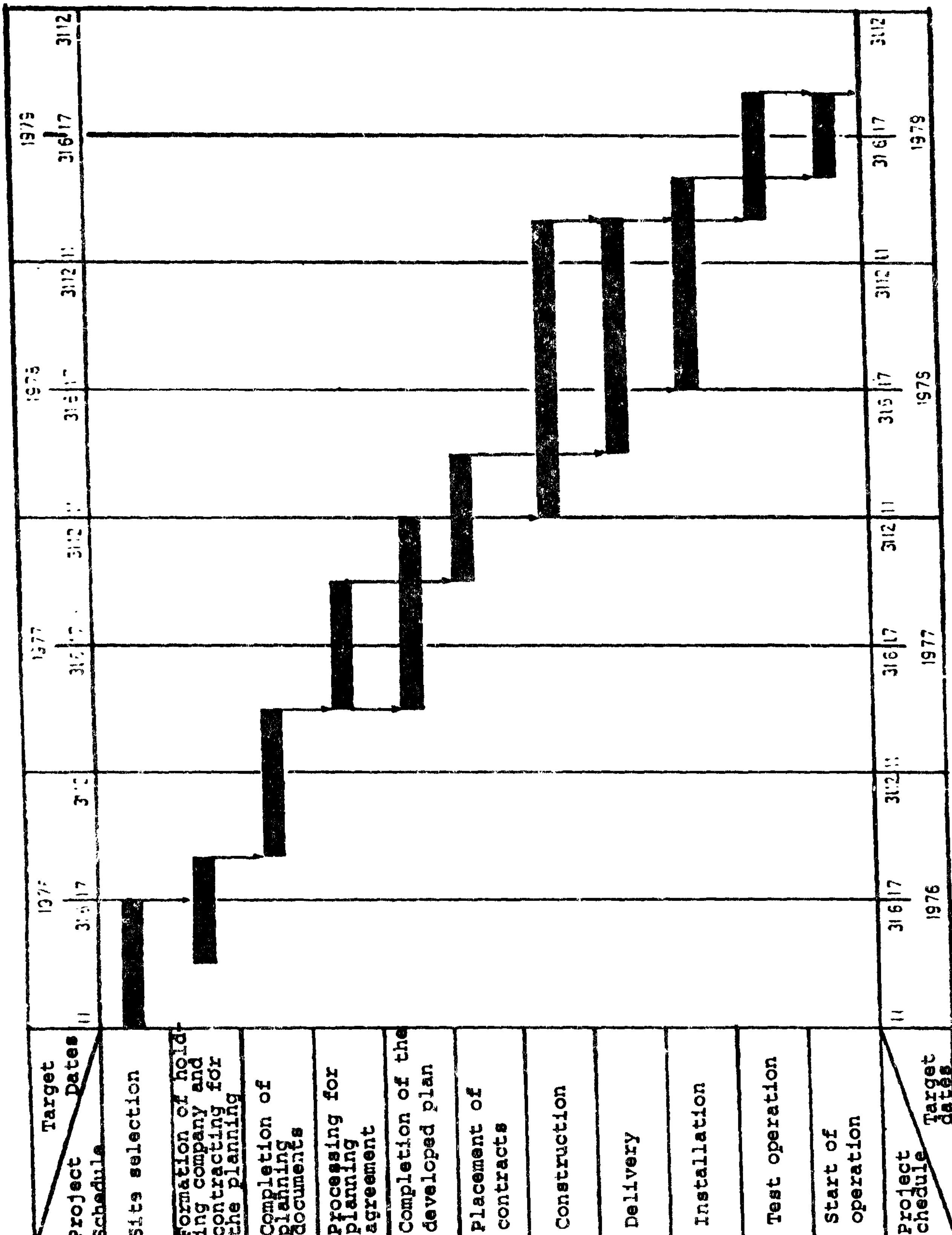


Figure 12: Timing schedule

Note: In contrast to the project schedule presented here, a delay of 9-12 months is currently estimated (see paragraph 4.8)

4.3.8 Current Status of the Project

The Federal Minister for Research and Technology (BMFT) and the State of Baden-Württemberg had already made a joint offer at the beginning of 1976 to the rural districts of Reutlingen and Tübingen, and promised the following grants:

Investment	10 million DM from the State Government
	ca. 11 million DM from the Federal Government
Total	ca. 21 million DM

(estimated investment costs including cost increases, total ca. 51 million DM)

Operation ca. 27 million DM from the Federal Minister for Research and Technology, including grants for adjustment investments during the 5-year testing phase.

In further negotiations, which extended until the middle of 1976, contractual arrangements were laid down relating primarily to questions of securing the risk in the event of failure of the Model trials and the exceeding of reasonable support from the rural districts themselves. The date originally established (1st October 1976) for the decision by the rural districts to accept or reject the offer of support had to be delayed twice, as the related decision on siting created difficulties.

Pressure groups were also set up in the municipalities short-listed as possible sites which provided considerable opposition, while at the same time other cities and rural districts from Baden-Württemberg and other Federal states revealed their interest in the project.

A positive decision was ultimately brought about on 15.1.1977, when the city of Reutlingen had offered a site alongside the present "Schinderteich" landfill site. Simultaneously, the municipality of Dusslingen in the district of Tübingen made an alternative site available.

The final decision between these two sites still remains outstanding.

At the end of 1976, after carrying out a limited call for tenders, a pre-planning contract was placed with the firm of Thyssen Energie GmbH, Bottrop, which aims at examining the technical concept and cost estimates proposed in the Federal Environment Agency's (Umweltbundesamt) project study of October 1975.

The result of this pre-planning exercise will be available at about the beginning of May 1977, and will serve as the basis for the placing of further contracts by the Administration Union of the rural districts of Reutlingen and Tübingen, the setting-up of which should be completed by this date.

Depending in the meantime on how clearly plans for similar projects in other European countries have been put in concrete form, sufficient incentive should be given in order to now rapidly push ahead with the Federal Waste Recovery Model, after overcoming the first hurdles.

5. Description of a Comparison and Evaluation Model for Household Waste Mechanical Sorting Systems

Because of the big amount of household waste mechanical sorting systems and the qualtitative different informations about them , for further studies it will be necessary to use a uniform comparison and evaluation model.

The starting point is the context of the decision-making situation. In the case of the household waste separation systems the question of the analysis and choice between plants is determined mainly by technical and operating criteria for the plant. These , however, should not be overemphasized and obscure the fact that decisions must also take into account nontechnical criteria and viewpoints.

The relevant descision makers are the governmental departments for each country and the decisions are then carried out mainly by local government agencies.

The goals for the decision-making problem should, as far as possible, be derived from the macro-economic context.

The decision context implies that the decision maker (government departments) has a national economic goal system. The decisions about investment in household waste disposal then are based on both, the important technical criteria and consideration of the following question: "What contribution does a particular plant-type make to the fulfillment of individual economics goals ?".

5.1 General Goal System

The general goal system for household waste mechanical sorting systems shows the following categories:

1. Input Factors

1.1 Quantity and quality of household wastes
1.2 Consumption of resources
1.3 Environmental standards

2. Output Factors

2.1 Quality and acceptability of reclaimed materials
2.2 Effect on landfill
2.3 Impact on the environment

3. System Goals

A Process criteria

3.1 Applied processes
3.2 Flexibility
3.3 Treatment scheme
3.4 Effectiveness

B Plant criteria

3.5 Depreciation and consumption
3.6 Compatibility
3.7 Reliability
3.8 Degree of automation
3.9 Plant characteristics
3.1o Operating history
3.11 Manufacturer characteristics
3.12 Impact on the environment

4. Cost Factors

4.1 One-time cost-factors
4.2 Operation cost-factors

5.2 Description of the System Goals

Within the single categories should be given the following detailed informations.

A Process Criteria

3.1 Applied processes

3.1.1 Preparatory treatment

- bag splitting

- shredding, pelletising
- sieving
- further reduction in size

3.1.2 After-treatment
- desicating and drying
- compacting

3.1.3 Separation processes
- air classifying
- froth flotation
- magnetic separation
- electro-static separation
- heavy media separation
- optic separation
- ballistic separation
- thermal separation

3.2 Flexibility

3.2.1 General suitability(min.content, max.content, optimal content in %)
- paper and board
- glass
- ferrous metals
- non ferrous metals
- plastics
- ash
- organic material

3.2.2 Input quality
- humidity content (in %)
- size distribution (ø min, ø max)
- state of decomposition

3.2.3 Quantities (t)
- through put

3.2.4 Possibilities of adjustment to variations in the quantity and composition of household waste

3.2.4.1 Quantities of wastes

3.2.4.2 Composition of wastes

3.2.4.3 Type of adjustment

3.3 Treatment Scheme

3.3.1 Continuous treatment processing

3.3.2 Discontinuous treatment processing
- duration of a treatment cycle
- quantity treated per cycle

3.4 Effectiveness

3.4.1 Reclaimed materials yield index (in %)
- ferrous metals
- aluminium
- glass
- paper and board
- plastics
- organic materials

3.4.2 Quality of reclaimed material (purity, form and contaminants
- ferrous metals
- aluminium
- glass
- paper and board
- plastics
- organic materials

3.4.3 Weight and volume reduction , calculated as a % of the reclaimed materials
- individual process stages
- total process

B Plant Criteria

3.5 Depreciation and consumption

3.5.1 Energy needs

3.5.1.1 Installation efficiency

3.5.1.2 Average energy input
- main processes
- auxiliary processes

3.5.2 Fuel and materials

3.5.3 Personnel needs (distinguished according to skills and work areas)

3.5.4 Floor space requirements
- main plant
- auxiliary plant

3.5.5 Space requirements (in m^3 enclosed space)

3.5.6 Building and completion times for
- planning
- building construction
- installation
- testing phase

3.5.7 Auxiliary plant
- central cleaning plant
- delivery and weighing
- analysis
- incineration
- residue treatment

3.6 Compatibility

3.6.1 Modular building system

3.6.2 Is the whole plant built from a single manufacturers design ?

3.6.3 Are extensions/extra units available ?

3.6.4 Is the plant compatible with existing and/or future industrial processes ?

3.7 Reliability

3.7.1 Susceptability to breakdown

3.7.1.1 Plant life expectancy/actual length of operation (determined by life expectancy of the unit with the shortest operation lifespar)

3.7.1.2 Availability of whole plant and individual units

3.7.1.3 Idle time of whole plant and individual units

3.7.1.4 Resistance to normal wear and tear of individual units:
- no information available
- standard life expectancy achieved
- standard life expectancy exceeded

3.7.1.5 Number of key units/elements, whose breakdown results in the stopage of the whole system

3.7.1.6 Can the reliability of individual units be improved ?

3.7.1.7 Number of established reliable plants and individual units

3.7.1.8 Number of newly developed plants and individual units

3.7.2 Ease of service

3.7.2.1 Number of standardized units in the plant

3.7.2.2 Possibility of "self service" repair

3.7.2.3 Number of plant units that do not require servicing

3.7.2.4 Availability of manufacturers servicing/maintenance inspections

3.7.3 Servicing and inspection / monitoring costs

3.7.3.1 Automatic monitoring

3.7.3.2 Servicing and repair times for:
- single units
- the complete plant

3.7.3.3 Number of supervisory personnel

3.7.3.4 Number of repair/maintenance personnel

3.7.3.5 Servicing or maintenance requires stoppage

3.7.3.6 Total check up of the plant:
How many operating hours and/or how much treated material is lost ?

3.8 Degree of Automation

3.8.1 Number of automated and partially automated units

3.8.2 Number of machines and machine-units that could be automated

3.8.3 Number ofoperatives per shift supervising automated processes

3.8.4 Supervising system
- centralised control and direction
- decentralised control and direction

3.9 Plant characteristics

3.9.1 Type of construction
- permanent structure
- prefabricated/demountable structure
- inflatable structure

3.9.2 Type of building
- massive structure/lightweight structure
- single storey/ multiple storey
- above ground / underground
- enclosed / open plan

3.9.3 Site plan
- area allocated to plant
- area allocated to transportation

3.9.4 Design of the work place
- ease of operation
- number of jobs involving heavy manual labour
- number of jobs as machine operatives
- stress as a result of: dust, noise, heat, humidity, smell

3.9.5 Internal transport system
- flexible / rigid
- number of employees
- reliability / breakdown rates

3.1o Operating History

3.1o.1 Running time

3.1o.2 Proportion of plant capacity utilized

3.1o.3 Development levels
- concept

- labouratory plant
- pilot plant
- demonstration plant
- fullscale normal plant

3.11 Manufacturer Characteristics

3.11.1 Know-how

3.11.2 Range and type of plants and subplant units offered

3.11.3 Number of subplant units provided from own stock - number of subplant units used from other manufacturers stock

3.11.4 Independent research activities

3.11.5 Customer service

3.11.6 Production capacity and delivery time for units

3.11.7 Delivery form / installation help

3.12 Impact on the environment

3.12.1 Air pollution

3.12.2 Water pollution

3.12.3 Soil pollution

3.12.4 Noise pollution

3.12.5 Aesthetic (Subjective evaluation of the effect of the whole plant on the surrounding environment)

4. Cost factors

4.1 One-time cost factors
(sum of all investment costs, not including costs for capital financing)

4.1.1 Development costs
- research and development costs
- planning costs

4.1.2 Investments
- site development costs

- building costs (incl. sundry building costs)
- costs of equipment (basic and auxiliary)
- costs of emergency backup equipment
- costs for necessary ancillary equipment (e.g. tools) and spare parts
- installation costs
- transport equipment costs
- one-time finance-costs, taxes, insurance, etc.
- training costs
- sundry costs

4.2 Operating cost factors

4.2.1 Costs of maintaining the plant in working condition (fixed costs)

- capital costs
- personnel costs
- administrative costs
- taxes
- insurance (health insurance, pension plan, etc.)

4.2.2 Costs for running the plant (variable costs)

- energy costs
- material costs
- repair and maintenance costs
- personnel outfitting and replacement costs (tools, clothing, etc.)
- residue disposal costs (incl. transport)

5.3 Practical Application of the Goal System

The members of the CREST study-group have relaized that at this time it is very difficult if not impossible to get exact informations. This applies as much to the two German plants as to all European household waste mechanical sorting systems. Relatively good data are available on the input factors, though the data on qualities and quantities of household wastes are not allways comparable. In all cases it is possible to describe the technical flowsheet, but for none of the two German systems the technical large-scale realisation is available. Therefore there is only little knowledge about practical installation and realistic efficiency on the one hand and on running costs on the other hand. Because these data are very necessary for all communities that want to build up mechanical sorting plants there is a lot of work for the future in realizing the given goal system.

6. Final Recommendations for R & D

The members of the pilot and the co-pilot countries have discussed the possible recommendations for research and development programmes and have proposed to include the following recommendations for concerted actions and for indirect actions in the final reports.

6.1 Recommendations for Concerted Actions

There are already several major research programmes in progress or planned within several member countries of the Community. The project team is very concerned to avoid recommending duplication of this research. It is felt, however, that there are certain areas where international discussion and co-ordination of this research would enhance its value, both to individual countries and to the Community as a whole. The spirit of international co-operation which has been experienced during the present study has been of great benefit and this could provide a foundation upon which further collaborative work could be built.

It is therefore recommended that a programme of concerted action should be established, provided that the support of national governments can be obtained. It is recognised that in some cases existing R & D is funded by commercial interests and could not be included in a concerted action programme. The programme should be organised to cover the following aspects of household waste sorting technology:

- Work in progress or planned in member countries (e.g. the Bundesmodell Abfallverwertung Reutlingen Tübingen) should be monitored, existing links between research groups should be maintained and new ones encouraged wherever possible. These links should be used to promote comparative investigations of different systems under consistent conditions, and studies of the effect of varying the composition of the feed. It is recognized that different project timescales might give rise to problems in making comparisons, but when the planned new generation of experimental plants working at a realistic scale is in operation co-ordination of research and parallel investigations in different locations could be very valuable.

- Standard methods should be obtained and established for sampling and analysing household wastes, specifying the quality of waste-derived products, and reporting cost and related economic data. Comparison of processes in different locations is very difficult, but the value of such comparisons would be greatly enhanced if better standardisation of feed analysis, process parameters and product specification were achieved. The effect of statutory requirements applying to waste recovery in different member countries on the design and viability of waste sorting processes might also be considered.

- Potential health hazards arising from the handling, treatment and storage of domestic waste and related products should be in - vestigated. This is an area which would require considerable co - ordination of testwork and data collection.

The method envisaged for implementation of the concerted action programme is a series of meetings of technical experts from the member countries. Because of the wide range of topics for discussion it is suggested that these meetings should take the form of symposia lasting 2 - 3 days with , say, 2o invited delegates per symposium

6.2 Recommendations for Indirect Action

It is recommended that the major proportion of the financial resources allocated to R & D in waste sorting should be used in a programme of indirect action. Research is recommended into topics where it is felt that more fundamental studies or the development of new or improved separation techniques are required. The recommended topics for investigation come under three headings:

- Separation Technology
- Material Recovery
- Energy Recovery

6.2.1 Separation Technology

The possibility of two to three projects in this area is envisaged.

The highest priority is placed upon an investigation of air classification, but liberation and comminution of waste is also recommended for study.

6.2.1.1 Air Classification

There are several air classification systems available, but there is a serious lack of the information necessary for scale-up of pilot installations and to enable the best choice for a particular situation to be made. It is therefore recommended that a fundamental investigation of the parameters affecting separation should be carried out prior to larger scale trials in association with the experiments on front-end systems. The main aims of this work should be:

- To compare existing types of air classifier under consistent conditions.
- To investigate the effect of changing design variables and composition of the feed.
- To establish criteria for the design and scale-up of air classification systems to process household wastes.
- To investigate the influence of different comminution systems on different types of air-classifier.

6.2.1.2 Liberation / Comminution

The choice of a front-end system for a sorting plant is still largely a subjective one. Information in the literature is of limited help because of the varying conditions under which the experiments are carried out. It is therefore proposed that comparative investigations of shredding and sizing systems at a scale of at least 10 tonnes/h should be carried out under consistent conditions with a clearly defined feed. Particular attention should be paid to the following points:

- The suitability of the processed waste for subsequent separation into products.
- Elimination of gross oversize materials in sizing plants.
- Maintenance and reliability.

The concerted action programme could be of assistance in promoting this research. The cost of purchasing new equipment could be minimised by co-ordination of studies in different research groups using existing equipment as far as possible.

6.2.2 Materials Recovery

The two most important topics for further research are paper recovery and plastics recovery. Two projects in each of these topics are envisaged.

6.2.2.1 Paper Recovery

In most locations paper is potentially the most valuable constituent of the waste so there is a strong incentive for its recovery. The importance of household waste as a source of secondary fibre has already been recognised by the CREST Working Party on Paper Recycling, and a number of research topics in this field have been included in a proposal for a research programme on paper and board recycling. It is felt that certain aspects of this earlier programme have been largely achieved in the present study. In particular most of the work recommended in Part A of the programme has been done in the present study e.g. classification of urban wastes, the technical feasibility of separating fibre from household wastes and economics of processing to obtain a fibre product. Further effort should concentrate on the recommendations in Parts B and C which relate to the use of urban fibre by the paper industry and health problems which might arise from its use. In addition it is considered very important that support should be given for further R & D on paper separation technology, an aspect which was not included in the earlier recommendations by the Working Party:

- Most existing paper fibre recovery systems are based in part on air classification to provide a paper-rich concentrate for further upgrading. There is a requirement for research into the design and operation of air classification systems to produce a better paper-rich product.
- Further work is needed on methods of separating plastics film from paper which are less costly in terms of capital equipment and energy consumption than existing ones.

- The development of other novel methods of paper recovery should be encouraged.
- As an alternative to dry separation of a paper fibre product, wet processing at the front-end of the paper mill should be investigated in co-operation with the paper industry.

6.2.2.2 Plastics Recovery

Recovery of paper fibre will normally result in the production of a by-product which is rich in plastic film. In some member countries bottles are a significant constituent of household wastes and these can also be separated as a product. Research is therefore recommended into the separation and cleaning of plastics concentrates, paying particular attention to the following aspects:

- The indications are that the size and nature of the potential market for plastics products recovered from household wastes varies considerably between the member countries. In some locations it might be possible to sell a mixed plastic product, while in others segregation of polymer types will be necessary. A community-wide market study is therefore recommended to determine where R & D effort might be most profitably applied.

- There are several processes available for the manufacture of products from mixed waste polymer. Although perhaps the main problem to be solved in this field is the creation of new market for the products, there is scope for further work on the feedstock formulations required for specific end-products, and the effect of additives on product quality.

- The potential for developing technology for separation and cleaning of mixed and contaminated polymer waste merits investigation. The nature and level of contaminants which inhibit the use of reclaimed polymer in standard moulding or film blowing equipment should be studied, taking into account the possibility of developing new chemical additives to counteract the degradation of secondary polymers during moulding.

6.2.3 Energy Recovery

The project team is aware that an EEC Energy Research Programme was adopted by the Council of Ministers in 1975. One of the main subject areas is Energy Conservation and project proposals have already been received which relate to the use of the energy content of wastes. This is therefore, another area where close co-ordination of projects by the Commission is essential. It is considered that further work is needed on the use of both shredded and densified waste-derived fuels, and the following project areas are suggested for consideration:

- Community support should be given to encourage an investigation of the use of shredded waste-derived fuel, shredding, handling and firingsystems for suspension-fired boilers will need to be developed, but there is much relevant experience in the USA which can be drawn upon.

- It seems that for industrial use a densified fuel product is most likely to have adequate storage and handling characteristics. A great deal of work is required on the continuous production of fuel pellets or briquettes. Most work carried out to date has used machines designed for agricultural purposes and many problems have been encountered. Pilot-scale tests to measure specific power consumption, die wear and throughputs are needed to enable suitable equipment to be designed. Methods of handling densified waste-derived fuel are needed and extended firing trials are necessary to determine the effect of firing waste-derived fuel on corrosion, fouling of boiler tubes and atmospheric emissions. Possible additives to the fuel from the point of view of increasing its calorific value, prolonging its storage life, reducing its susceptibility to water and inhibiting biological activity should be examined.

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COMMISSION OF THE EUROPEAN COMMUNITIES

(Directorate General XII - Research, Science Education)

HOUSEHOLD WASTE SORTING SYSTEMS :
COSTS AND DEVELOPMENTS
IN THE FRENCH ECONOMIC SITUATION

A report

by

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December 1977

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ABSTRACT

This report describes the work carried by B.R.G.M. acting as representative of the co-pilot country - France - in the CREST study "Bulk consumer (Household) waste mechanical sorting systems".

It presents :

- household waste statistics en France,
- a comparative assessment of the French operating costs of the seven following processes :
  U.S.B.M. (USA), W.S.L. (U.K.), Adaro (Spain), Fläkt (Sweden), T.N.O. (Holland), Roma-Perugia type (Italy), Combor (France),
- a discussion about its results and the potential markets of the recovered products.

The differences in the calculated net operating costs of the processes under consideration (44 to 161 F/t for a 20 t/h capacity plant) are probably not very significant because of the different circumstances prevailing in the countries where they are being operated : nowadays in France, national agreements stabilize the costs of the glass cullet and the polyvinyl chloride (its importance in French wastes is a specific problem), but the other recoverable materials (waste paper, ferrous metal, compost...) have yet too fluctuating prices and markets.

A list of recommendations relating to general and specific actions to promote within the E.E.C. is included.

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INTRODUCTION

This study is a part of a Europe-wide investigation involving Britain (pilot country represented by the Warren Spring Laboratory), Germany and Italy (co-pilot countries together with France) and other European countries. The recycling experience of the United States has also be taken into consideration.

The initial chapter presents household waste statistics in France. In the following chapters, the economics of the waste sorting processes assessed in the study of the pilot country, are transposed to specific french situation ; their results and the french potential markets of the recovered products are discussed.

A list of recommendations relating to general and specific actions to promote within the E.E.C. is included.

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1. WASTE ELIMINATION IN FRANCE .

1.1. Amount of municipal wastes produced .

13 millions tons/year or per capita :

0.2 to 0.4 kg/inhabitant/day in rural areas

0.6 to 0.9 kg/inhabitant/day in urban areas

0.9 to 1.1 kg/inhabitant/day in commercial areas.

1.2. Composition of municipal wastes .

fines (< 20 mm) :	10 to 20 %
organic putrescible substances :	15 to 30 %
paper - cardboard :	20 to 40 %
rags :	1 to 6 %
plastics :	2 to 6 %
glass :	3 to 11 %
metals :	2 to 6 %

For this study, domestic waste in France is assumed to have the following average composition :

fines (< 20 mm) :	15 %
organic putrescible substances :	30 %
paper - cardboard :	30 %
rags :	3 %
plastics (25 % PVC) :	5 %
glass :	8 %
metals :	4 % (non ferrous < 0,5 %)
others :	5 %

1.3. Physical caracteristics of municipal wastes .

		Density (kg/l)	Humidity (%)	Net heating value (Kcal/kg)
Summer	High	0.23	42	1 800
	Low	0.12	38	1 300
Winter	High	0.32	33	2 100
	Low	0.17	28	1 700

1.4. Previsions of composition for 1990.

fines :	2 to 5 %
organic putrescible substances :	10 to 15 %
paper - cardboard :	40 to 60 %
rags :	5 to 7 %
plastic :	8 to 10 %
glass :	5 to 12 %
metals :	4 to 6 %

1.5. Waste treatment plants in 1975 .

284 French plants treat about 20 000 tons/day of wastes. Types of treatments are listed in the following table :

Treatment	Number of plants	% population concerned	Nominal capacity (t/h)	tpd treated
Incineration	126	29	558	5 796
Incineration with heat recovery	20	43	385	8 149
Composting	46	9	336	1 739
Dumping after shredding	52	7	413	1 629
Composting with refuse incineration	40	12	297	2 415
T O T A L	284	100	1 989	19 728

2. THE COST OF WASTE SORTING IN FRANCE.

2.1. Estimations of investments.

Based on Lang factor utilization and plant capacities of 10 and 20 t/h, investment costs C_F related to the French situation in 1976 are calculated from :

- the investment-cost of plants in the country of origin and in its currency: Co,
- the country cost index in 1970 (given by K.M. GUTHRIE) on the basis of 1 in USA) : $I°_c$ (Ic^F for France),
- the plant cost index in each country in 1976 : I_o (basis 100 for 1970),
- the plant cost index in France in 1976 (in 1970) given by :

$$I_F = 100(0.10 + 0.30 \frac{Tma}{Tmao} + 0.60 \frac{S}{So})$$

  where Tma and Tmao are the cost index of iron for 1976 and 1970 and S and So of labour for 1976 and 1970 (INSEE). Then, $I_F = 183$,
- the exchange rate of the currency of the country of origin in French Francs in 1970 : $\mathring{Ex}$.

Then C_F (in 1976 francs) is given by :

$$C_F = Co \times \mathring{Ex} \times \frac{Ic^F}{I_c} \times \frac{IF}{Io}$$

The table 1 give $\mathring{Ex}$, I°c, Io and $\frac{CF}{Co}$ for the different countries.

Country	Country cost index I^o_C	Plant cost index I_o	Exchange rate $E_x{}^o$	$^{CF}/_{Co}$
France	0.98	183	1	1
Italy	0.96	224	8.82×10^{-3}	7.356×10^{-3}
Spain	0.76	205	7.94×10^{-2}	0.1024
Sweeden	0.86	184	1.065	1.207
United Kingdom	0.89	236	13.250	11.3
United states	1	148	5.53	6.7

Table 1 :

Economic index for investment estimations in France .

2.2. French data for operating costs in 1976.

- capital charges are calculated over 15 years at a rate of interest of 10 %,
- monthly wages are as follows :

  5 000 F for a manager
  3 500 F for a foreman
  2 500 F for a shift operator
  2 000 F for a day man.

Consequently, annual labour cost (including social security contribution,pensions funds , overtime, vacation time) is given by 11.3 x 1.75 x total of monthly wages.

- administration overheads are taken as 12 % of total operating costs excluding capital charges,
- prices for utilities are as follows :

  electricity : 0.21 F/Kwh
  natural gas : 0.04 F/therm
  water : 0.60 F/m^3

- annual maintenance costs are taken as 4 % of the total investment cost,
- the cost of residue disposal is assumed to be 15 F/t.

2.3. Estimated revenues from recovered products in France.

- ferrous metals : 100 F/t
- glass : 125 F/t
- derived fuel : low quality (after paper recovery): 44 F/t
  only shredded : 55 F/t
  shredded and pelletized : 66 F/t
  shredded, pelletized, dryed, but roughly sorted : 66 F/t
- paper : 130 F/t
  in refined pulp : 400 F/t
- animal food : 450 F/t
- compost : high quality : 20 F/t
- plastics : not yet marketed
- fines (organic and mineral) for clay brick manufacture : 8 F/t

2.4. Processes assessment under French conditions .

U.S.B.M. PROCESS

a) Recovered material balance :

Constituents	recovery %	% of constituants in french wastes	% of recovered in put
glass	70	8	5.6
ferrous metal	90	3.5	3.2
fuel	-	-	37.0
residue	-	-	54.2

b) Operating costs :

Plant capacity :	10 t/h	20 t/h
waste in put :	31 000 t/y	62 000 t/y
capital cost :	36.2 MF	54.9 MF ✖
annual costs :	x 10^3 F/y	x 10^2 F/y
capital charges :	4 760	7 220
labour :	790	990
administration overheads :	320	510
maintenance :	1 450	2 200
electricity (22 kWh/t):	145	290
natural gas for space heating :	30	50
water :	20	40
chemicals por froth flotation :	30	60
residue disposal (54 % of input):	250	500
T O T A L	7 795	11 860

Revenues :	x 10^3 F/y	x 10^3 F/y
ferrous metal	99	198
fuel (only shredded)	631	1 262
glass	217	434
T O T A L	947	1 894
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	6 848	9 966
	or 221 F/t	or [illegible] F/t

✖ *If it is assumed like in the pilot country study that a basic 20 tons/hour U.S.B.M. process could be installed for 5 M $ or 33.5 MF, the reduction in capital change and maintenance would amount to 3 680 000 F and the net operating cost would then be 101 F/t.*

W S L PROCESS

a) *Recovered material balance :*

Constituents	% recovery	% of constituents in french wastes	% of recovered input
Ferrous metal	80	3.5	2.8
Glass	50	8	4.0
Fuel	-	-	30.0
Residue	-	-	62.8

b) *Operating costs :*

Plant capacity :	10 t/h	20 t/h
Waste input :	31 000 t/y	62 000 t/y
Capital cost :	15.8 MF	22.6 MF
Annual cost :	x 10^3 F/y	10^3 F/y
capital charges :	2 077	2 971
labour (including manager and oncost) :	790	990
administration overheads :	243	370
maintenance :	644	920
electricity (40 Kwh/t) :	260	520
natural gas for space heating :	30	50
water :	7	11
chemical :	4	8
residue disposal (63 % of input) :	293	586
T O T A L	4 348	6 426
Revenues :	x 10^3 F/y	x 10^3 F/y
ferrous metal	87	174
fuel (shredded and pelletised)	614	1 228
glass	155	310
T O T A L	856	1 712
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	3 492	4 714
	or 112 F/t	or 76 F/t

ADARO PROCESS

a) *Recovered material balance :*

Fuel and ferrous metal recovery option

C o n s t i t u e n t s	% recovery	% of constituents in french wastes	% of recovered input
Air classifier-paper	80	30	24
Air classifier-plastics	42	5	2.1
Air classifier-rags	48	3	1.4
+ 65 non magnetics-paper	20	30	6
+ 65 non magnetics-plast.	32	5	1.6
+ 65 non magnetics-rags	52	3	1.6
T O T A L fuel			36.9
Ferrous metal	85	3.5	3
Residue	-	-	60.1

Paper, fuel and ferrous metal recovery option

C o n s t i t u e n t s	% recovery	% of constituents in french wastes	% of recovered input
Paper	60	30	18
Ferrous metal	85	3.5	3
Fuel	-	-	17
Residue	-	-	62

b) *Operating costs* :

Fuel and ferrous metal recovery option

Plant capacity :	10 t/h	20 t/h
Waste input :	31 000 t/y	62 000 t/y
Capital cost :	10.8 MF	16.4 MF
Annual costs :	x 10^3 F	x 10^3 F
capital charges :	1 420	2 156
Labour (including manager and oncost) :	613	811
administration overheads :	174	272
maintenance :	432	656
electricity (15 kWh/t) :	98	195
fuel for space heating :	30	50
residue disposal (60 % of input) :	279	558
TOTAL	3 046	4 698
Revenues :	x 10^3 F/y	x 10^3 F/y
Ferrous metal	93	186
fuel (only shredded)	648	1 296
TOTAL	741	1 482
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	2 305	3 216
	or 74.4 F/t	or 51.9 F/t

Paper, fuel and ferrous metal recovery option

Plant capacity :	10 t/h	20 t/h
Waste input :	31 000 t/y	62 000 t/y
Additional annual cost :	2.7 MF	2.7 MF
Additional annual costs	x 10^3 F/y	x 10^3 F/y
capital charges :	355	539
labour, oncosts and administration overheads :	126	135
maintenance :	108	164
electricity (2.7 kWh/t) :	18	35
additional costs :	607	873
Total annual costs	x 10^3 F/y	x 10^3 F/y
	3 653	5 571
Revenues	x 10^3 F/y	x 10^3 F/y
Paper :	725	1 451
Fuel (low quality) :	232	464
Ferrous metal :	93	186
T O T A L	1 050	2 101
Net operating cost	2 603	3 470
	or 84.0 F/t	or 56.0 F/t

FLAKT PROCESS

a) *Recovered material balance :*

Products	% of constituent in french waste	% of recovered input in magnetic concentrates	% of recovered input in paper concentrates (light and heavy)	% of recovered input in fuel concentrates	Refuse
Paper : wet	30	-	24	4.5	-
Paper : dry	-	-	21	-	-
Ferrous metal	3.5	3	-	-	-
Plastics	5	-	-	2.5	-
Rags, vegetable putrescible	33	-	-	7	-
Total of input	100	3	24 (wet) 21 (dry)	14	59

b) *Operating costs :*

Plant capacity :	10 t/h	20 t/h
waste input :	31 000 t/y	62 000 t/y
capital cost :	13.3 MF	20.2 MF
annual costs	x 10^3 F/y	x 10^3 F/y
capital charges :	1 749	2 656
labour (including manager and oncost) :	613	811
administration overheads :	210	339
maintenance :	532	804
electricity (25 kWh/t) :	163	326
fuel oil for paper heating :	141	282
fuel oil for space heating :	30	50
residue disposal (59 % of input) :	274	549
TOTAL	3 712	5 817
Revenues	x 10^3 F/y	x 10^3 F/y
paper :	846	1 693
fuel (only shredded) :	239	477
ferrous metal :	93	186
TOTAL	1 178	2 256
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	2 534 F or 81.7 F/t	3 561 or 57.4 F/t

T N O PROCESS

a) Recovered material balance :

Constituents	recovery %	% of constituents in french wastes	% of recovered input
Paper : wet	-	-	21
Paper : dry	60	30	18
Ferrous metal	85	3.5	3
Fines (after shredding)	-	-	25
Residue	-	-	51

b) Operating costs :

Plant capacity :	10 t/h	20 t/h
waste input :	31 000 t/y	62 000 t/y
capital cost	11.7 MF	17.8 MF
Annual costs :	x 10^3 F	x 10^3 F
capital charges :	1 538	2 340
labour (including manager and oncost) :	613	811
administration over heads :	211	345
maintenance :	468	712
electricity (20 kWh/t) :	130	260
fuel oil for paper drying :	284	569
fuel for space heating :	30	50
residue disposal (51 % of input) :	237	474
T O T A L	3 511	5 561
Revenues	x 10^3 F/g	x 10^3 F/g
paper :	725	1 451
ferrous metal :	93	186
fines :	62	124
T O T A L	880	1 761
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	2 631	3 800
	or 84.9 F/t	or 61.3 F/t

PERUGIA - ROMA - TYPE PROCESS

a) Recovered material balance :

Constituents	recovery %	% of constituants in french wastes	% of recovered input
paper (in pulp)	60	30	18
ferrous metal	85	3.5	30
animal food (dry)	-	-	8
compost	-	-	15
residue	-	-	10

b) Operating costs :-

	10 t/h	20 t/h
Plant capacity :	31 000 t/y	62 000 t/y
waste input :	30.9 MF	39.7 MF
capital cost :		
Annual costs :	x 10^3 F/y	x 10^3 F/y
capital charges :	4 063	5 219
labour (including manager and on cost):	1 870	2 440
administration over heads :	440	549
maintenance :	1 236	1 588
electricity :	98	352
auxilary fuel :	371	65
water :	43	37
residue disposal :	47	93
T O T A L	8 168	10 343
Revenues :	x 10^3 F/y	x 10^3 F/y
paper :	2 232	4 464
animal food :	1 116	2 232
ferrous metal :	93	186
compost :	93	186
T O T A L	3 594	7 068
Net operating cost :	x 10 F/y	x 10 F/y
	4 634	3 275
	or 149.5 F/t	or 52.8 F/t

COMBOR PROCESS

a) *Recovered material balance :*

Ferrous metal : 3 % (85 % of recovery)

Fuel (pelletised, dryed, but not very well sorted) : 45 % (recovered)

Fuel (pelletised, dryed, but not very well sorted) : 15 % (self consumption)

Loss of humidity : 10 %

Residue : 27 %.

b) *Operating costs :*

plant capacity :	10 t/h	20 t/h
waste input :	31 000 t/y	62 000 t/y
capital cost :	10.4 MF	19.1 MF
Annual costs :	x 10^3 F/y	x 10^3 F/y
capital charges :	1 367	2 510
labour (including manager and on cost) :	613	811
administration over heads :	181	303
maintenance :	412	764
electricity (50 kWh/t) :	325	651
fuel for space heating :	30	50
residue disposal (27 % of in put) :	126	251
T O T A L	3 054	5 341
Revenues	x 10^3 F/y	x 10^3 F/y
ferrous metal :	93	186
Combor derived fuel :	921	1 841
T O T A L	1 014	2 027
Net operating cost :	x 10^3 F/y	x 10^3 F/y
	2 040	3 314
	or 65.8 F/t	or 53.5 F/t

3. DISCUSSIONS.

3.1. About the comparison of processes .

The chapter 2.1. of this study shows the high difficulty to evaluate investments from experimental data in a foreign situation.

. Comparison between different processes is another delicate problem : for exemple, the classification of processes by their net operating cost *related to the input* , gives the following results in a french context :

Process : 10 t/h		Process : 20 t/h	
Combor	53.6 F/t	Combor	43.5 F/t
Adaro (fuel recovery)	74.4 F/t	Adaro (fuel recovery)	51.9 F/t
Fläkt	81.7 F/t	Roma	52.8 F/t
Adaro (paper recovery)	84.0 F/t	Adaro (paper recovery)	56.0 F/t
T.N.O.	84.9 F/t	Fläkt	57.4 F/t
W.S.L.	112.6 F/t	T.N.O.	61.3 F/t
Perugia	149.5 F/t	W.S.L.	76.0 F/t
U.S.B.M.	220.9 F/t	U.S.B.M.	160.7 F/t

. But if these costs are referred to *the non landfilled output* the distribution becomes :

Process : 10 t/h		Process : 20 t/h	
Combor	74.4 F/t	Roma	58.7 F/t
Perugia	166.1 F/t	Combor	60.4 F/t
T.N.O.	173.3 F/t	T.N.O.	125.1 F/t
Adaro (fuel recovery)	186.0 F/t	Adaro (fuel recovery)	129.8 F/t
Fläkt	199.3 F/t	Adaro (paper recovery) }	140.0 F/t
Adaro (paper recovery)	210.0 F/t	Fläkt }	140.0 F/t
W.S.L.	304.3 F/t	W.S.L.	165.7 F/t
U.S.B.M.	480.2 F/t	U.S.B.M.	349.3 F/t

. It is also important to note the difference between processes,(like the Roma type) the net operating cost of which comes from the difference between high revenues and high annual costs (including capital charges) and other processes with moderate revenues : for exemple, in France, investments of waste treatment plants are often granted up to 40 %, which ranges the different operating costs as follows :

Process : 10 t/h		Process : 20 t/h	
Combor	48.2 F/t	Roma	19.1 F/t
Adaro (fuel recovery)	56.0 F/t	Combor	37.3 F/t
Fläkt	60.1 F/t	Adaro (fuel recovery)	38.0 F/t
Adaro (paper recovery)	61.1 F/t	Adaro (paper recovery)	38.6 F/t
T.N.O.	65.0 F/t	Fläkt	40.3 F/t
W.S.L.	85.8 F/t	T.N.O.	46.2 F/t
Perugia	97.1 F/t	W.S.L.	56.9 F/t
U.S.B.M.	159.5 F/t	U.S.B.M.	114.1 F/t

. Finally, the most important remark points out difficulties occuring in the comparisons of the processes developped under local economic contexts : some of them are based on the recovery of a major product on which revenues are assessed, but in fact, could produce other materials with very low over-investments in a foreign or future situation : it is the case of U.S.B.M. or W.S.L. processes. In an other side, further recovery of some materials (like fines for bricks manufacturing) would easily better the financial balance of several projects.

3.2. About french recovered products markets.

321. Paper marketability.

At the present time, old papers are used, almost exclusively in the cardboard industry, with the following draw backs :

- cardboard industry cannot, on its own, even in a favourable economic situation, absorbs the quantities of old paper which could be recycled,
- this single utilization makes the market very unstable and open to all short-term fluctuations.

Moreover, the present relation ships between paper manufacturers and waste suppliers are established on the basis of short term negociations in an essentially speculative market.

Recent governmental decisions try to promote :

- the stabilisation of the price of old papers (long term contracts, controlled stock),
- the utilization of secondary fibres in the printing sector (introduction of a minimum proportion of old papers in various articles, aid to investments in de-inking facilities, prohibition of using reagents which may impede paper recycling...).

322. Glass cullet marketability.

A national agreement between the manufacturers and the government has fixed an indexed price to glass cullet (180 F/t delivery fees included in November 1977). This material needs no colour sorting but must be cleaned from contaminants and sized without - 3 mm elements : especially, a glass extracted by froth flotation is too fine to be accepted as cullet.

323. Plastics marketability.

Along side the "glass" plan, a "polyvinyl chloride" plan now exists, established by contract between Ministry of Industry and dealers in order to increase the quantity of recovered polyvinyl chloride, the rate of which in French domestic wastes is about 1 to 1.5 % (P.V.C. bottles).

A pilot unit has been set up at ROUEN and handles 1 200 tons/year of regenerated polyvinyl chloride, which is used essentially at the moment in the manufacture of tubes, sheaths, rigid shapes and in road making (SGREG process).

The sale price of PVC bottles is 800 F/t including delivery fee (November 1977). The increase in quantity of recovered PVC product may be :

From 1978 :	3 500 tons	(building of a new plant in LYON : 1 000 t/y)
1980 :	25 000 tons	
Final objective (1983) :	40 000 tons	

Other waste plastics, mainly polyethylene (PE), have no market yet in France because they are too spoiled. But in fact, the development of cleaning processes may increase the P.E. recovery since equipments and markets are more common than PVC.

324. Refuse derived fuel (R.D.F.) marketability.

It will be important to distinguish between RDF, the calorific power of which is essentially obtained by drying the materials, and the ones resulting from an efficient sorting of highly combustible products : in the first case, the total energy balance is not necessary very valuable and problems of combustion (ash content) or corrosion and pollution (PVC content) can occur.

325. Ferrous metal marketability.

The market of tin coated scraps is very low at this time, because of of the general reduction of the ferrous scraps market and the particular french situation where no detinning plant exist, even on new scraps.

326. Organic materials marketability.

The sales of compost in France reach about 350 000 t/y with :

54 % in vineyards
13 % in mushroom-beds
10 % in open fields
7 % in horticulture
5 % in arboriculture
4 % in market-gardenning
4 % in seed-beds
3 % in other cultures, gardens and sports-grounds.

The average sale value is near to 15 F/t F.O.B.

But the development or at least the conservation of this market seems to need a more efficient sorting of inorganic materials (glass, metals, plastics, ...).

Then, the up grading of fermestescible materials may be of interest toward a marketing as animal food (like in ROMA) : the total french production of animal food reaches to9 millions t/year and the recovery of organic food from domestic wastes would produce about 1 million of tons of animal food.

In an other side, these feed can be prepared (drying and sterilization) with steam resulting from the combustion of other residual fractions : the on site utilization of energy so allows a lowering in operating cost (60 % in energy cost), combined with the great increase of value of the final product (500 F/t).

4. CREST WASTE SORTING STUDY GROUP RECOMMENDATIONS .

4.1. Recommendations for concerted action .

There are already several major research programmes in progress or planned within several member countries of the Community. The project team is very concerned to avoid recommending duplication of this research. It is felt, however, that there are certain areas where international discussion and co-ordination of this research would enhance its value, both to individual countries and to the Community as a whole. The spirit of international co-operation which has been experienced during the present study has been of great benefit and this could provide a foundation upon which further collaborative work could be built.

It is therefore recommended that a programme of concerted action should be established, provided that the support of national governments can be obtained. It is recognised that in some cases existing R & D is funded by commercial interests and could not be included in a concerted action programme. The programme should be organised to cover the following aspects of household waste sorting technology.

1°) Work in progress or planned in member countries (e.g. the Doncaster prototype plant in the UK, the Bundesmodell Abfallverwertung in Germany) should be monitored, existing links between research groups should be maintained and new ones encouraged wherever possible. These links should be used to promote comparative investigations of different systems under consistent conditions, and studies of the effect of varying the composition of the feed. It is recognized that different project timescales might give rise to problems in making comparisons, but when the planned new generation of experimental plants working at a realistic scale is in operation co-ordination of research and parallel investigations in different locations could be very valuable.

2°) Standard methods should be established for sampling and analysing household wastes, specifying the quality of waste-derived products, and reporting cost and related economic data. Comparison of processes in different locations is very difficult, but the value of such comparisons would be greatly enhanced if better standardisation of feed analysis, process parameters and product specification were achieved. The effect of statutory requirements applying to waste recovery in different member countries on the design and viability of waste sorting processes might also be considered.

3°) Potential health hazards arising from the handling, treatment and storage of domestic waste and related products should be investigated. This is an area which would require considerable co-ordination of testwork and data collection.

The method envisaged for implementation of the concerted action programme is a series of meetings of technical experts from the member countries. Because of the wide range of topics for discussion it is suggested that these meeting should take the form of symposia lasting 2-3 days with, say, 20 invited delegates per symposium. The estimated cost of a four years programme of 3 symposia per year is 200,000 units of account.

This sum would not include any funds for specific projects arising from the concerted action programme.

4.2. Recommendations for indirect action .

It is recommended that the major proportion of the financial resources allocated to R & D in waste sorting should be used in a programme of indirect action. Research is recommended into topics where it is felt that more fundamental studies or the development of new or improved separation techniques are required. The recommended topics for investigation come under three headings :

1) *Separation technology*
2) *Material recovery*
3) *Energy recovery*

Separation technology

The possibility of two to three projects in this area is envisaged. The highest priority is placed upon an investigation of air classification, but liberation and comminution of waste is also recommended for study.

Air classification

There are several air classification systems available, but there is a serious lack of the information necessary for scale-up of pilot installations and to enable the best choice for a particular situation to be made. It is therefore recommended that a fundamental investigation of the parameters affecting separation should be carried out prior to larger scale trials in association with the experiments on front-end systems. The main aims of this work should be :

a) To compare existing types of air classifier under consistent conditions.

b) To investigate the effect of changing design variables and composition of the feed.

c) To establish criteria for the design and scale-up of air classification systems to process household wastes.

Liberation/Comminution

The choice of a front-end system for a sorting plant is still largely a subjective one. Information in the literature is of limited help because of the varying conditions under which the experiments are carried out. It is therefore proposed that comparative investigations of shredding and sizing systems at a scale of at least 10 tons/h should be carried out under consistent conditions with a clearly defined feed. Particular attention should be paid to the following points :

a) The suitability of the processed waste subsequent separation into products.

b) Elimination of gross oversize materials in sizing plants.

c) Maintenance and reliability.

The concerted action programme could be of assistance in promoting this research. The cost of purchasing new equipment could be minimised by co-ordination of studies in different research groups using existing equipment as far as possible.

Material recovery

The two most important topics for further research are paper fibre recovery and plastics recovery. Two projects in each of these topics are envisaged.

Paper recovery

In most locations paper is potentially the most valuable constituent of the waste so there is a strong incentive for its recovery. The importance of household waste as a source of secondary fibre has already been recognised by the CREST Working Party on paper recycling, and a number of research topics in this field have been included in a proposal for a research programme on paper and board recycling. It is felt that certain aspects of this earlier programme have been largely achieved in the present study. In particular most of the work recommended in Part 1 of the programme has been done in the present study e.g. classification of urban wastes, the technical feasibility of separating paper fibre from household wastes and economics of processing to obtain a fibre product. Further effort should concentrate on the recommendations in Parts 2 and which relate to the use of urban fibre by the paper industry and health problems which might arise from its use. In addition it is considered very important that support should be given for further R & D on paper separation technology, an aspect which was not included in the earlier recommendations by the Working Party :

a) Most existing paper fibre recovery systems are based in part on air classification to provide a paper-rich concentrate for further upgrading. There is a requirement for research into the design and operation of air classification systems to produce a better paper-rich product.

b) Further work is needed on methods of separating plastics film from paper which are less costly in terms of capital equipment and energy consumption than existing ones.

c) The development of other novel methods of paper recovery should be encouraged. These might be based, for example, on the selective detection and removal of specific contraries from a paper-rich concentrate.

d) As an alternative to dry separation of a paper fibre product, wet processing at the front-end of the paper mill should be investigated in co-operation with the paper industry.

Plactics recovery

Recovery of paper fibre will normally result in the production of a by-product which is rich in plastic films.In some member countries plastic bottles are a significant constituent of household wastes and these can also be separated as a product. Research is therefore recommended into the separation and cleaning of plastics concentrates, paying particular attention to the following aspects :

a) The indications are that the size and nature of the potential market for plastics products recovered from household wastes varies considerably between the member countries. In some locations it might be possible to sell a mixed plastic product, while in others segregation of polymer types will be necessary. Similarly, requirements for reclaimed polymer for use in moulding or film blowing applications will vary. A community-wide market study is therefore recommended to determine where R & D effort might be most profitably applied.

b) There are several processes available for the manufacture of products from mixed waste polymers. Although perhaps the main problem to be solved in this field is the creation of new markets for the products, there is scope for further work on the feedstock formulations required for specific end-products, and the effect of additives on product quality.

c) The potential for developing technology for separation and cleaning of mixed and contaminated polymer waste merits investigation. The nature and level of contaminants which inhibit the use of reclaimed polymer in standard moulding of film blowing equipment should be studied, taking into account the possibility of developing new chemical additives to counteract the degradation of secondary polymers during moulding.

Energy recovery

The project team is aware that an EEC Energy Research Programme was adopted by the Council of Ministers en 1975. One of the main subject areas is Energy Conservation and project proposals have already been received which relate to the use of the energy content of wastes. This is therefore, another area where close co-ordination of projects by the Commission is issential. It is considered that further work is needed on the use of both shredded and densified waste-derived fuels, and the following project areas are suggested for consideration :

a) Community support should be given to encourage an investigation of the use of shredded waste-derived fuel (for example, in the generation of electricity), shredding, handling and firing systems for suspension-fired boilers will need to be developed, but there is much relevant experience in the USA which can be drawn upon.

b) Experience in the U.K. suggests that for industrial use a densified fuel product is most likely to have adequate storage and handling characteristics. A great deal of work is required on the continuous production of fuel pellets or briquettes. Most work carried out to date has used machines designed for agricultural purposes and many problems have been encountered. Pilot-scale tests to measure specific power consumption, die wear and throughputs are needed to enable suitable equipment to be designed. Methods of handling densified waste-derived fuel are needed and extended firing trials are necessary to determine the effect of firing waste-derived fuel on corrosion, fouling of boiler tubes and atmospheric emissions. Possible additives to the fuel from the point of view of increasing its calorific value, prolonging its storage life, reducing its susceptibility to water and inhibiting biological activity should be examined.

Funding.

In making suggestions for the allocation of funds to the three project areas the project team has taken into account the close inter-relationship between these areas and the fact that results of the work on separation technology will support and benefit research into materials and energy recovery. Nevertheless, materials recovery is regarded to be of primary importance and the largest share of the funding should be directed to this area. With these considerations in mind the following allocations of funds for indirect action over a period of four years are suggested :

Separation technology	(3 projects)	0.8 - 1.0	mua
Materials recovery	(4 projects)	1.9 - 3.0	mua
Energy recovery	(2 - 3 projects)	0.8 - 1.2	mua
	total :	3.5 - 5.2	mua

It is expected that the indirect action programme would attract a 50 % contribution from the Commission i.e. a sum of 1.75 - 2.6 mua.

A total budget requirement of 3.7 - 5.4. million units of account over a period of 4 years is suggested for the combined concerted and indirect action programmes.