Resource Recovery from Municipal Solid Wastes

Volume I
Primary Processing

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RESOURCE RECOVERY FROM MUNICIPAL SOLID WASTES

Luis F. Diaz, George M. Savage, and Clarence G. Golueke

Volume I
Primary Processing

Introduction
Storage Collection and Transport
Planning, Designing, and Modeling the Resource Recovery Facility
Size Reduction
Air Classification
Trommel Screening
Materials Recovery

Volume II
Final Processing

Incineration
Preparation and Use of Refuse-Derived Fuel
Biological Resource Recovery
Biogas Production
Hydrolysis and Single Cell Protein and Ethanol Production
Composting
Environmental Aspects
Landfill—The Ultimate Disposal

TABLE OF CONTENTS

Chapter 1
Introduction 1

I. Introduction 1

II. Factors and Problems in Resource Recovery 1
A. Need for Homogeneity 2
B. Long-Term Uninterrupted Availability of Items 3
C. Reasonable Transportation Cost 4
D. Ability of Recovery Process to Accommodate Secondary Materials 5
E. Government Assistance 5
F. Public Attitude 6
G. Technological Weaknesses 6

III. Objectives and Contents of the Volume 7

References 8

Chapter 2
Storage, Collection, and Transport 9

I. Introduction 9

II. Storage at Point of Origin 9
A. Principles 9
B. Containers 10

III. Collection 10
A. Considerations 12
1. Separate vs. Combined Collection 12
2. Frequency 12
3. Point of Collection 13
4. Pickup Density 14
5. Programming 14
6. Equipment 14

IV. Transport (Haul) 15
A. Introduction 15
B. Pipe Transport 16

V. Source Separation 17
A. Introduction 17
B. Arguments For and Against Source Separation 18

References 21

Chapter 3
Planning, Designing, and Modeling the Resource Recovery Facility 23

I. Introduction 23
  A. Factors That Affect Quality of Design 23
  B. Integration of Unit Processes 23
  C. Mass Balances 23
  D. Knowledge of Feedstock, Product, and Equipment 24
  E. Manner of Recompense 24
  F. Equipment Selection 25

II. Storage at the Processing Site 25
  A. The Case Against Storage 25
  B. Solutions for Storage Problems 26

III. Belt Conveyors 26

IV. Flow-Rate Control Equipment 28

V. Pneumatic Transport 28

IV. Modeling of System Mass and Energy Balances 29
  A. Method of Establishing a Material and Energy Balance 29
  B. The Recovery Factor Transform Function Matrix 30
  C. Rationale in the Development of the Model 31
  D. Setting Up a System Mass Balance 33
  E. System Comparison Through Modeling 38
  F. Unit Process Energy Requirements 40

References 41

Chapter 4
Size Reduction 43

I. Introduction 43

II. Types of Size-Reduction Equipment 43
  A. Hammermills 43

III. Process Principles 45
  A. Disruptive Forces 45
    1. Basic 45
    2. Analysis and Interaction 46
  B. Initial Energy Comminution Relations 46
  C. Size Distribution Relations 48
    1. Matrix Analysis of Breakage 49
    2. Breakage Process Models 50
      a. π—Breakage Process 50
      b. Repeated Breakage Cycles 50
      c. Discussion 51

IV. Regulating Hammermill Performance 51
A. Particle Size Distribution 52
1. Loading Rate 52
2. Number of Passes 53
3. Rotational Velocity 53
4. Moisture Content 53
5. Condition of Hammers 54
B. Specific Energy Consumption (Power Requirement) 54
1. Characteristic Particle Size 54
2. Flow Rate 55
3. Machine Design 56
C. Machine Wear-and-Tear 57
1. Relation of Maintenance to Costs 59

V. Evaluating Performance in Field 60
A. Monitoring Power 60
B. Methodology 61
1. Hammer Wear 61

VI. Selecting a Shredder 65
A. General Criteria 65
B. Types of Machine 65
1. Vertical vs. Horizontal Hammermills 66
2. Machine Components 66
a. Motor 66
b. Hammers 66
C. Establishment of Required Specific Equipment Specifications 67
1. Basic Principles 67
2. Hammer Tip Velocity 67
3. Desired Particle Size 68
4. Power and Energy Requirements 68
5. Design Considerations 69
6. Maintenance 71
D. Operational Alternatives 72
1. Multiple-Stage Size Reduction 72
2. "Separate Grinding" 72
3. Fine Grinding 72
References 73

Chapter 5
Air Classification 75

I. Introduction 75
A. Principles 75

II. Types of Air Classifiers 75

III. Design and Operational Factors 80
A. In-Feed Systems 80
B. Air Classifier Split 80
C. Material Loading (Air-to-Solids Ratio) 81

D. "Choked" Condition 83
E. Column Loading 84
F. Pressure Drop Considerations 86
G. Power Consumption 86
H. Yields and Overall Efficiency 86
I. Air Classifier Performance 88
J. Light Fraction Quality 89
K. Optimization of Column Velocity 89
1. Definition of Column Velocity 90
L. Aerodynamics of Air Classification 90
1. Column Reynolds Number 90
2. Entry Length Considerations 92
3. Drag Coefficients and Reynolds Numbers 92
4. Determination of Floating Velocity of Particles 94
M. Aerodynamic Aspects of Particle Shapes 95
N. Determination of Floating Velocities of Shredded Refuse Components 96
O. Analytical Development of Composition and Properties of Air Classifier Fractions 104
P. Summary of Design Considerations for Vertical Classifiers 105
1. Typical Design and Performance Characteristics 105
2. Fluidization 105
3. Air-to-Solids Ratio 106
4. Recommended Specifications 107

IV. Cost of Air Classification 107

References 108

Chapter 6
Trommel Screening 109

I. State of the Art and Fundamentals 109
A. Utilization of Screens in Solid Waste Processing 109
1. Trommel Screen 109
2. Pretrommel Screening 111
B. Trommel Screening the Air-Classified Light Fraction 112
1. Benefits 112
2. Principles 113
3. Processing Comparisons 113

II. Theoretical Aspects of Particle Motion Within a Trommel Screen 114

III. Parameters 116
A. Screening Efficiency 116
1. Residence Time 117
2. Bed Depth 118
3. Critical Frequency 118
4. Longitudinal Velocity 120
5. Screen Capacity 120
B. Energy Requirements 120

C. Design and Screen Performance Parameters 120
1. Screen Loading 120
2. L/D Ratio 121
3. Angular Velocity 122
D. Screen Performance 122

IV. Material Characteristics 122

V. Lifters 123

VI. Scale-Up Considerations 125

References 126

Chapter 7
Material Recovery 127

I. Introduction 127

II. Paper 127
A. The Need to Recycle Paper Fiber 127
B. Uses for Reclaimed Paper 128
C. The Wastepaper Industry 128
D. Sources of Wastepaper 128
E. Demand (Market) for Wastepaper 131
F. Recovery from Mixed Solid Wastes 131
1. CRS Process 132
G. Public Health Constraint 133

III. Glass 134
A. Rationale for Removal of Glass 134
B. Uses for Recovered Glass 135
1. Aggregate 136
2. Manufacture of Bricks 137
3. Glass Polymer Composite (GPC) Manufacture 137
4. Foamed Glass Insulation Panels and Glass Wool 137
5. Cullet 137
C. Methods for Recovering and Processing MSW Glass 138
1. Mechanized Removal of Glass 139
2. Processing to Meet Cullet Specifications 139
a. Froth Flotation 139
b. Optical Color Sorting 140
D. Economics of Glass Recovery 141

IV. Aluminum 141
A. Classification of Aluminum Waste 141
B. Technology of Aluminum Recovery 142
1. Preprocess Steps 142
2. Separation of Aluminum 144
a. Al Mag® 144
b. Air Knife® 146

c. Recyc-Al® 146
d. Inclined Ramp 147
e. Vertical Symmetric-Field Separator 148
f. Heavy or Dense Media Separation 148
g. Black Clawson Method 149
C. Status of Mechanized Aluminum Recovery 149

V. Magnetic Metals (Ferrous Metals) 150
A. Quantity and Composition of Magnetic Solid Waste 151
B. Methods of Recovery 153
1. Equipment 154
2. Efficiency Factors 154
C. Uses for Separated Magnetic Wastes 156
1. Detinning 156
2. Copper Precipitation 156
3. Specifications 157
D. Cost of Magnetic Separation 157

References 158

Index 161

Chapter 1

INTRODUCTION

I. INTRODUCTION

As recently as 1980, it would have been exceedingly difficult to have found a point about which the public consensus was as great as that existing on the desirability and even the necessity for resource recovery. Even in the politically conservative climate of 1981, the desirability continues to be almost unanimously recognized, although feelings regarding the degree of urgency vary widely. The variation is manifested by the diversity of opinions regarding the intensity of effort and the extent of concessions and even sacrifices to be made in carrying on resource recovery. Certainly, the more urgent one regards an activity as being, the greater is the effort willingly expended and sacrifices made to ensure its successful outcome. On a public scale, urgency translates itself into priorities in undertakings. Logically, the more urgent the need, the higher the priority accorded it. Priority may be expressed in the form of extent of practice and through special consideration accorded the practice in question. Judged on the basis of the first criterion, as of 1978 recycling had a low priority, inasmuch as in that year overall recovery amounted to less than 7% of the gross municipal discards, and that mostly in the form of reclamation of paper.[1] Examples pertaining to the second criterion are the allowing of exceptions, the granting of a subsidy, and the imposition of a legal specification. A very practical manifestation of the existing wide range of estimates of urgency may be found in the long-standing dispute between the National Association of Secondary Materials Industries (NASMI) and the Interstate Commerce Commission (ICC) regarding freight rates. The priority given resource recovery by the ICC apparently is so low as of this writing that the agency would like to permit higher rates to be charged for transporting secondary materials than for virgin materials. On the other hand, the NASMI and resource conservationists continue to press for at least an equalization of rates, and hopefully even preferential treatment.

II. FACTORS AND PROBLEMS IN RESOURCE RECOVERY

Lest one be unduly critical of past and present inaction, several factors, or more aptly termed "problems," exist which combine to impede progress in resource recovery. One of the problems, and a very serious one indeed, is the disparity between the requirements regarding the quality of secondary materials intended for energy production and for use in the manufacture of new items, and the nature and quality of these materials as they exist in the municipal waste stream. The requirement of homogeneity of feed material in energy production and in the manufacture of useful products as contrasted to the heterogeneity of municipal wastes exemplifies this disparity.

Homogeneity, as it applies to wastes destined for use in thermal energy recovery, implies that the wastes be combustible and free of substances that are not combustible, or can interfere with combustion, or can corrode the energy conversion unit either directly or indirectly. As applied to energy recovery by biological means, the term implies the absence of biologically nondegradable materials and of substances that are toxic to microorganisms. The term has a somewhat narrower connotation when applied to the recovery of materials from wastes for use in the maufacture of useful products. To be used in the manufacture of a given product, a substance must be in the form of a uniform mass, that is, it must be characterized by a certain degree of purity. Taken in its broad sense, homogeneity implies that all items in a given mass are comparable in composition, e.g., aluminum beverage containers, all-steel containers, etc. Moreover, the composition of the materials used in manufacturing the items should be identical in all items. Thus, the constituents of alloys should be the same, or at least should be known. Taken in the narrow sense, homogeneity refers to single elements (e.g., ferrous metal, paper fiber).

As far as the manufacturer and the energy producer are concerned, the difficulty with establishing an industry based upon the use of secondary materials scavenged from municipal waste is not confined to the shortcomings described in the two preceding paragraphs. Four additional factors can be adduced, each of which has the potential of exercising a decisive role in determining the success or failure of an undertaking. Briefly stated they are (1) assurance of long-term and uninterrupted availability of the material to be recovered; (2) availability of the material at a price competitive on an overall basis with virgin (primary) material; (3) distances to and between sources of the secondary material are such that transportation costs are not excessive; and (4) transportation (freight) rates must at the least not be higher than those for virgin materials.

A. Need for Homogeneity

The need for homogeneity in thermal energy recovery ultimately relates to the requirement that the recovered waste material be economically competitive with fossil energy sources. To be so, the waste material must have a reasonably high heating value and must be adaptable for use in existing energy conversion systems. The required characteristics are explained in some detail in the sections on energy recovery. The need for homogeneity, as it relates to biological energy recovery, rests upon the fact that the waste material must serve as the principal substrate in the culture of the microorganisms involved in the energy recovery process. The ramifications of this function are elaborated upon in the section on biological energy recovery. Inasmuch as the energy implications of homogeneity are amplified in subsequent sections, the remainder of this section is devoted to homogeneity as it relates to waste materials destined for use in the manufacture of products.

The origin of the need for homogeneity in the manufacture of products is not hard to determine. Uniformity of quality and specifications of a product in a manufacturing operation demand precise control over the raw materials used in the process. Obviously, one of the essential factors in precise control is a knowledge of the identity of the components of the raw material, as well as the capability of feeding those components into a process at carefully regulated rates and amounts. The further the deviation from this ideal, the lower will be the quality of the manufactured product. The quality of certain types of products, especially those made of plastic or of aluminum, are especially sensitive to degree of homogeneity. In fact, with plastic, the very act of refashioning the material in a recycling operation results in a product having a quality lower than that of the original.

The need for cleanliness stems from the requisites, homogeneity and purity, inasmuch as uncleanliness bespeaks contamination with foreign substances. In certain manufacturing processes, the presence of even minute amounts of foreign materials drastically and adversely affects the quality of the product. For example, trace amounts of copper in iron scrap reduces the tensile strength of the steel. In the manufacture of paper from reclaimed fiber, plastic, or dirt particle contaminants can disrupt the paper manufacture process and seriously detract from the utility of reclaimed paper as a raw material. For example, according to the U.S. Environmental Protection Agency, (EPA), the manufacture of paper products from paper that had been in contact with pathogenic material may result in a new product not hygienically safe for use in packaging food.

In the preceding paragraphs a case was built up for the need of a raw material that is homogeneous in nature and composition and which exists in a clean state. In this paragraph is described the spread between the quality of the material in the waste stream and that which would be ideal. A collection of tables on the composition of municipal refuse is not needed to demonstrate the great gap between the ideal and the actual, because a visit to a local transfer station or dump would overwhelmingly reveal the enormity of the disparity. Among the many types of wastes generated by human activity, municipal waste is the most heterogeneous in composition. The heterogeneity is inevitable since municipal waste is a conglomeration of rejects from everything used in typical urban existence. Not only is the waste a heterogeneous mass, but the components are intermingled in a seemingly hopelessly intertwined tangle. As if the heterogeneity were not sufficient to discourage the prospective scavenger, the sheer dirtiness of the mass is dismaying. Joined with the heterogeneity and filthiness of the waste is a third important characteristic, namely abrasiveness. Because of the unusually severe abrasiveness of municipal waste, wear and tear on equipment used in processing it is greatly intensified. The combination of the preceding three characteristics has heretofore practically ruled out centralized resource recovery, excepting perhaps for the magnetic removal of ferrous products.

At this point in the discussion, it might be said that source separation could eliminate or minimize the problems discussed in the preceding paragraphs, and perhaps rightly so, as is shown in a later section. The fact remains, however, that thus far the practice of source separation has been almost infinitesimal in extent. Partial explanations for rarity of source separation in the past and present are inconvenience for the householder and alleged reduction in efficiency of collection and a consequent increase in cost. Nevertheless, the principal reason is the fact that to the public-at-large and hence to politicians, the need to recycle seems to be less than imperative. This latter reason, in turn, takes away from the average citizen a prime motive for the additional exertion required to classify and store his or her daily output in a collection of separate containers. Of course, factors other than the preceding will come into play as resource recovery becomes more widely practiced.

B. Long-Term Uninterrupted Availability of Items

This requirement is an obvious one and rests upon the fact that it would be folly to build an industry on an uncertain supply of raw material. With the existing rate of municipal waste generation, the response as to the fulfillment of this requirement would almost unanimously and immediately be one of positive and unequivocal assurance. The fact is that as long as our present way of life persists, waste will continue to be generated at least at the present rate. The question, however, is not one of total amount, but rather of the individual components that together make up the total mass. An example is the steel container, i.e., the "tin can". Here, gain in the fraction of food products marketed as frozen foods is reflected by a decline in the amount marketed in steel cans, and consequently in a drop in number of cans discarded. Additionally, if the present move towards the compulsory use of returnable beverage containers takes hold, the usage and subsequent discard of steel cans will drop. The fact that at present the use of steel cans in the beverage industry is far less than that of aluminum cans does not alter the overall situation.

Related to availability of given waste materials is the question of ownership of the materials. Despite the fact that for the present almost every municipality is eager to give a part or even all of its waste stream to any and all takers, provided of course the taking is done under proper and controlled conditions, the continued duration of that magnanimity is not necessarily assured. Chances are that if the industry presently receiving the material *gratis* should prosper, the citizenry upon becoming aware of the fact would begin to question the community's apparent munificence to the industry. Undoubtedly, the questioning would be followed by the imposition of a charge for the material, and the financial benefit accruing from the use of the latter would be correspondingly less. In summary then, the ownership of the waste resources and the future policies of the owners with respect to the wastes must be unequivocally established before a candidate industry is willing to commit itself to the utilization of the waste resource.

Unfortunately, because the nature and amount of materials discarded are influenced by the vagaries of man's activities and the fluctuations in his economic well-being, extrapolations as to the extent of availability of given components must be attended by a high degree of uncertainty. The same uncertainty applies to predictions concerning the future attitude of the public regarding access of a resource recovery industry to a waste that has developed a market value because of the economic success of an enterprise based upon its (the waste) utilization. Obviously, the processor's interest in the components will come to an abrupt end when he finds that the cost of the primary resource is lower than that of the secondary material.

C. Reasonable Transportation Cost

The requisite, reasonable transportation costs, pertains to degree of concentration of the sources of the waste and of accessibility to the sources. Expressed in a negative way, the sources of the component wastes must not be so scattered or so distant that the costs of transporting them to the user significantly exceed the cost of transporting primary material. This requisite probably is the most difficult one to meet in resource recovery. As would be expected, the largest individual concentrations of wastes, and hence of given waste components, are to be found near areas in which the human population is at its densest. While these latter areas may contain a sizeable percentage of the nation's population, the larger fraction is to be found in small to medium-sized communities across the country. Consequently, a large portion of the nation's discarded resources also is widely scattered. Unless an economically viable means of collecting the latter wastes is found, a significant portion of recoverable resources will have to be by-passed.

The problem of scattered waste disposal sites can be alleviated considerably by establishing a regional approach to solid waste management. This can be done through statewide planning in which is provided a statewide policy for resource recovery, much as was done by the state of Wisconsin.[2] Of course, even with the establishment of regional centers, the need would remain for developing an effective transportation system. Probably, a combination of rail and truck haul would be the best approach.

The generally appreciable distance between the location of the potential user of a reclaimed resource and of that where municipal wastes are generated and disposed, is the source of yet another difficulty as far as materials recovery is concerned. As one would expect, the most efficient and hence cost-effective approach in the manufacture of a product is to locate the manufacturing plant as closely as possible to the source of its raw material. This is precisely what happens in the paper industry, in that paper manufacturing plants generally are located in close proximity to the forests from which the pulpwood used in paper manufacture is obtained. If more than one raw material is used in an industry, then a compromise location is selected, but even here the site of choice almost invariably is not in close proximity to large population centers. Consequently, it is not surprising that an acute problem arises when an attempt is made to substitute secondary materials for all or even only a part of the primary materials hitherto used in an industry. In most instances the secondary material must be transported over a longer distance to reach the plant than is the case with primary material. The latter problem becomes especially severe when a switch is made from primary to secondary fiber in an existing paper manufacturing plant. However, the transportation problem will disappear when older plants become obsolete and are replaced by modern versions. The reason is that part of the renovation would include relocation to a site more accessible to centers of waste generation.

D. Ability of Recovery Process to Accommodate Secondary Materials

Transporting the secondary material to the manufacturing plant or energy production facility is only a part of the difficulty. Once at the plant or facility, the latter must have the capacity to accommodate secondary as well as primary materials (e.g., fossil fuels). Accommodating secondary materials almost invariably involves modification of existing processes and, hence, of equipment. The extent of the required modification may be quite great. Fortunately, most existing manufacturing and energy conversion processes are designed such that they can incorporate at least some secondary materials. Thus, in thermal energy conversion, processed municipal wastes can be used as a substitute for coal. In glass making the use of cullet is an essential part of the process. In paper making, rejected paper is recycled by way of the pulpers, and in steel making, scrap in the form of rejects is used along with iron ore. However, it should be pointed out that in the three immediately preceding examples, manufacturing rejects generally are used. In terms of homogeneity and cleanliness, manufacturing rejects are a far cry from rejects (wastes) reclaimed from the municipal waste stream.

A handicap of governmental origin is constituted by the differences between the treatment accorded the use of secondary material and that given to the use of primary materials. On the one hand, the Federal government subsidizes the iron ore industry, actually a subsidiary of the steelmaking industry, through tax deductions in the form of extremely generous depletion allowances. On the other hand, no such subsidization is accorded the secondary materials industry. The resulting handicap in terms of disparity of costs is substantial.

E. Government Assistance

While the nature of the course of action required to rectify inequities may be straightforward and quite obvious, that of providing governmental assistance is not as clear-cut. One approach could consist in the provision of some type of a subsidy. A relatively straightforward subsidy is the tax break. The first step, of course, in allowing tax breaks would be to establish a program that would result in a monetary assistance to compensate for any increase in cost that may attend the use of secondary materials. Moreover, the long-term benefits resulting from the use of secondary materials, namely, conservation of resources and lightening of the solid waste burden, justify the assistance required to expand the use of secondary materials, even to the extent of allowing a reasonable economic advantage over the use of primary materials.

A second form of governmental assistance could be a price support system. Arguments for and against price support are quite well summarized by G. S. Gill in an article in *Compost Science*.[3] According to Gill, an important feature of a price-support program is its apparent flexibility. The support "can be instituted, expanded, contracted, or even withdrawn without causing too much ado."[3] Of course, the costs involved would not only be those of the price-support plan itself, but also those of administering the plan. The experience with agriculture price-support systems would be useful in determining the magnitude of the administrative costs. Gill probably is somewhat overly optimistic in his statement, "Even though institutional rigidities will develop in time, even in relation to as flexible a program as the price-support programs—these obstacles will be relatively easy to overcome inasmuch as there are no sunk costs involved."[3] The stiff resistance put up by interested parties in the past few years to governmental attempts to drastically reduce price-support for certain agricultural commodities tends to belie Gill's predictions as to ease of withdrawing price supports. Nevertheless, as he states, price-support programs do constitute an incentive program that would merit investigation.

The solution to governmentally oriented problems seems obvious, namely positive action at least to remove existing inequities. The removal would seem to be a rather straightforward task, but the unsuccessful outcomes of attempts by the secondary materials industry to bring about a redress of their complaints has proved to be an arduous undertaking attended by only a modicum of success. The reason is the intense opposition of powerful industries committed to the use of primary materials.

Another problem area is that of marketing. Ultimately the source of the difficulty is the nature of the municipal waste from which the secondary materials are extracted. The effects of the nature of municipal waste were discussed in the preceding paragraphs under the guise of difficulties associated with the nature of the reclaimed materials and the attendant factors (e.g., "dirtiness", nonhomogeneity, uncertainty of continued supply) and their bearing on the utilization as raw material in a particular industry. These difficulties combine to make the reclaimed items less attractive to potential consumers.

F. Public Attitude

A factor not covered in the preceding paragraphs and which is exceedingly influential in marketing is public attitude. With the average individual, the prospect of using a "secondhand" item brings with it a feeling of repugnance or at least, of reluctance. This feeling is the result of a cultural heritage in which the use of salvaged goods is associated with economic distress, unless the item happens to fit under the classification "heirloom" or "antique". The feeling also stems in part from a conviction, often based on fact, that reclaimed items, because of having already been subjected to use, have thereby lost some of their original utility or durability. However, this feeling is more apt to occur when the discarded item is used directly (e.g., "second-hand" clothing), than when it is processed to become a raw material for the production of a different item. This cultural problem area in marketing will diminish as potential consumers become aware of the fact that there is a considerable difference between using a discarded item unaltered (except for a certain amount of refurbishing) and processing it to serve as a raw material in the production of a new item. The difference is more pronounced with the reuse of metals than with fibers. The latter do deteriorate significantly with each reuse. Unfortunately, while all that has been stated in these sentences may be true and most individuals are convinced of the facts, translating the conviction into action has a long way to go.

The public attitude is much more positive towards the use of wastes in energy recovery. The favorable attitude undoubtedly stems from the public's awareness of the critical energy situation. Not to be overlooked is the fact that in energy recovery, the contact between the user of the recovered energy and the raw waste is far removed.

G. Technological Weaknesses

The final obstacle to progress in the reclamation of discarded resources owes its origin to the relative lateness of the concern about conservation and the consequent interest in recovering discarded resources. Because of the lateness, existing technology with which to accomplish resource recovery still leaves much to be desired. To remedy the