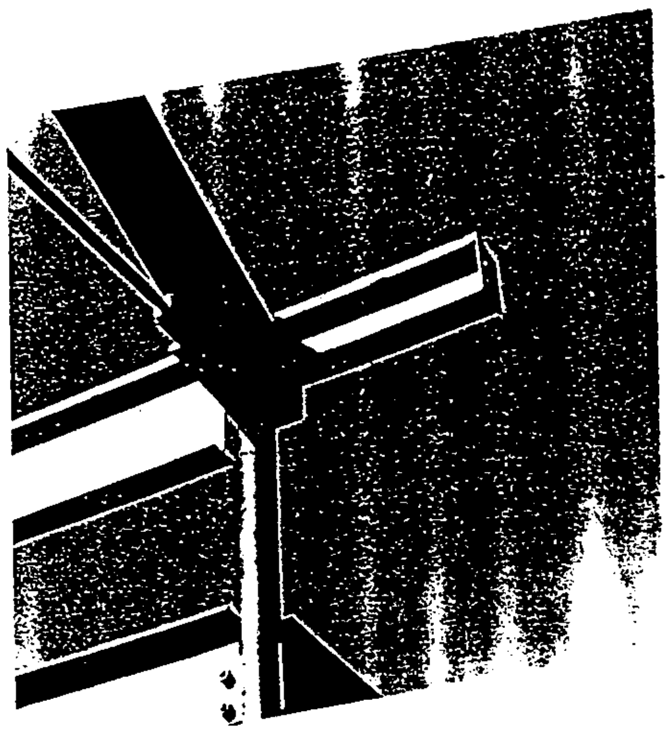
TECHNICAL PUBLICATION NO.68

A FEASIBILITY STUDY TO DETERMINE METHODS OF UTILIZING COMMINGLED PLASTICS IN BUILDING CONSTRUCTION APPLICATIONS

SPONSORED BY A GRANT FROM THE BUILDING CONSTRUCTION INDUSTRY ADVISORY COMMITTEE



WEILIN P. CHANG

D. LINDA WALLER

XUEMING S. SHEN

School of Building Construction
University of Florida

1990

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#4910-1503473-12

BCIAC Coordinators:

Mr. Kinney Harley

Mr. Paul Scheele

Mr. John Pistorino

Principal Investigator:

Weilin P. Chang

Co-Principal Investigator:

Linda Waller

M.E. RINKER, SR. SCHOOL OF BUILDING CONSTRUCTION

UNIVERSITY OF FLORIDA

Gainesville, Florida 32611

Telephone: (904) 392-5965

May 21, 1990

This feasibility study was sponsored by the Building Construction Advisory Committee under a grant from the State of Florida Department of Education.

EXECUTIVE SUMMARY

To assess the feasibility of recycling mixed plastics into commercially viable products, special attention must be given to three primary issues. The first is concerned with the need for recycling of products made from a diminishing resource and the ramifications of a failure to address this. The second is concerned with the cost associated with environmental concerns and quality of life issues of continuing to dispose of plastics by landfill or incineration. The third issue is concerned with the inherent physical and chemical problems of plastics recycling and how these might be ameliorated to improve end products, broaden the applications, and increase marketability.

For commingled plastics recycling to become more cost effective, the inherent difficulties created by polymer incompatibility must be overcome and/or the rate of production compared to present rates must be increased. New product applications must be developed both for non-critical use categories as well as applications for which specifications would be required. These applications must develop in tandem with research efforts to provide manufacturing conditions conducive to the setting of specifications. In spite of this, methods designed to create products from recycled commingled plastics, exist. Many of these are construction related. These products, while not competitive on an initial cost basis, with limitations in their uses, have certain value added factors increasing their desirability as choices for discrete applications. If research on reactive extrusion processes, only now in the

beginning stages, is successful; potential exists that methods will be developed to analyze feedstock and correct it with the addition of other polymers or materials. This will create the ability to design products for which specifications might be set and thereby broaden the applications in building construction. The most significant reasons for continuing efforts to improve the technologies for the recycling of plastics rests in the following:

1. They are derived from a valuable and finite resource which should be conserved as much as possible.

2. The solid waste management crisis will continue to force regulations for upgrading all recycling programs to mitigate landfill containment.

3. There is potential for avoiding adverse environmental affects derived from landfill containment or incineration.

4. Products manufactured from commingled plastics waste have value added advantages over wood in certain applications.

5. Recycled products from commingled plastics waste show potential for profit.

Commingled plastics recycling technologies are expected to improve as new research moves this process closer to initial profitability. Even at present conditions, certain applications are viable alternatives to traditional applications utilizing treated wood. Copies of this final report may be obtained by contacting:

Executive Secretary
Building Construction Industry Advisory Committee
M.E. Rinker, Sr. School of Building Construction
University of Florida
Gainesville, Florida 32611
(904) 392-5965

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Purpose and Scope

This report contains information pertaining to the state of technologies associated with the processing of commingled plastics waste into building construction products with the potential of becoming commercially viable. An overview of the solid waste stream characteristics of the state of Florida is also provided to present a description of the economic and environmental impact of a failure to recycle the valuable materials inherent in the solid waste stream; particularly those contained in the plastics portion. A description of the major types of polymers found in the post-consumer plastics waste stream with their basic physical and chemical characteristics is provided to facilitate an understanding of the problems associated with recycling plastics. A review of the products and markets for various types of plastics in the waste stream is provided to present a framework for the evaluation of the various technologies associated with plastics recycling and to promote understanding of their inter-relationships.

1.2 Organization

This document is organized into eight chapters, each of which addresses particular aspects of the problem of recycling commingled plastics waste. The ninth chapter provides a bibliography of reference material.

Chapter I, Introduction, provides the purpose and scope of the problem.

Chapter 2, Background, describes the current state of the crisis in solid waste management, the study area of the State of Florida and provides accompanying information on waste disposal practices and the impact of the plastics waste stream upon these practices in the state which are related to the problems of future solid waste management.

Chapter 3, Characterization of the Solid Waste Stream in Florida, establishes a profile of the waste stream and outlines considerations associated with generating an accurate profile to provide a basis of reference for quantitites associated with plastics waste for future management considerations. An explanation of the methodology employed is presented for valuative purposes.

Chapter 4, Classification of the Plastics Waste Stream, explains the types of plastics typically found in the waste stream, their generation sources, and environmental concerns associated with certain disposal methods. It describes further in an overview format, the problems connected with plastics recycling efforts related to the non-homogeneous nature of the plastics waste stream.

Chapter 5, Technology Evaluation, delineates the two major types of polymers which are actively recycled and describes the commingled plastics resultant with explanation of how these components are inter-related. This section also provides a history of existing commingled plastics recycling and continues discussion of the problem of compatibility. It further describes technologies which are able to utilize a portion of commingled products acting as contaminants in a process relying upon a pure polymer type as a major component. Patent reviews of several major commingled plastics recycling technologies are included.

Chapter 6, Commingled Plastics Product Evaluation, presents an overview of products available on the market which are generated through a recycling technology relying solely or in part upon commingled plastics waste as feedstock. It also describes the progress in the testing of some of these products as well as the basic strengths and weaknesses of the products. A brief outline of potential new products which might be generated from recycled commingled plastics is provided.

Chapter 7, Marketability of Recycled Plastic Building Products, describes the sources of available feedstock, transportation considerations, the role of specific polymer markets, and the current state of marketability of building products from commingled plastics. Impediments to the creation of viable markets are also described. The role of Government policy making considerations is briefly reviewed.

Chapter 8, the Summary of Recommendations for Further Study, presents an overview of viable issues requiring further research to investigate the uses of commingled plastic products in construction applications.

2.0 BACKGROUND

2.1 Problem Description

Solid waste management is at a crisis stage in the United States today. Solid waste generation rates are escalating at such unprecedented levels that landfill capacity in the United States is dangerously close to being depleted. The National Solid Waste Management Association, Washington, D.C., reports that in 1960, the average person produced around 2.9 lbs per day of solid wastes. In 1987, this figure had risen to around 5 lbs per day and current estimates show an increase of between 6.2 lbs and 7.2 lbs per day by the year 2000. Traditional methods of disposal, still largely in use, have become inadequate due to the dramatic increase in solid waste amounts. These methods were developed at a time when land was more plentiful and significantly less expensive, concerns about a negative impact upon the environment played no role in the devised methods of operation, and the population of urban areas along with the amount of solid waste generated per capita were both significantly lower. These changes in the external environment in which solid waste management operates have resulted in a disposal problem of monumental proportions.

The solid waste stream is the term which describes anything in a post-useful state destined to be disposed of permanently and is analyzed according to type and quantity of waste. The major categories of solid waste are :

- paper,
- ferrous and non-ferrous metals,
- glass,
- rubber,
- organic wastes including yard wastes and food, and
- plastics.

Plastics waste, originating from two major sources, industrial and post-consumer, have become a significant concern in solid waste management due to the rapid increase in plastics production in the United States and a corresponding increase in discarded plastics. The term commingled plastics refers to a mixture of dissimilar polymers which could have a certain portion of other contaminates associated. This term describes the various discarded products which make up our plastic garbage. The commingled plastics waste stream is currently an increasingly serious problem as the majority of it must be landfilled or incinerated unless a viable commingled plastics recycling technology with associated markets for the products is developed.

The plastics portion of the solid waste stream is increasing more rapidly than any other. In 1988, it was reported that the plastic content of municipal solid wastes was estimated to be around 20 billion pounds per year.(28) Other sources report the total plastics production in 1987 to be 55 billion pounds with 22 billion pounds attributed to discarded plastic packaging. This represents a compounded growth rate for total plastic production in the United States of approximately 9.3% since 1958.(18) The dramatic change in the amount of plastics in the waste stream since 1960 when the plastics portion amounted to 1% compared with today's estimate of 7% to 9% coupled with the economic and environmental concerns associated with landfill containment and incineration has prompted renewed interest in plastics recycling. Of the total amount of plastics wastes generated, 50% is estimated to derive from packaging alone (14). Packaging is a serious waste disposal problem as it takes valuable raw materials from a non-renewable resource for use in a brief moment in time application.

The majority of plastic containers are manufactured from five different polymers. These include:

- high density polyethylene (HDPE),
- polyethylene terephthalate (PET),
- polyvinyl chloride (PVC),
- polypropylene (PP) and
- polystyrene (PS).

Whereas some industries such as the dairy industry have standardized their packaging, in this case plastic milk bottles made from unpigmented HDPE, many other products come in containers made from a variety of materials and may be colored. These kinds of discarded products made from composite materials are difficult to segregate as single resin sources and more difficult to recycle into useful products.

The American consumer relies so heavily upon plastics packaging that it is unwise to postulate any solution based upon a meaningful voluntary decrease in its use. In addition, plastics are replacing metal in cars, a variety of materials in construction, and many other materials normally found in durable goods. The year 1989 is expected to show plastics production numbers reaching 60 billion pounds with sales of plastic products to exceed $150 billion (4). By the year 2000, plastics production could increase 25% and reach 75 billion pounds. At that rate of production, discarded plastic would reach 38 billion pounds.(4)

Recently, efforts have been initiated by some municipalities across the country to determine the content of the post consumer stream in order to set recycling policies. Post-consumer plastics waste assessment is critical for several reasons. The amount of plastics generated in a particular location as well as an analysis of the polymers present must be determined to assess the ability of present disposal methods to effectively contain plastics waste and determine which plastics are available for recycling. The polymer content of the waste stream is important to analyze if proper recycling technologies are to be designed and collection and sorting systems appropriately developed.

It has been estimated that nationally, plastics comprise between

7% and 9% by weight, of the solid waste stream. (13) This represents 31,500 tons of the 450,000 tons of solid wastes generated in America every 24 hours and thereby creates a considerable impact upon solid waste management considerations. Plastics presently have the lowest rate of recycling of all categories with less than 1% recycled on a national basis. A study performed by Franklin and Associates, Inc. shows the current national state of recycling of municipal solid wastes.

Characterization of the National Solid Waste Stream

Material	% in MSW	% Recovery Rate	% Recycled
Paper	42	21	8.6
Glass	9	7	0.7
Steel	8	3	0.2
Plastics	7	<1	0.1
Aluminum	1	27	0.4
Misc.	33	<1	0.2
Total	100		10.2

Table 2.1.1 Characterization of the National Solid Waste Stream (13)

Plastics are highly complex molecular structures derived predominantly from our limited petroleum and natural gas resources. After fulfilling a primary use, they are discarded into landfill containment or incinerated and the valuable hydrocarbons of which they are composed become lost forever. This is significant as the oil reserves in the United States have a limited life span estimated to be as low as a 25 year supply. The return of hydrocarbons as recycled products will help to elongate this period of time and reduce dependency on foreign oil. The portion of the plastics waste stream represented by packaging, expected to increase, will cause a proportionate increase in the rate at which a valuable resource is lost.

Because most plastics waste generated is deposited in landfill containment, the amount by volume becomes an even more critical factor than the weight. Various estimates place plastic wastes at between 30% and 50% by volume of solid wastes contained in landfills. (28) It is reported that if plastic beverage bottles are capped, they behave as balloons rising to the surface with time. (1) This threatens to cause a rapid excess filling of landfill space, a considerable problem in view of escalating cost of landfill construction now estimated to be between $75,000 and $150,000 per acre, on a national basis. The NIMBY (not in my backyard) syndrome associated with new landfill construction only increases the complexity of this problem. Roughly 80% of solid wastes generated are disposed of in landfills each year in the United States whereas Japan deposits only 16% in landfill containment. (34) Conditions in Florida closely mirror this with estimates of between 75% and 80% of all solid wastes deposited in landfill containment. (22)

The EPA reports that in 1979, there were 18,500 municipal landfills in operation in the United States. Today the number has decreased to around 6,000 with another 1200 expected to close within the next two years. If the current rate of landfill containment is continued, it is expected that within the next five years, the remaining 6,000 will close. This is a dire prediction because the 563 new landfills opened between 1981 and 1986 represent a 35% decrease from a start-up volume of an identical time frame the decade before. (34) Presently, the State of Florida has 170 active landfills, down from over 500 in 1979. Landfill capacity is expected to be depleted in three years if the current solid waste generation rate is continued. (22)

Since plastics in the waste stream are composed of different chemical structures, the degree of strength of engineering properties associated with a final product made of various incompatible polymers is weak and inconsistent. The growing trend in plastic films of a laminated product consisting of several layers of polymers chosen for their respective properties and sandwiched together in one unit creates the problem of increasing amounts of incompatible polymers in the form of discarded laminates and co-extrusions used in flexible, semi-rigid and rigid packaging products. The increase in the variety of plastic films extruded as laminates or co-extrusions of disparate polymers and non-polymer materials presents the problem of the failure of these plastics to be recycled as a single resin source. Most films are created in this manner which means that 42% of the amount represented by packaging, or 5.5 billion pounds per year fall into this category. This creates a discard situation which at present, may only be handled by landfill containment, incineration, or application of a mixed plastics recycling technology. Since research efforts are concentrated upon methods to analyze and improve the feedstock for the production of recycled commingled plastics products and the largest commingled feedstock emanates from the post consumer waste stream, the entire waste stream and the plastics portion thereof should be analyzed. The recycling of plastics from post consumer wastes is in its infancy and information which could lead to proper recycling methodology and accurate foundations for policy setting is either scattered or in early stages of development and evaluation. Even in view of these difficulties, the decreasing availability of adequate landfill containment as the dominant form of disposal of plastics creates a situation in which recycling, in spite of its premature state of associated technologies, may be the only viable answer.

Plastics have previously been thought of as non-recyclable, from an economic standpoint, due to the variability of non-compatible polymers comprising the plastics waste stream and the significant amount of contaminants, both organic and inorganic, associated with the contents held by plastics packaging. Plastics cannot be recycled as a waste stream category in the manner in which aluminum or scrap iron may be. Aluminum is a single material. The plastics portion of the waste stream is not a single material but consists of several groups of materials represented by incompatible classes of polymers. These cannot be "blended" together and reprocessed without a significant loss of properties. Each polymer acts as a contaminate to the other. In order for plastics to be recycled as single resin sources, separate polymers must somehow be diverted from the rest of the plastics waste stream. This is labor intensive and presents collection and sorting problems which are quite complex.

Within the plastics waste stream are two types of polymers which are currently considered more valuable than others. In municipal recycling programs which include plastics, these are chosen for recycling while the remainder is disposed of by incineration or landfill containment. The two major types of plastic resins targeted for municipal recycling programs, PET (polyethylene terephthalate) and HDPE (high density polyethylene), are the ones which currently have viable markets due to the relative ease of consumer and hand sorting identification and the purity of the products manufactured from these polymer classes. PET is the primary material of plastic soda bottles while HDPE is the opaque material from which plastic milk bottles are made. However, these two classes of resins comprise only slightly more than 2% of the plastics waste stream. (18) Once these polymers have been removed, the resultant plastics waste stream is composed in varying amounts of products manufactured from over sixty-eight families of polymers, other materials which might be associated with the product such as paper and metals, and a portion of the original contents.

It should be noted that the plastics industry inherently must practice a certain amount of recycling for both profitability and efficient waste disposal methods. Therefore a history of recycling efforts associated with certain polymers and products exists. In spite of this, there is a significant amount of plastics waste generated by industry that is either immediately or eventually landfilled or incinerated. Industry produced plastic wastes and the potential for recycling expansion will be examined in Sections 4.3, 5, and 7. The remainder of this chapter presents background information pertinent to the assessment of the solid waste management concerns of the study area which is the State of Florida. An examination of issues relevant to post-consumer waste assessment is provided and the portion represented by plastics is examined.

Subsequent sections in this chapter describe factors such as solid waste collection and disposal practices, considerations for producing viable data on solid waste generation rates, population growth, and an overview of disposal costs in Florida; all of which have a direct bearing on the issues of plastics recycling and the production of commingled plastics waste.

2.2 Description of Study Area

The study area consists of the sixty-eight counties which comprise the State of Florida. Florida is the 22nd largest state in the nation with a total area of 58,560 sq. miles. With a climate which ranges from a northern temperate region to the more sub-tropical and tropical regions, Florida developed slowly as an agricultural and rural based economy. The state received the majority of its growth after World War II. In this period, tourism and retirement contributed to escalating population growth. The Florida League of Cities represent that around 900 to 1000 people move to Florida each day. Between 1970 and 1980, Florida's population grew by 43.5% compared to a national rate of 11.4% The total population has increased by almost two million people since 1980. Currently, Florida is the fourth most populated state in the United States. The factors that once made Florida attractive to agriculture and tourism have now contributed to a more diversified economy, accompanying growth in population, a corresponding decrease in available space for landfill construction and a dramatic increase in both the industrial and the post-consumer waste stream.

The population projections for the state of FLorida show a significant increase in growth over the next ten years.

Florida Population Projections

1980	1987	1990	1995	2000
9,746,324	12,043,608	12,986,215	14,333,708	15,431,009

Table 2.1.2 Florida Population Projections (35)

Since the most prevalent method of estimating solid waste generation rates is by utilizing a per-capita figure with accompanying conversion factors based on location specific parameters, population growth must inevitably be tied to solid waste management concerns. Escalating population will bring a directly proportional increase in solid waste generation rates.

2.3 Florida Solid Waste Collection and Disposal Practices

At present, the typical systems in place for the collection and disposal of solid wastes follow traditional standard practices formulated when land was plentiful, populations were considerably lower, and associated costs were evaluated without consideration of long range costs pertaining to negative environmental impact. This has resulted in the present situation the state faces with the impending closing of the remainder of its active landfills in the next three years. To help mitigate this problem, the Florida Resource Recovery and Management Act, Chapter 88-130 was passed by the Florida Legislature. This law mandates that by 1994, each county in Florida should reduce the amount of wastes that would have been landfilled or incinerated by 30%.

There are a variety of systems employed on a national basis for collection, sortation, and recovery. Basically, wastes maybe collected via the following methods:

a. Non-organized: Wastes are collected and transported by county residents and private haulers.

b. Municipal: All services are provided by the municipality.

c. Contract: The government entity has contracted with the private hauler for collection services.

d. Franchise agreement: The municipality has awarded exclusive franchise to a private hauler within the franchise area. (9)

Consumer-based collection systems can fall into two categories:

a. curbside recovery and

b. voluntary buy-back.

Voluntary Buy-back is used in 17 states at the present time. Dade County and Pinellas County are two counties in Florida which have initiated agreements with private organizations to employ this system as well. Voluntary Buy-back relies upon the consumer voluntarily returning used containers to a central collection center. There are two basic models for this system. One is managed entirely by the municipality and the other is in cooperation with a private concern which either partially or completely owns and operates the center. The consumer is rewarded with cash for return or a coupon for cash or merchandize at a local grocery store. It is reported that this method has produced the highest rate of return of recyclables in general. Currently, this is the only significant manner in which plastic bottles are returned in the United States. (18) There are nine states which have bottle deposit legislation. It is from these states that the majority of the feedstock for the recycling of PET and HDPE, the two polymers which have the healthiest market, is bought by major recyclers. (8)

At present, Florida municipalities dispose of the majority of their plastics waste by landfill containment, incineration or waste to energy methods. The vast majority is handled through landfill containment. Each of these methods poses problems associated with economic feasibility, the ability to continue similar practices in the future, and toxic emission production. These problems will be outlined in the sections entitled PROBLEM DESCRIPTION and ENVIRONMENTAL IMPACT OF PLASTICS WASTES DISPOSAL METHODS which follow.

2.4 Problem Description

Although the recycling of plastics has been studied for the last thirty years, alternating shifts in the economy and public opinion of environmental issues have created a sporadic body of knowledge. Steady increases in the production of plastics are accompanied by the dichotomy of consumer demand for convenient packaging and concern for the growing waste problem. Evidence of a shift in public opinion is manifested in the over 800 new laws regulating policy for dealing with the plastics portion of the solid waste management problem which have been passed by legislatures on all levels in the past two years. Plastics are now specifically targeted in the form of taxes on packaging, outright product bans, product modifications such as the issue of biodegradability.

An example of this may be found in Portland, Oregon where a ban on polystyrene foam in the form of fast food coffee cups and sandwich clamshells is now in effect. (10) The Florida Legislature has passed legislation placing an Advance Disposal Fee on plastics packaging consisting of materials which cannot be recycled at the rate of 50% or more. These restrictions will have the natural outcome of raising the cost of purchasing plastic products. This will directly affect consumer choice as well as affecting major category users of plastics such as the packaging industry and the construction industry. Only a few years ago, the major plastics producers showed no budget for recycling. In 1989, the industry will spend 40 million dollars on recycling projects. This is driven by their fears of losing major markets in plastic products. There is growing awareness that many major products are in danger of disappearing overnight. An example of this is the problem faced by the disposable diaper business. Nebraska has recently passed a disposable diaper ban and legislation is pending in Oregon and California. Proctor and Gamble, Inc. reported 1.6 billion dollars earned in 1988 from the sale of diapers which they have no interest in seeing legislated away. (10) The auto industry spends $500 million annually on disposable packaging and more to burn it. McDonald's spends around 250 million annually on packaging. (10) These are not only major market areas which will be adversely affected but also represent dramatic shifts in lifestyle patterns of American consumers.

3.0 CHARACTERIZATION OF THE SOLID WASTE STREAM IN FLORIDA

3.1 Introduction

Any research concerning the recycling of solid wastes must be grounded in a definitive study of the amounts and kinds of wastes generated. This is particularly important in the case of plastics waste because there are critical factors associated with the proper mix of the feedstock which affect the usefulness of the product. Unfortunately, very little information on these amounts exists. Florida has a significant lack of data on this subject and any figures describing these amounts must be subject to a variety of qualifications With a few exceptions, the vast majority of the cities and counties in Florida have not performed any quantifying studies on waste generation amounts. In counties where there are waste-to-energy facilities, a variety of studies have been conducted, but as the methodology of the studies has not been consistent, the data produced is difficult to consistently analyze. Data evaluation differs because samples are counted by weight, truckload, and volume. This significant omission of data is important as it provides the foundation upon which proper evaluation of recycling technologies should rest. Economic projections and product viability depend upon a predictable and quantifiable availability of feedstock. In quantifying the amount of plastics in the solid waste stream, estimates derived from other data have been utilized. The results are described in section 3.4

of this chapter.

The following sections in this chapter describe the classes of the solid waste stream, national quantities, and estimated quantities for Florida. Also described are the problems inherent in accurately predicting amounts of generated wastes. A description of the chemical and physical properties of the polymer types found in the plastics waste stream portion of the solid waste stream is given in Chapter 4.

3.2 Solid Wastes Classification

On a national basis, the most definitive study of the amounts and classifications of the municipal solid waste stream, remains the 1986 report completed for the U.S.Environmental Protection Agency by Franklin and Associates. Table 3.1 is derived from information in this report and presents an overview of the solid waste stream nationally which can be compared to the Florida Estimated Solid Waste Stream in Section 3.4. The composition of the solid waste stream in Florida was derived from federal, state and local sources. These sources include:

1. "Characterization of Municipal Solid Waste in the United States, 1960-2000", a US EPA report by Franklin and Associates.
2. "North Central Florida Comprehensive Regional Solid Waste Master Plan" prepared by Camp Dresser & McKee.

3. Florida High Technology and Industry Council, Research Requirements for the Recycle and Reuse of Solid Waste Materials, Tallahassee, Florida: Office of the Governor, February, 1989.

4. Research conducted for the purposes of this report by Dr. Charles Spindler, Center for Environment Studies, Auburn University, Auburn, Al.

3.3 Considerations for Evaluating Solid Wastes Classification

<u>Characterization</u> refers to the determination of mass, volume, weight, and composition with measurements extending to rates and totals. The following three criteria of:

A. Locale of Generation,

B. Growth Patterns, and

C. Seasonal Variations

are considerations which directly affect accurate predictions in solid waste generation.

A. Locale of Generation

A per-capita generation method is not sufficient in itself if consideration is not given to locale of generation and appropriate conversion factors applied. For example, in some Florida counties a significant amount of waterfront recreational area is present and the plastics portion of the waste stream is likely to be higher than in predominantly agricultural counties due to the larger amount of recreational activities. Take-out foods and beverages for beach or waterfront activities contribute significantly to the amount of consumer-generated plastic in the waste stream. Tourism is therefore a significant factor in determining solid waste generation in Florida. The per-capita figure for solid waste generation in a non-tourism oriented state such as Kansas could not provide accurate numbers for Florida. This may be supported by statistics derived from a clean-up operation conducted in Florida by the Center For Marine Conservation, Washington D.C.

In April, 1989, 12,041 volunteers picked up 307 tons of litter from 966 miles of ocean, gulf and river shoreline. The results from trash picked up in the area of the Florida Keys prove that the "Florida Factor" significantly affects solid waste generation rates. It was reported that more than 60% of the trash picked up in this area consisted of plastics. This included over 234 miles of monofilament fishing line. The Center for Marine Conservation, Washington D.C., believes the excessive amount of trash in this area stems from tourists, cruise ships, and other merchant vessels.

Other locale factors should consider the ratio among residential, commercial, institutional, and industrial generators found in the area to be quantified. One single entity such as the University of Florida in Alachua County or Disney World in Orange County can have a significant impact on quantity and class of solid wastes generated. Finally, the difference in socio-economic characteristics found in a rural based economy versus an urban based economy can produce a meaningful shift in per-capita generation rates.

B. Growth Patterns

Development and construction activities in a high growth area can have a major impact on solid waste generation. The so-called bulky wastes generated from land clearing, demolition, and construction activities will increase. The accompanying influx of people will increase the residentially-generated stream. A new industry in a given area may potentially increase industrially generated wastes as well as residentially generated wastes from new people coming in for employment.

C. Seasonal Variations

In areas where tourism is a significant contributor to the economy, solid waste generation may be subject to changes in quantity and type. The above considerations should explain why a simple per-capita rate of generation derived from national figures would not be a sufficient indicator for Florida. An additional impediment to accurately depicting solid waste generation rates for the State of Florida is the lack of consensus in gross sampling. The following considerations can significantly affect accurate totals:

1. Size of sample -- In many Florida Counties where attempts were made to quantify the waste stream, totals were generated by visual inspection. Variations in truck size and load size make

this data difficult to use in comparisons with other locales.

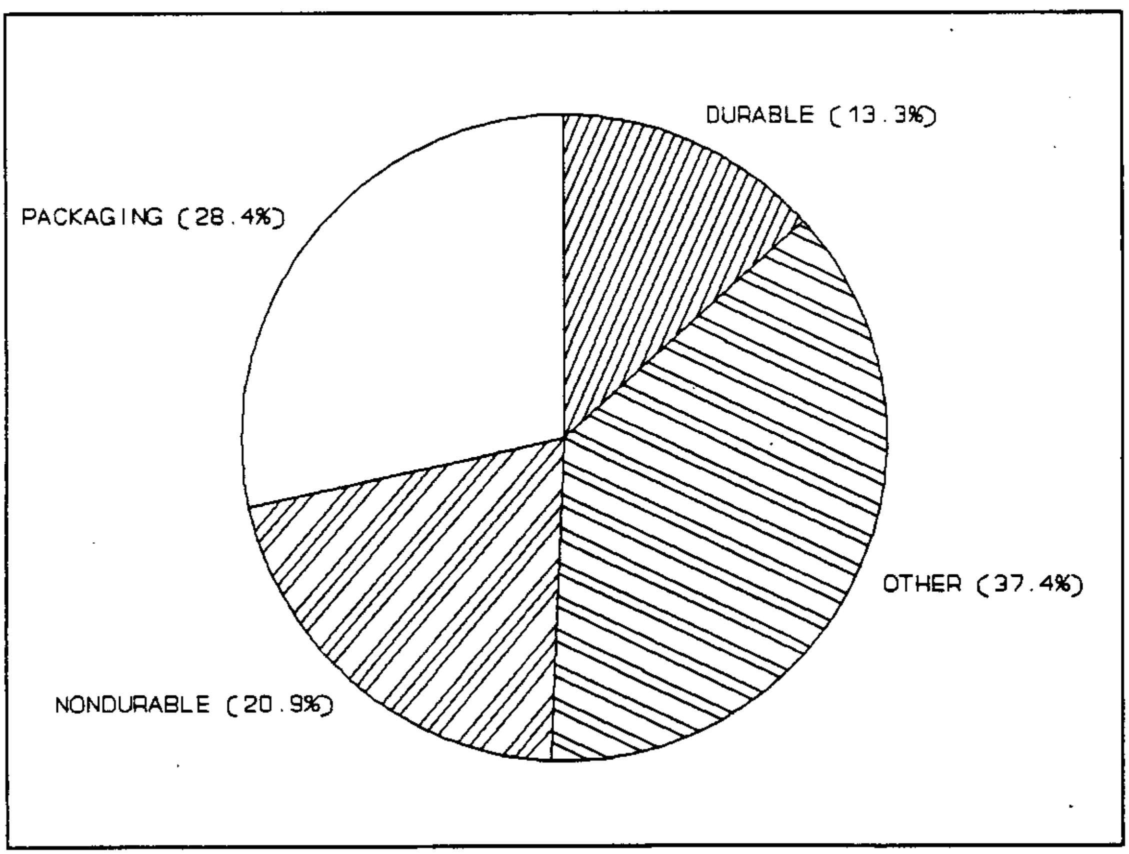
If no distinction is made among residentially, commercially or industrially generated wastes, the amounts of each component in the waste stream can vary significantly.

2. Mixed Sample Class -- Certain items are difficult to assign a classification because the discrete item contains materials belonging to more than one class. An example of this is the discarded PET soda bottle which might consist of several different kinds of plastics (the bottle, the base cup, the cap, plus a paper label, some adhesive material, and a metal cap, and remaining contents.

3.4 Methodology

The total tonnage of solid waste entering Florida's waste stream will increase by approximately 4 million tons from 12.3 million tons in 1989 to 16 million in 2000 (see tables I and II). The composition of the waste stream will continue to shift, as illustrated below. The following three graphs summarize Table I and II - Products discarded into Florida's Municipal Waste Stream - 1986; 1990; 2000.

GROSS DISCARDS INTO SOLID WASTE STREAM
FLORIDA - 1986



PRODUCTS DISCARDED INTO THE MUNICIPAL WASTE STREAM
FLORIDA TOTALS - REPORTED AND ESTIMATED
TABLE I

	1986		1987		1988		1989	
Component	Tons	Percent	Tons	Percent	Tons	Percent	Tons	Percent
Durable Goods								
Major Appliances	204000	1.8%	195000	1.7%	175000	1.5%	150000	1.3%
Furniture and Furnishings	487000	4.3%	507000	4.3%	513000	4.4%	522000	4.5%
Rubber Tires	136000	1.2%	145000	1.2%	152000	1.3%	160000	1.4%
Miscellaneous Durables	680000	6.0%	716000	6.1%	736000	6.3%	761000	6.5%
TOTAL DURABLES	1507000	13.3%	1563000	13.4%	1576000	13.5%	1593000	13.6%
Nondurable Goods								
Newspapers	679000	6.0%	700000	6.0%	700000	6.0%	700000	6.0%
Books and Magazines	254000	2.2%	272000	2.3%	275000	2.4%	278000	2.4%
Office Papers	331000	2.9%	356000	3.1%	361000	3.1%	366000	3.1%
Commercial Printing	195000	1.7%	216000	1.8%	221000	1.9%	226000	1.9%
Tissue Paper and Towels	N/A		N/A		N/A		N/A	
Other Nonpackaging Paper	458000	4.0%	467000	4.0%	465000	4.0%	464000	4.0%
Clothing and Footware	238000	2.1%	245000	2.1%	245000	2.1%	245000	2.1%
Other Miscellaneous Nondurables	215000	1.9%	232000	2.0%	235000	2.0%	238000	2.0%
TOTAL NONDURABLES	2370000	20.9%	2487000	21.3%	2502000	21.4%	2517000	21.6%
Containers and Packaging								
Paper								
Corrugated Boxes	1044000	9.2%	1081000	9.3%	1082000	9.3%	1084000	9.3%
Other Paperboard	289000	2.6%	298000	2.5%	298000	2.5%	297000	2.5%
Miscelleneous Paper	229000	2.0%	231000	2.0%	229000	2.0%	228000	1.9%
Total Paper	1562000	13.8%	1610000	13.8%	1609000	13.8%	1609000	13.8%
Wood Packaging	N/A		N/A		N/A		N/A	
Plastics								
Plastic Containers	N/A		N/A		N/A		N/A	
Other Plastics	N/A		N/A		N/A		N/A	
Total Plastics	770580	6.8%	824000	7.1%	834000	7.1%	844000	7.2%
Metals								
Steel								
Beer and Soft Drink Cans	N/A		N/A		N/A		N/A	
Food and Other Cans	N/A		N/A		N/A		N/A	
Other Steel Packaging	N/A		N/A		N/A		N/A	
Total Steel	153000	1.4%	148000	1.3%	144000	1.2%	141000	1.2%
Aluminum								
Beer and Soft Drink Cans	68000	.6%	70000	.6%	70000	.6%	70000	.6%
Other Cans	26000	.2%	27000	.2%	27000	.2%	27000	.2%
Foil and Closures	N/A		N/A		N/A		N/A	
Total Aluminum	94000	.8%	97000	.8%	97000	.8%	97000	.8%
Glass and ceramics								
Beer and Soft Drink Cans	297000	2.6%	281000	2.4%	273000	2.3%	264000	2.3%
Wine and Liquor Bottles	N/A		N/A		N/A		N/A	
Food and Other Bottles and Jars	N/A		N/A		N/A		N/A	
Other	339000	3.0%	349000	3.0%	349000	3.0%	349000	3.0%
Total Glass	636000	5.6%	630000	5.4%	622000	5.3%	614000	5.3%

Component	1986 Tons	1986 Percent	1987 Tons	1987 Percent	1988 Tons	1988 Percent	1989 Tons	1989 Percent
Other Miscellaneous Packaging	N/A		N/A		N/A		N/A	
TOTAL CONTAINERS AND PACKAGING	3215580	28.4%	3309000	28.3%	3306000	28.3%	3305000	28.3%
TOTAL DURABLES, NON-DURABLES AND PACKAGING	7092580	62.6%	7359000	63.0%	7384000	63.3%	7415000	63.5%
Other Wastes								
Food Wastes	1688170	14.9%	1714000	14.7%	1706000	14.6%	1698000	14.5%
Yard Wastes	2549250	22.5%	2571000	22.0%	2553000	21.9%	2535000	21.7%
Miscellaneous Inorganic Wastes	N/A		N/A		N/A		N/A	
TOTAL OTHER WASTES	4237420	37.4%	4285000	36.7%	4259000	36.5%	4233000	36.3%
TOTAL SOLID WASTE	11,330,000	100.0%	11,673,000	100.0%	12,027,000	100.0%	12,391,000	100.0%

Note: Percentages for 1986 computed from Source (1) with the exception of Durable Goods; this data estimated from Source 2. Totals and percentages for 1987-1989 estimated by applying national annual growth rate projections from Source 2. Estimated 1987-1989 total solid waste calculated as 3.03 percent annual compound increase over each previous year's total. This is based on rate of population increase for 1980-1986. 1986 Total Solid Waste amount from Department of Environmental Resources. Each category of packaging waste was divided by total solid waste to calculate percentage.

Percentage of food waste calculated from national averages for 1960 base; percentage yard waste calculated using 1965 base from Source 2. Data provided in Source 1 considered unreliable for these categories. National data for these categories significantly lower than estimated in Source 1.

SOURCES:

(1) Florida High Technology and Industry Council, Research Requirements for the Recycle and Reuse of Solid Waste Materials, Tallahassee, Florida: Office of the Governor, February, 1989.

(2) Franklin Associates, Characterization of Municipal Solid Waste in the United States 1960 - 2000. Washington, D.C.: U.S. Environmental Protection Agency, 1986: 1-13.

Population Table

1986 Population	11657843.0
1980 Population	9747063.0
1980-1986 % change	16.39%
Compound Annual Increase	3.03%

PRODUCTS DISCARDED INTO THE MUNICIPAL WASTE STREAM
FLORIDA TOTALS - ESTIMATED
TABLE II

Component	1990 Tons	1990 Percent	1995 Tons	1995 Percent	2000 Tons	2000 Percent
Durable Goods						
Major Appliances	150000	1.3%	150000	1.3%	150000	1.3%
Furniture and Furnishings	526000	4.5%	531000	4.5%	538000	4.6%
Rubber Tires	160000	1.4%	160000	1.4%	160000	1.4%
Miscellaneous Durables	754000	6.5%	747000	6.4%	747000	6.4%
TOTAL DURABLES	1590000	13.6%	1588000	13.6%	1595000	13.7%
Nondurable Goods						
Newspapers	706000	6.0%	712000	6.1%	716000	6.1%
Books and Magazines	286000	2.5%	294000	2.5%	298000	2.6%
Office Papers	373000	3.2%	379000	3.3%	386000	3.3%
Commercial Printing	230000	2.0%	235000	2.0%	240000	2.1%
Tissue Paper and Towels	N/A		N/A		N/A	
Other Nonpackaging Paper	464000	4.0%	464000	4.0%	468000	4.0%
Clothing and Footware	248000	2.1%	250000	2.1%	250000	2.1%
Other Miscellaneous Nondurables	242000	2.1%	247000	2.1%	251000	2.1%
TOTAL NONDURABLES	2548000	21.8%	2580000	22.1%	2612000	22.4%
Containers and Packaging						
Paper						
Corrugated Boxes	1100000	9.4%	1117000	9.6%	1128000	9.7%
Other Paperboard	296000	2.5%	294000	2.5%	290000	2.5%
Miscelleneous Paper	226000	1.9%	224000	1.9%	218000	1.9%
Total Paper	1622000	13.9%	1635000	14.0%	1636000	14.0%
Wood Packaging	N/A		N/A		N/A	N/A
Plastics						
Plastic Containers	N/A		N/A		N/A	
Other Plastics	N/A		N/A		N/A	
Total Plastics	863000	7.4%	882000	7.6%	896000	7.7%
Metals						
Steel						
Beer and Soft Drink Cans	N/A		N/A		N/A	
Food and Other Cans	N/A		N/A		N/A	
Other Steel Packaging	N/A		N/A		N/A	
Total Steel	136000	1.2%	132000	1.1%	128000	1.1%
Aluminum						
Beer and Soft Drink Cans	70000	.6%	70000	.6%	73000	.6%
Other Cans						
Foil and Closures	N/A		N/A		N/A	
Total Aluminum	70000	.8%	70000	.9%	73000	.9%
Glass and ceramics						
Beer and Soft Drink Cans	259000	2.2%	254000	2.2%	249000	2.1%
Wine and Liquor Bottles	N/A		N/A		N/A	
Food and Other Bottles and Jars	N/A		N/A		N/A	
Other	343000	2.9%	337000	2.9%	332000	2.8%
Total Glass	602000	5.2%	591000	5.1%	581000	5.0%

Component	1990 Tons	1990 Percent	1995 Tons	1995 Percent	2000 Tons	2000 Percent
Other Miscellaneous Packaging	N/A		N/A		N/A	
TOTAL CONTAINERS AND PACKAGING	3293000	28.5%	3310000	28.6%	3314000	28.7%
TOTAL DURABLES, NON-DURABLES AND PACKAGING	7431000	63.9%	7478000	64.3%	7521000	64.7%
Other Wastes						
Food Wastes	1684000	14.4%	1670000	14.3%	1652000	.14.2%
Yard Wastes	2513000	21.5%	2492000	21.3%	2470000	21.2%
Miscellaneous Inorganic Wastes	N/A		N/A		N/A	
TOTAL OTHER WASTES	4197000	36.0%	4162000	35.7%	4122000	35.3%
TOTAL SOLID WASTE	12,766,000	100.0%	14,501,000	100.0%	16,085,000	100.0%

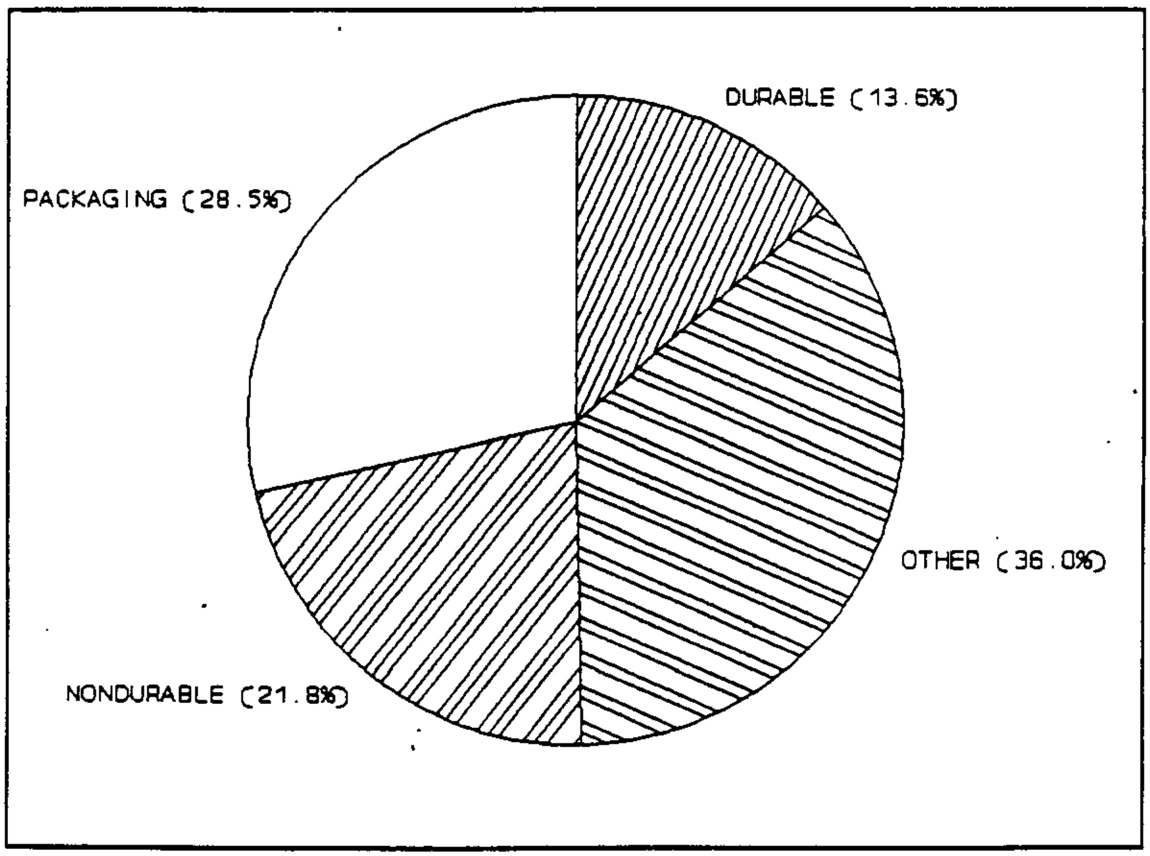
Note: This table is based on data developed in Table I the years 1986-1989. In the earlier table, the total reported amount of solid waste genetated in 1986 was obtained from DER. An annual compound rate of population growth was computed, and this used to estimate the increase in waste generated. It was assumed that the rate of solid waste generation would match the rate of population growth. Naturally, there are conditions under which this assumption will result in the underestimation of the rate of production. For example, the move toward more "convenience" type packaging will result in more packaging waste. It was assumed that the rate of solid waste production would parallel nation averages. The national rate of increase or decrease in production for each category was based on data from Source 2.

SOURCES:
(1) Florida High Technology and Industry Council, Research Requirements for the Recycle and Reuse of Solid Waste Materials, Tallahassee, Florida: Office of the Governor, February, 1989.

(2) Franklin Associates, Characterization of Municipal Solid Waste in the United States 1960 - 2000. Washington, D.C.: U.S. Environmental Protection Agency, 1988: 1-13.

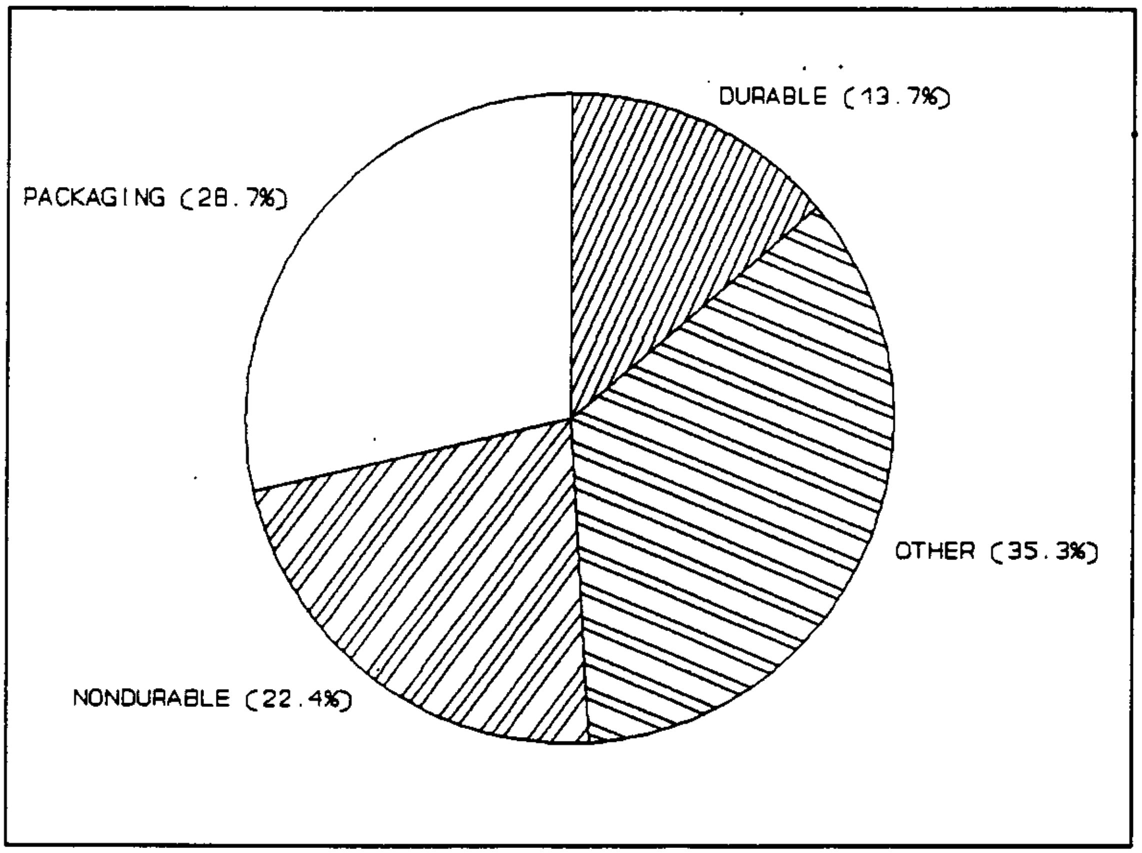
The level of durable goods discarded into Florida's waste stream is estimated to increase very slightly between 1986-2000 as a percentage of the total solid waste stream. The percentage of total nondurable goods entering the solid waste stream will also increase slightly during this time period.

GROSS DISCARDS INTO SOLID WASTE STREAM
FLORIDA - 1990



The level of containers and packaging entering the Florida waste stream will increase slightly over the same time period in terms of both total tonnage and relative share of total waste. The Franklin study (1988) estimates plastics packaging to be approximately 14 percent of all packaging waste in 1990. Estimates for Florida indicate plastics packaging waste is approximately 26 percent of all packaging waste in Florida (see Table I).

GROSS DISCARDS INTO SOLID WASTE STREAM
FLORIDA - 2000



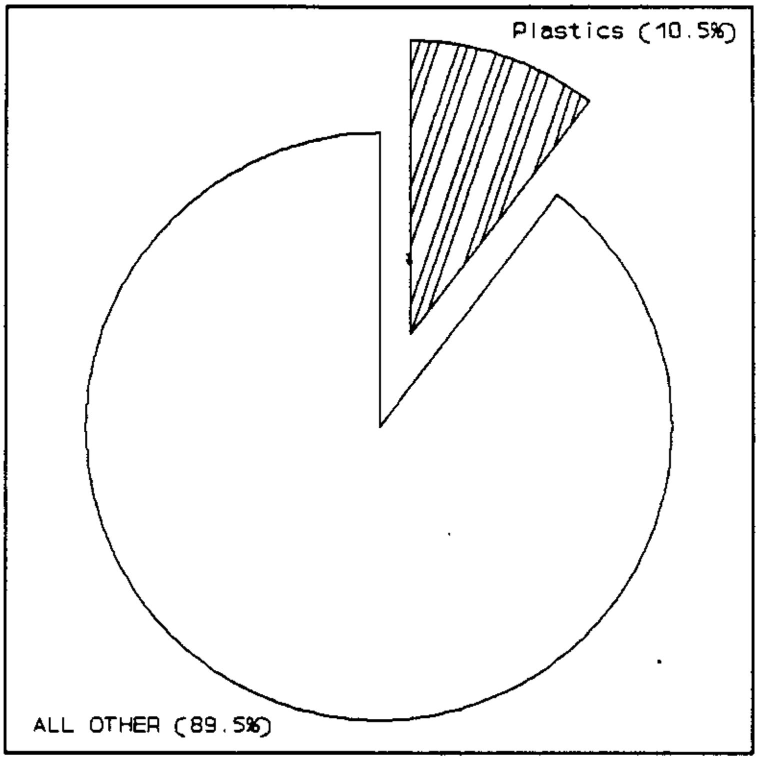
The increases in the level of durable, nondurable and packaging wastes are the result of both an increase in the gross weight of these types of products discarded into the waste stream, as well as a decrease in the total amount of food and yard wastes discarded.

Of primary concern in this report is the level of plastics products entering the Florida waste stream. There are two broad categories of plastics waste. Table I estimates are for the amount of plastics packaging only. These estimates are calculated on the basis of state data reported by the Florida High Technology and Industry Council in 1989. Extrapolation of present data to estimate future trends is made on the basis of national trends. Once the Florida base was established, national growth trends for all categories including plastics were computed and applied to the base. This procedure is less desirable than random landfill site inspections to determine composition, but this procedure was beyond the scope of this report. The procedure used is likely to result in a conservative estimate of the total level of plastics in the waste stream. Plastics comprise a greater proportion of the Florida waste stream for several reasons. Tourism and recreation are a significant part of Florida's economic environment. The use and subsequent disposal of plastic containers; fast food or otherwise; and plastic cups, bottles and disposable utensils will be higher in Florida than the national average. Florida's fast growing population fuels an expanding housing market with the use of plastics in housing construction increasing. The "Florida life-style", with its focus on recreation, translates into more "convenience" type foods and more plastic convenience packaging.

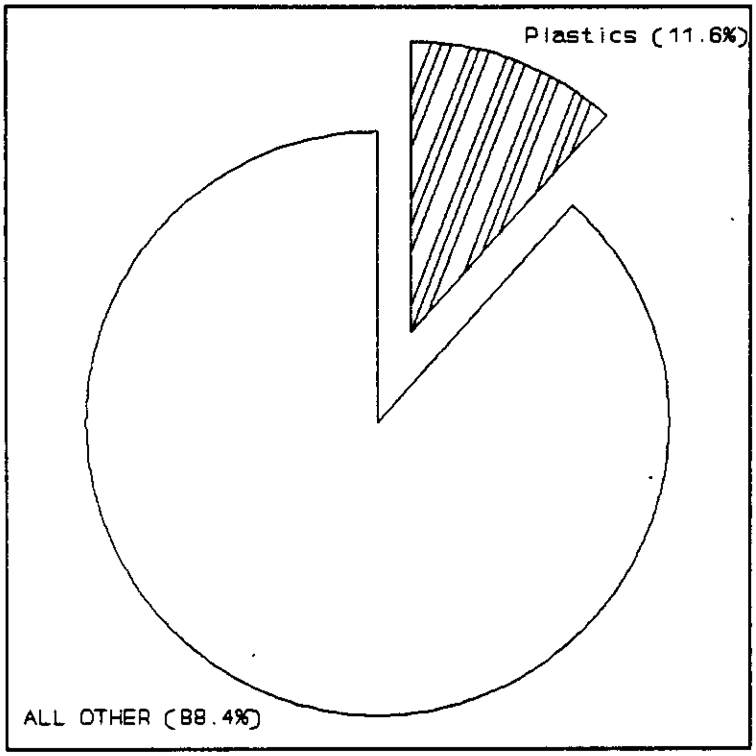
Without specific industry data for Florida, which is unavailable, or on-site composition studies, which have varied significantly in accuracy when available, the use of national trend data is the most reasonable and acceptable alternative.

The second broad category of plastics waste is simply non-packaging waste. It was assumed that the ratio of non-packaging plastics waste to packaging plastics waste in Florida would also parallel national averages. For the reasons given above, this assumption will produce a conservative estimate of the total level of plastics products entering the waste stream in Florida. By adding non-packaging to packaging plastics waste, the total amount of plastics waste is estimated. The next three graphs display the total amount of plastics products entering the waste stream as a percentage of the waste stream. The level of plastics discarded into Florida's waste stream will continue to increase.

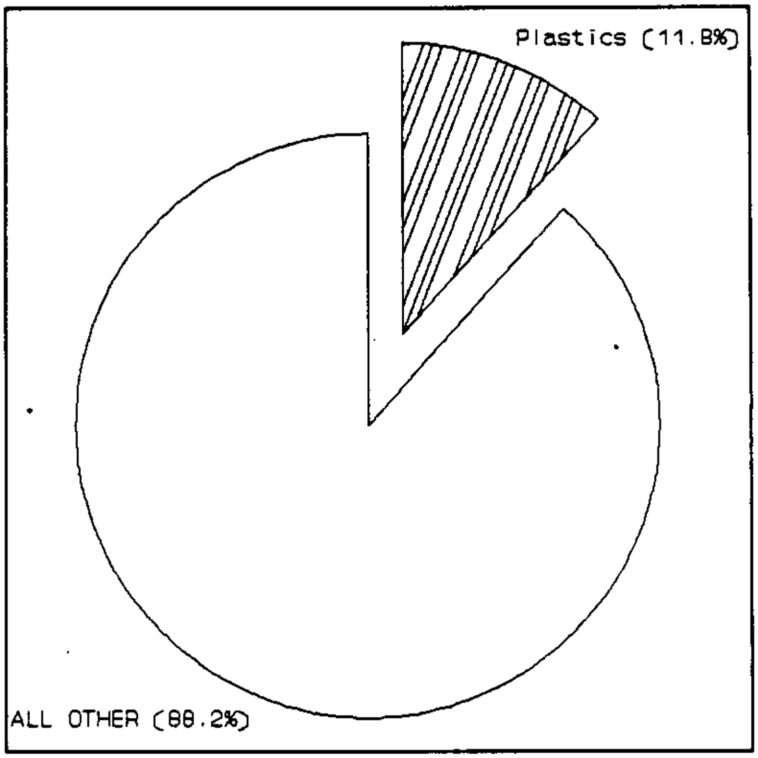
PLASTICS PRODUCTS IN THE WASTE STREAM
FLORIDA - 1986
Percent of Total Waste



PLASTICS PRODUCTS IN THE WASTE STREAM
FLORIDA - 1990
Percent of Total Waste



PLASTICS PRODUCTS IN THE WASTE STREAM
FLORIDA - 2000
Percent of Total Waste



4.0 CLASSIFICATION OF THE PLASTICS WASTE STREAM IN FLORIDA

4.1 Introduction

As reported in Chapter 3, the per capita generation figures amended by the "Florida Factor" currently shows the amount of plastics in the Florida post-consumer waste stream to be around 11.6% with this amount expected to increase. The impact of tourism upon the plastics waste stream in Florida is a significant component of post consumer generated plastics waste due to its impact upon the increase of volume and the present difficulty in capturing these plastics wastes through curbside recovery programs.

The following sections of Chapter 4 describe the types or classes of plastics found in the waste stream and the sources of these plastics from products of their typical end-use applications. A description of the problems associated with possible negative environmental impact and an overview of the problems of compatibility among polymers is included.

4.2 Types of Plastics in the Waste Stream

Plastics in the waste stream have been divided into six major categories. The following is a list of these categories accompanied by a description of typical uses.

MAJOR CLASSIFICATIONS OF PLASTICS IN THE WASTE STREAM

POLYMER RESIN	USE
LDPE (low density polyethylene)	containers package films bags, bottles
HDPE (high density polyethylene)	rigid containers bottles
PP(polypropylene)	non-rigid wrappers, linings
PS (polystyrene)	foams, insulation semi-rigid containers protective packaging
PET (polyethylene terephthalate)	soft drink containers
PVC (polyvinyl-chloride)	(used mainly as an additive) rigid containers, films, coatings

Table 4.2.1 Major Classifications of Plastics in Solid Waste Stream

4.3 Generators of Plastic Wastes

The plastics waste generated from a post-consumer source is currently under review by several municipalities in Florida for inclusion in recycling programs. As described in Chapter 2, Alachua County in Florida has already included plastics recycling in its overall recycling strategy. This recycling is confined to HDPE and PET only which are predominately used in packaging.

Packaging represents the largest broad use of plastics which find their way into the waste stream. The singling out of HDPE and PET for extraction from the waste stream for recycling is based upon this fact, the relative ease of consumer identification, and the degree of purity of the extracted resin. Therefore, plastics from packaging are the sole source of plastics waste targeted by municipalities for recycling. The only methods of recovering plastics from consumers are by voluntary buy-back and curbside recovery. Both methods rely upon labor intensive hand sorting either by the consumer previous to pick-up or at the materials recovery facility (MRF). The following table provides an overall picture of what is available to the consumer or municipality to hand sort from the post-consumer waste stream.

POLYMER PROPORTION BY END USE

POLYMER RESIN	FILMS(%)	BOTTLES(%)	CONTAINERS(%)
LDPE	80.0	0.0	0.0
HDPE	5.5	62.1	53.4
PP	9.1	3.4	6.9
PET	NIL	24.1	12.1
PVC	3.6	6.9	5.2
PS	NIL	NIL	15.5
OTHERS	1.8	3.4	6.9

Table 4.3.1 Polymer Proportion by End Use (37)

This illustrates that in a consumer based sorting program to recover plastics, the largest available polymer will be HDPE. If HDPE is included within the mixed plastics waste stream and not separated for a specific market, the feedstock for processing commingled plastics into recycled products will consist primarily of an HDPE matrix to which additions of other plastics and fillers will be added. If HDPE and PET are separated for use in their discrete markets, then the commingled plastics waste resultant will lack significant amounts of these polymers. The composition of the feedstock available for use in commingled plastics waste recycling technology is critical to the expansion of the variety of products from those now existing which can only be designated for <u>non-critical use</u>.

This limit of use is directly tied to the inability to increase the engineering properties of the product. In order to increase the strength characteristics of the products made from this technology, research concerning methods to analyze and "correct" the feedstock must advance. When this level of knowledge is reached, predictable sources of particular polymers will be instrumental in providing proper feedstock mix.

Industry has always produced scrap and waste from normal manufacturing operations. Where possible, recycling this relatively clean source of plastics waste has been incorporated into the economic viability of a product. This is dependent upon the type of product produced. Sources of scrap or waste can stem from a reject product in which the polymer/polymers utilized are good, but the product is marred in some way by mistake. An example of this would be a PET soda bottle whose labels were incorrectly applied or discovered after the fact to contain wrong information. This would render the entire batch of a certain bottle count useless as a finished product. A mistake such as this does not produce "scrap" which is easily recyclable in house due to separation problems. The batch consists of finished bottles which contain a variety of resins and other materials. A batch of perfectly good but unused soda bottles would, in this case, most likely be sold or given to an intermediate recycler for separating and grinding.

Another source lies in the normal manufacturing process itself which might produce sprues or runners from a molding process or trim from a die cutting process. This source is the best source of plastic waste due to its relative cleanliness, ease of polymer identification, and no requirement for separating. These characteristics of ease of separation and quality control of cleanliness, permits plastic waste from this source to be economically viable to recycle into the same end-use product or sold for an alternate application.

Wastes generated from the normal manufacturing process are frequently recycled in house for use in the production of the same product. When contaminated by other plastics it is most frequently ground and sold to an intermediate recycler. When the contamination is too high for any viable potential recycling, the scrap or batch is considered as wastes for disposal.

4.4 Environmental Consideration of Plastic Wastes Disposal Methods

Most plastics burn in a similar manner to natural gas with emission production limited mainly to carbon dioxide, water vapor, and nitrogen oxides. (12) It has been recommended that incineration of plastic wastes (quartenary recycling) is enhanced by the presence of plastics due to the ability to achieve higher combustion temperatures. This in turn creates a higher production of BTUs which is a favorable factor in waste to energy plants. However, chlorinated plastics can produce dioxins and furans.

The burning of chlorinated plastics also produces additional hydrochloric acid vapors which are typically scrubbed from the vent gases. It is reported that since this operation is built into all modern incineration facilities, there is no significant impact on the operational economics of incineration. The incineration of plastics in an environmentally safe manner can only be done with new incinerators designed for such burning. Older incinerators are not capable of burning clean and the cost of retro-fitting is so high that new construction of incinerators is favored. While researchers generally agree with the concept of proper burning of plastics waste being relatively environmentally safe, convincing the public will be difficult. These factors are significant contributors to enhancing the value of commingled plastics recycling. There is no good data on increasing levels of hydrochloric acid production tied to increasing levels of chlorinated plastics nor increasing levels of dioxins or furans in stack gases or fly ash. It is therefore presently assumed from the data available, that incineration performed with the proper technology is a viable alternative use for wastes plastics that have been recycled so many times that their engineering properties have been significantly reduced, rendering them inadequate for further recycling.(1)

However, public sentiment about toxic emissions no matter how minimal, may not, in the future tolerate any additional levels of dioxins or furans. The location of incinerators is becoming as complex as the location of landfills. Incineration, while producing energy in some cases, produces fly ash which amounts to 10% of the original weight. Incineration will require that fly ash be recycled into useful products instead of landfilled as recycling efforts increase. Some of this fly ash could contain toxic or hazardous materials depending upon the mix of wastes to be incinerated. Therefore a greater effort towards recycling is expected to be warranted in the future.

It has been reported that there is little effect on a landfill from a chemical point-of-view because only small amounts of carbon dioxide and methane have been found to evolve from the degradation of plastics in a landfill. (1) The greatest issue for disposing plastics in landfill containment centers around the resistance of plastics to bacterial attack. This means that once placed in the landfill, plastics cannot be expected to break down like organic matter. The lifespan of plastics in a landfill containment situation is now thought of to be easily up to 100 years (Jonathon Earle, Bioprocess Engineering). This could be even longer as an archeological excavation of a landfill in Arizona by Dr. William Rathje has produced recognizable organic matter as old as 40 years. This graphically illustrates the idea that some landfill construction utilizing membrane liners is so anaerobically sound, little or no natural degradation is expected to occur.

4.5 Problem Description

Compatibility is the one factor which has previously made the recycling of plastics waste undesirable. The great variety of packaging materials reflects the diversity of properties necessary to contain certain kinds of liquids and food materials. This wide variety of resins may be found in one small consumer waste sample. Most plastic products are not labeled and cannot be distinguished by the untrained. Therefore, separation of resin types both by the consumer and by municipalities is difficult and sometimes impossible. To help correct this problem, the Society of Plastics Institute has suggested that plastics producers utilize a marking or coding system to certify the polymer content of the product.

Many polymer experts anticipate that, in the future, it will only be viable to separate HDPE and PET for discrete markets. This leaves a large commingled plastics waste resultant and makes the development of recycling technologies associated with the processing of commingled plastics waste and the creation of marketable products from this technology all the more important.

Additionally, the problem with plastics waste separation does not end with the variety of resins found in different kinds of packaging and products due to different end-uses and the difficulty of the individual to recognize each one. The practice of combining a polymer with other materials to produce a single product will continue to contribute to plastics recycling problems. Many plastics products consist of multiple configurations. The greater effort of recycling in terms of procedures related to cleaning and separating compared with that represented by the recycling of an aluminum can, a single, pure recyclable which requires only cleaning will create a greater need for the development of commingled plastics waste recycling.

Additionally, the natural degradation of plastics in recycling situations must be considered. The number of times a polymer has been recycled also has a significant affect. With each re-processing, specifications are lowered. This is due to oxidation which occurs when plastics are heated. The results are the occurrence of chain scissors with the average molecular weight decreasing. Along with this phenomenon comes changes in color, reduced flexibility, strength, and resistance to impact.(1) In this way, a significant loss of engineering properties occurs.

By the addition of new polymers and co-polymers to the feedstock, some of these properties can be improved. This is an area of on-going research with the goal of creating better "recipes" by the introduction of new "ingredients".

5.0 TECHNOLOGY REVIEW

5.1 Introduction

Several commercial commingled plastics recycling technologies are either currently in place or beginning operations in the United States. Systems developed and used by commercial operations produce large cross section profiles from a mixed feedstock that has received very little cleaning and sorting. These similar technologies can process a feedstock that may in some cases contain up to 50% contaminates (by weight). Contaminants in this case can include a dissimilar polymer or any non-plastic item such as the material which comprises content residue. As reported in Chapter 6, commercial technologies in the United States are limited in the range of products offered compared with their counterparts in Europe. Recycling rates are significantly higher throughout Europe, in part due to lack of available space for landfill siting. This problem has been more critical throughout Europe for much longer than it has been in this country. Therefore, recycling technologies were primarily developed in Europe and Japan and many commercial recycling technologies are approaching 20 years as extant operations.

The different technologies currently employed in the United States, some holding patents, are actually very similar. All are extrusion molding processes which "melt" the feedstock through friction into a molten matrix within which are captured discrete particles of plastics requiring a higher temperature to melt. Products are being produced which have been termed as viable in "non-critical" uses or those uses which do not include either habitable space or a reliance upon load bearing capacity.

This section will provide an overview of technologies associated with various types of plastics wastes recycling systems with a particular emphasis on the recovery and reprocessing of commingled plastics. The various technologies share certain similarities and some exist as an extension of others. In commingled plastics technology, although systems can accept almost any type of mixed stock, they must take into account the amount and types of polymers (if any) that have been removed from the potential feedstock. The feedstock mix will affect the appearance and mechanical properties of the end products. Although the technologies associated with the processing of commingled plastics waste have the capability of accepting a wide range of feedstocks, experiments are now underway to improve the content of the feedstocks by polymer additions in order to enhance the strength properties of the final products. Therefore, the composition of the feedstock is expected to become more important in the future.

For these reasons, an overview of technologies associated with the recovery and processing of particular polymers, such as the highly marketable HDPE and PET, is included to facilitate the understanding of the current feedstock situation which would apply to any of the technologies connected with commingled plastics processing. Additionally, some PET and HDPE recycling technologies are capable of accepting a small amount of contaminants and additional polymer types and may, therefore, have potential in the future for modification to technologies capable of processing a certain amount of commingled plastics waste.

5.2 HDPE and PET Recovery System

Efforts in plastics recycling gained serious impetus with the advent of the plastic beverage container which was introduced in 1978. It is necessary to understand the role the recycling of beverage containers plays in the recycling industry in order to understand the recycling of commingled plastics. Additionally, it is important to understand the differences in the technologies employed for the recovery and recycling of HDPE and PET from that of commingled plastics to grasp some of the economic parameters of commingled recycling with respect to the sources of commingled plastics feedstocks.

At this time, plastics recycling technology remains heavily concentrated upon the two polymers, HDPE and PET, from which milk containers and soft drink containers are made. This strategy is supported by two important considerations:

A) These containers constitute the bulk of plastics solid waste;

and

B) Polymer experts consider these resins as being the most conducive to recycling.

HDPE or high density polyethylene, is the material of choice for milk containers. PET, polyethylene terephthalate, is used primarily for soft drink containers. The harder plastic bottoms of most soft drink containers, known as base cups, are made from HDPE. PET is the most common polymer utilized in packaging today.

The basic steps of plastics recycling concern size reduction and materials handling. For in house industrial scrap, size reduction is accomplished by granulation and/or shredding. The resulting material is known as <u>regrind</u>. This step may be accomplished at the location of generation or at other locations providing this regrinding service after the baled or compressed material has been transported away from its location of generation. This step is inherent in any plastics recycling.

Materials handling includes conveying, storage, and controlled feeding, back into a virgin raw material stream. Even with the re-processing of relatively pure resin scrap, in some cases, an analysis must be performed to determine the type and amount of additives which must be utilized to "correct" the mix to produce a final product with appropriate properties.

The following table illustrates the amounts of PET and HDPE found in packaging. Since virtually all plastics packaging enters the waste stream, the significant amounts of PET and HDPE are important portions of the mix. These portions are reflected in table 5.2.1. Most systems recovering PET or HDPE from feedstock emanating from post consumer wastes utilize a sequence of procedures similar to

MATERIAL	1986		1987	
	MM lbs	%	MM lbs	%
LDPE	3789	33.0	4116	32.6
HDPE	3460	30.2	3876	30.7
PP	1142	10.0	1265	10.0
PET	745	6.5	912	7.2
PS	1247	10.9	1346	10.6
PVC	594	5.2	611	4.1
OTHER	500	4.4	523	4.1
TOTAL	11,477	100.0	12,649	100.0

Table 5.2.1 TYPES OF POLYMERS IN PLASTICS PACKAGING, 1986-1987 (millions of pounds and percent)

**Source: Center for Plastics Recycling Research, Rutgers estimates.

the following general description:

a. Grinding.

Returned beverage containers are ground to particles or chips of a given optimum size to reduce volume and increase bulk density. This procedure may be done at the primary production plant, at a MRF, or sent to a middle-man to be ground and returned.

b. Air Classification.

The grind is blown in an air separator to remove extraneous light or fine materials such as dirt and paper.

c. Washing.

Air-cleaned chips are submerged in a hot, caustic solution to sanitize, loosen and digest attached paper, syrups, and adhesives.

d. Caustic Clean-up.

This may include the removal of chips from the solution, sludge removal from the caustic wash solution and the rinsing of chips for residual caustic removal.

e. Flotation Separation.

In this process, the lighter polyethylene is separated from the heavier polyester and aluminum.

f. Drying.

The remaining polyethylene and polyester are dried.

5.3 The Commingled Plastic Waste Resultant

5.3.1 Physical and Chemical Properties

The post-consumer plastics waste stream incorporates all plastics that are sold. These include high and low temperature thermoplastics plus network polymers. Network polymers are covalently connected polymer chains that range from elastomers like rubber (if they are used above their glass transition temperature) to thermosets like epoxies and fiberglass, (if they are used below their glass transition temperature). Most papers on waste management and plastics recycling ignore the network polymer in the post-consumer waste stream. These materials do exist and do not deform significantly under heat and pressure or mix with other polymers and therefore offer problems in terms of processing and properties. Ideally, all network polymers should be identified and removed from the post-consumer waste stream prior to recycling.

Polyvinylchloride (PVC) is often present in the waste stream in the form of bottles and pipe. Polyvinylidiene chloride (PVDC) is often present in the form of a random copolymer with PVC -- otherwise known as Saran - Wrap (Dow Chemical). These polymers degrade via a dehydrohalogenation reaction at temperatures necessary to melt polypropylene (PP) (temperatures > 200°C). The product of dehydrohalogenation of PVC is HCL gas, which is very corrosive to the processing equipment and is harmful to people if the HCL fumes are inhaled. Thus, it is very desirable to identify and remove all PVC from the waste stream before processing the commingled plastics post-consumer waste stream. Fortunately, this PVC component is small.

The overwhelming majority of polymers in the post-consumer waste stream are polyolefins (i.e., HPDE, LDPE, LLDPE, PP), PS, PET and PolyMethylMethacrylate (PMMA) or Plexiglass (Rhom & Haas). These polymers do not have significant degradation characteristics that inhibit them from being processed together. However, the post consumer waste stream which provides feedstock for commingled plastics recycling technologies will not contain significant amounts of PET and HDPE if these are included in municipal recycling programs.

5.3.2 Problems Associated with Compatibility

Compatibility is a major problem in the melt processing of commingled plastics. HDPE, LDPE, LLDPE have some compatibility as does PP in a more limited fashion. But fundamentally there are very few polymers that are compatible. That is, few polymers mix with different chemical composition polymers on a segmental or sub-molecular level that is necessary for chain entanglement and good mechanical and other physical properties. See Figure 5.3.1 to help visualize the coil-coil interpenetration required for molecular compatibility for polymer blends. Most of the polymers dislike each other enough that they phase separate into their own chemical type domains and do not mix. These

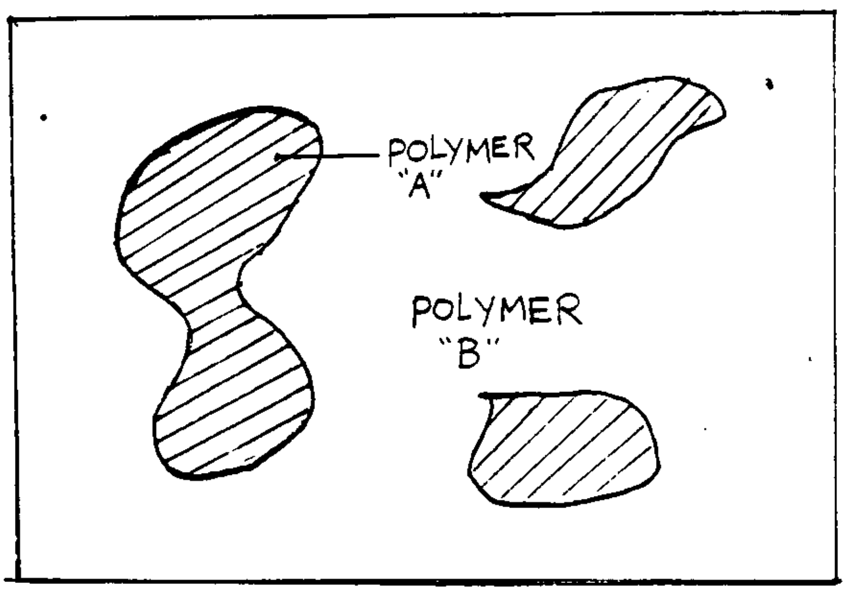


Figure 5.3.1

phase separated materials are invariably brittle in deformation behavior as there are few, if any, chains that cross the boundary between phases and therefore there is little transfer of stress between phases and hence little ductility. If only partial compatibility can be achieved, then stress transfer can occur and physical properties could be improved markedly. These types of materials are referred to as alloys and are currently fabricated from engineering plastics for automotive applications. There are no commodity plastic alloys made at this time. The technology for making alloys from commodity plastics is currently not available although such research is being conducted at the Material Science and Engineering Department, University of Florida.

5.4 Existing Commingled Plastics Product Technologies

5.4.1 General Description

Several commingled plastics processing technologies, in operation in the United States such as Recycloplast, Advanced Recycling Technology, and PRI are capable of producing large cross section profiles from a mixed stock that has received very little cleaning and sorting. At present, the technologies associated with the processing of commingled plastic products are in their infancy. All processes studied utilize the same basic principles and produce products which have been termed as viable in "non-critical" uses because of the diminished properties inherent in the final products.

The variety of processes developed have some common characteristics. The extrusion screw is the main part in the system. The flight and root of the screw are designed to maximize shear heating with a short residence time of the plastic in the screw. In addition, the clearances are large (compared to normal polymer processing equipment) to allow passage of metal particles, stones, wood chips, etc. The recyclable plastic scrap that is processed through these extruders is often significantly contaminated with objects that cannot be converted to the liquid state and therefore act as a filler or a defect depending upon their size and their adhesion to the polymer matrix.

The extrudate from these types of extruders is normally extruded into an open metal mold-- often constructed from pipe. The extrudate is at atmospheric pressure until the mold fills. Thus, the extrudate cools at an uneven rate from one end of the product to the other end. This gradient of cooling has effects on the internal morphology or structure of the product--usually a post or board. Because the extrusion design used usually does not have a vent to remove volatiles, this also affects the morphology by forming voids (See Figure 5.4.1). The filled molds containing molten mixed phase polymer have an inherent temperature gradient from highest at the just filled end of the mold to a lower temperature at the end of the mold filled first (the end away from

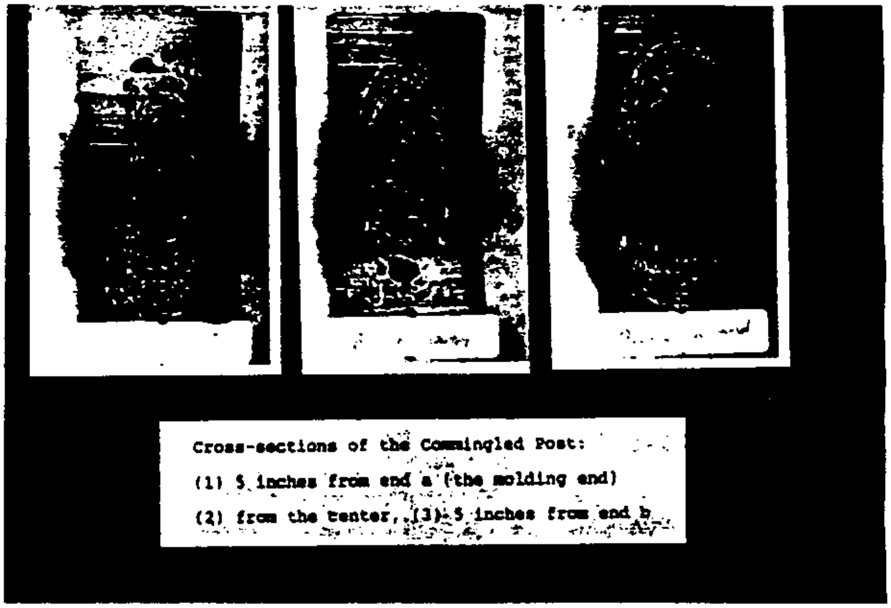
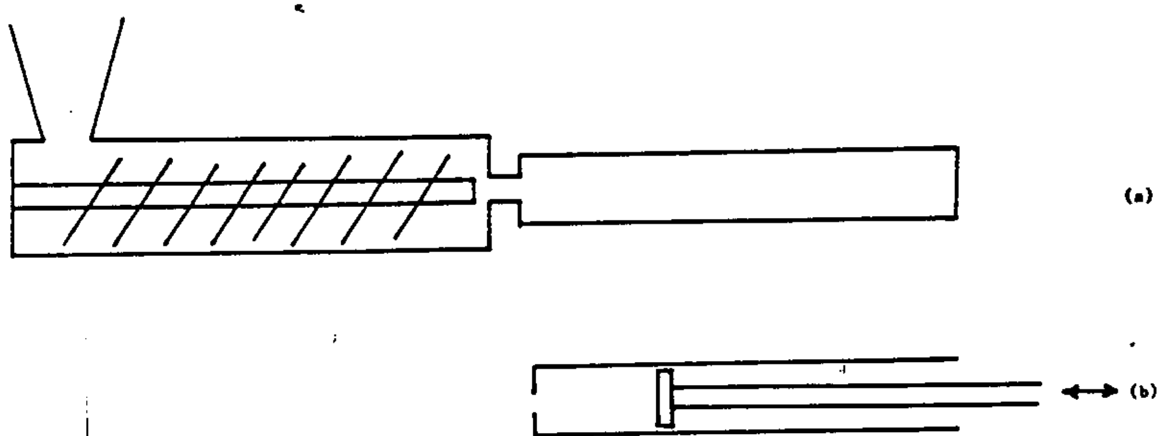


Figure 5.4.1 Voids in Commingled Plastics Products

the extrusion nozzle). The mold and molten polymer is usually cooled rapidly in a water bath to reduce the cycle time required to produce products. The subsequent rapid cooling can result in significant shrinkage as shown in Figure 5.4.2. These differences in internal structure of post and board products are directly a

Figure 5.4.2 Shrinkage Caused by Rapid Cooling

result of the processing technology described. A significantly better technology for fabricating these products utilizes the same basic processing except that the open pipe-type mold has a false end that is hydraulically forced against the molten extrudate to minimize cavitation and shrinkage. Thus, the mold is filled under pressure. As illustrated in Figure 5.4.3, this results in significantly less void formation and less shrinkage during cooling.



Schematic Drawing of Non-Vented Recycled Plastics Extruder (a) Without and (b) With Hydraulic Piston in Mold Cavity

Figure 5.4.3 Device Minimizing Cavitation & Shrinkage

The following presents a general methodology followed closely by various processors of commingled plastics:

1. Course sorting.

   The extraction of ferrous and non-ferrous metals, an optional process, might be performed.

2. Granulation/Pulverization.

   Plastics are ground into particles of 1/4" or less in size.

3. Secondary sorting.

   A second operation of metal extraction might be performed.

4. Air Classification

   The grind is blown in an air separator to remove dirt and paper.

5. Blending .

   The grind is blended for optimum mixture of polymers

6. Compounding.

   Heat and extrusion.

7. Molding.

   Compression or extrusion molding. In the molding/extrusion process, the temperature range is adjusted to allow the polyolefins and vinyls to flow and behave as a binder for the higher temperature polyesters and thermosets become fillers along with any other contaminates.

5.4.2 History and Patent Review

The recovery systems of monoplastic waste are relatively mature compared with those of commingled plastics. Due to the difficulty and high cost in separating mixed plastics, engineers, especially in Europe and Japan, started to develop viable technologies for recycling commingled plastics waste without separation in Mid-70s'. The major efforts undertaken have been to overcome two principal barriers in recycling commingled plastics: the incompatibility and degradation of various plastics.

There have been many patents associated with plastics recycling filed since mid-70's. Figure 5.4.4 is a profile for the patents filed worldwide (20). In the early 80's, a few technologies for

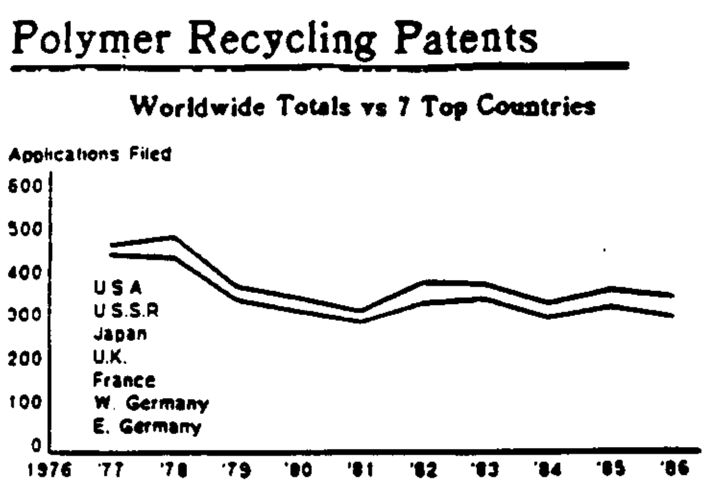


Figure 5.4.4 Patents Profile in Recycling Plastics

recycling commingled plastics were experimented with in Europe and Japan. Thereafter, recycling plants started to operate in Europe as well as in Japan. Beginning mid-80's, some of these technologies started in USA, mainly in the Northeastern states , such as New Jersey, Michigan, Massachusetts, and Iowa. Currently, the equipment and even the training for operation are available in US markets through agents of foreign companies as well as a few domestic recyclers. Information about these technologies may be found in Appendix A.2 and A.3. Copies of selected patents are located in Appendix A.4.

In order to present an overview of the technologies for recycling commingled plastics, several patents and some of the most successful systems are briefly reviewed here.

I. <u>US patent, 3,852,046, Dec. 3, 1974.</u>

This patent was invented by H. J. Brown, Long Beach, California. In the process, waste plastics comprising a mixture of two or more thermoplastic materials are treated by grinding the products to form a particulate thermoplastic mixture, washing the particulate mixture to remove non-plastic materials, placing the mixture in a mold or shaped vessel, and heating the mixture to a temperature above the softening point of the lower melting thermoplastic and below the temperature of the softening point of the highest melting thermoplastic of the mixture.

In another version, particulate thermoplastic is used as a filler for asphalt compositions. In a further embodiment, waste thermoplastics are mixed with combustible cellulosic materials and formed into large cross section pieces in which the thermoplastic mixture has been treated to remove halogen containing thermoplastics such as polyvinyl chloride.

II. US patent, 3,857,799, Dec. 31, 1974

This patent was invented by S. Ooba and S. Hirayama, Japan. It was assigned to Fuji Photo Film Co., Ltd., Japan. The process was designed to regenerate waste plastics by mixing these with an ether-type polyester and at least one member selected from the group consisting of a homopolymer of vinyl acetate, an ethylenevinyl acetate copolymer or a tacky polyolefin; and if necessary a foaming agent, and then molding the mixture into a desired shape.

A number of manufacturers have developed commercial recycling processes based on using mixed plastics waste. The Reverzer, a molding machine designed by Mitsubishi, Petrochemical, processes mixed plastics waste to produce end products such as building panels, cable drums, and U-shaped drains for roads.(17)

Another example is the Advanced Recycling Technology (ART), Brakel, Belgium, which entered plastics recycling in mid-70's. ART has developed a new, original and patented process for the direct recycling of mixed plastics waste into useful products. This process is based on the ET/1 extrusion/molding machine. ART has more than 12 plants in Europe and 3 in USA.

Two other companies, which have succeeded in recycling commingled plastics, are Plastic Recycling, Inc.(PRI), Iowa Falls, Iowa and Recycloplast Technology (RT) in Germany. The PRI technology was developed based on an earlier Netherlands extrusion system (5) and patented in 1986. The RT technology was invented in Germany but patented in US in 1980.

The last three technologies reviewed above are among the most successful ones and have already entered both world and U.S. markets. The principals of these technologies are believed very similar and are designed to overcome the two barriers of incompatibility and degradation of plastics in recycling. The products themselves, made by using these technologies, are currently being marketed in the United States.

5.5 Technologies Utilizing a Portion of Commingled Plastics as Feedstock

5.5.1 The ET-1 Technology

History The Extrusion Technology 1, (ET-1), is a product of Advanced Recycling Technology (ART) (Industrielaan 4, 9660 Brakel, Belgium). ART has 12 plants in Europe. Three ET-1 systems have been installed in the USA. These are:

-Summit Steel's Processed Plastic Division In Michigan.

-Center for Plastics Recycling Research, Rutgers University, Piscataway, New Jersey.

-New England Container Recovery, Inc., North Billerica, Mass.(5).

The ET-1 system can blend a wide range of plastic resins, including polyvinyl chloride (PVC), polyethylene terepthalate (PET) and polystyrene (PS), to make stable molded products, known as SYNTAL, while also tolerating up to 40% contamination (by paper, wood, textiles, grit, metals, etc.) commonly found in plastics wastes (29). The products made by the ET-1 machine are discussed in Chapter 6.0.

<u>Process System (11)</u> The ET-1 system consists of a self contained automatic processing machine, the ET-1, and associated mixing hoppers and finished product handling equipment. Among them are four main components:

-Extruder

-Molding unit

-Part extractor

-Control panel

The extruder is designed to process an unseparated contaminated mixture of thermoplastic materials, including heavily contaminated waste. The extruder uses a short, adiabatic screw rotating at high speed to melt the mixed plastic feed by friction. Unlike standard extruders, it uses no outside heat source which would degrade the materials' physical properties. The melt time and residence distance (short length and diameter screw) is kept to a minimum to avoid the degradation of sensitive resins. Melt temperature of 350-390 degrees F may be regulated by a cooling fan, water circulation lines, screw rotation speed adjustment, or adjustment to the gap between the extrusion screw and barrel. The unmelted waste will act as fillers in the products.

The molding unit comprises linear molds mounted on a turret, which rotates through a water tank to cool each molded part. The molds may be interchanged to meet specific production requirements. Custom molds can be built using standard seamless steel shapes.

The extraction unit is designed to eject molded parts out of the mold as the part cools down and to discharge the part to an open shelf for removal and to a rack for further cooling. The ET-1 system requires a 140 PSI compressor and a 100-gallon tank. The rack is made of continuous angle iron to prevent warping or deformation.

The Control Panel contains:

-heater band temperature controllers

-on/off switch

-timers

-pressure gauges

-RPM setter and monitor

-amp draw monitor

A photograph of the ET-1 machine may be found in Appendix A.3

Processing Procedures

The process for manufacturing Syntal products is illustrated in Figure 5.5.1 (29).

ADVANCED RECYCLING TECHNOLOGY'S
ET-1 PROCESS

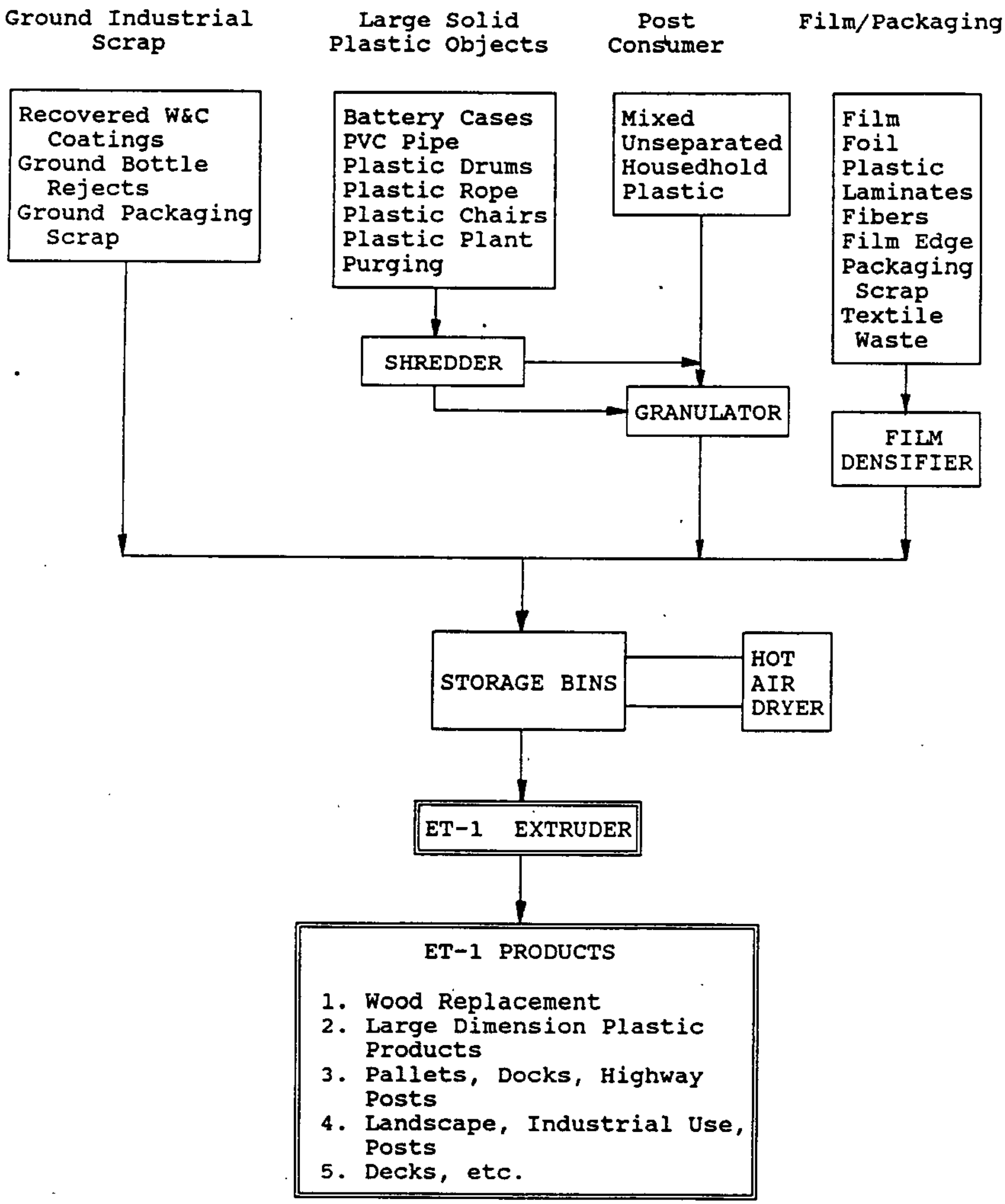


Figure 5.5.1 ET-1 Process

A typical production run involves following steps:

1. Raw materials are fed with a recipe of 60% polyolefin (about half film and half rigid items such as bottles or parts of bottles) and 40% other material in a mixture roughly equivalent to the proportions of other materials in the waste stream.
2. Waste is shredded.
3. The mix may be pre-washed if highly contaminated.
4. The light fraction (film) is automatically densified in the shredding phase to produce a feedstock of 8 mm mesh.
5. The material is fed to a vertical auger hopper which functions both as a mixer and storage silo. Here the material is dried and homogenized, additives are introduced, and the hopper is rotated continually to prevent clumping.
6. The material is then discharged from the mixer into an intermediate hopper, passed over a magnetic metal separator, and carried to the extruder.
7. In the extruder, a hydraulically-driven high speed adiabatic screw heats the mix by friction to 200°C-300°C and then feeds the melt through a compression zone into the molds.
8. 10-12 molds , mounted on a horizontally rotating turret, are successively presented for filling. While one mold is being filled, the one filled just before that is concurrently stabilizing. The 7-9 previously filled

molds are cooling in a water bath, and one finished product is being ejected from the last mold.

9. Products are then stored flat in a rack for 8-10 hours while the centers cool.

<u>Cost and Operation</u>

The price for a complete unit, excluding preparation equipment, is estimated from $200,000 to $250,000. The annual output of a single unit averages 500 tons. The system can be operated by one employee (29). The whole system, including preparation equipment (grinder, shredder, densifier, blenders, and conveyors) can cost from $375,000 to $450,000 and has an output of 200 to 400 lbs. per hour.

The ET-1 technology has been modified into a new recycler, known as the ET-2, with greater capacity and the ability to produce bigger and heavier parts. The average output of this machine exceeds 700 lbs. per hour. The discharge system has been modified with a mechanical arm which pushes the heavy profile to free the part in the mold and a puller to extract the part completely out of the mold. Profiles produced on the ET-2 can weigh up to 130 lbs. or more. Research and development is underway to design a molding machine capable of producing shaped parts. Known as the MT-1, this machine is able to produce a range of configurations from simple plate shapes to more complicated forms.

5.5.2 PRI Technology

History

Plastic Recycling, Inc. (also known as Polymer Products), Iowa Falls, Iowa, patented its technology for recycling commingled plastics in 1986. The technology was based on an earlier Netherlands extrusion system (5). The company was formed in 1984 (7) and spent almost 3 years in designing and building a production facility to recycle commingled plastic waste into commercially viable products. In 1987, PRI started processing mixed plastics and manufacturing products from mixed plastics. In March 1989, the PRI was changed to Hammer's Plastic Recycling Corp.. Besides the patented system, Hammer's also developed and patented several specialized molding techniques. Hammer's is currently recycling commingled plastic waste at an annual rate of excess of 4,000,000 pounds. Its products include car stops, park benches, speed bumps, boat docks & pilings, landscape stakes, pallet and various industrial custom moldings.

Manufacturing Process

Unlike the ET-1 machine, the details of the PRI's technology are proprietary. It is believed that the system can accommodate a wide range of mixed plastics, with varying degrees of contamination. The basic principal is similar to the ET-1 in that batches of 60% polyolefins allow other pre-shredded materials to be carried as fillers in the end products (5).

5.5.3 Recycloplast Technology

History

Recycloplast Technology, invented in Germany by Mr. Erich Weichenrieder, was patented in the U.S. in 1980. The first pilot plant opened in Neukolbing, West Germany, in 1984, and three industrial-scale plants are now in operation in West Germany. A few plants are being negotiated in the U.S. under proprietary auspices.

Manufacturing Process

Like the ET-1 and PRI technology, Recycloplast uses a mixture of mixed plastics resins and tolerates other materials present in MSW plastic. Filler materials such as rubber, paper or wood chips, natural or synthetic fibers, sand, quartz, clay, glass, metal, or metal oxides, may be added to the plastic to meet the specific product requirements (5). The production process involves the following basic steps (5):

1. Feedstock is manually loaded into a hopper, then conveyed via metal separation to a grinder.
2. Finely-shredded material is pneumatically conveyed to one of 6 silos; further metal separation occurs en route. Three of the silos are for storage of mixed post-consumer plastics, one for industrial scrap, one for coloring, and one for granulate, preheated and shredded plastic.
3. Computer-controlled dosing units discharge materials from

various silos into the plastificator according to "recipe";

4. In the plastificator, the mixed material is slowly melted by friction heat. The mixture is kneaded; impurities are embedded in the form of small particles.
5. The melt temperatures are controlled by computer to minimize plastic degradation.
6. Coloring agents, fire retardants, and other fillers may be introduced into the plastificator, according to desired product strength and surface appearance.
7. An automatically-adjusted scraper removes the melted paste from the plastificator and presses it, via a heated extrusion die, into pre-measured, roll-shaped loaves.
8. The roll-shaped loaves are conveyed to a sequence of molds mounted in large 300-1,500 ton hydraulic presses.
9. The products are stabilized by water-cooling molds on a pre -programmed cycle down to 40°C and then rejected onto a conveyor belt to be transferred to storage.
10. As an alternative, the hot Replast paste may be transferred to a granulator and made into pellets for later use.
11. Pollution control devices throughout the plant capture dust and particulates and draw off emissions through a gas scrubber system. Cooling water is recycled within the operation.

Cost and Operation

The Recycloplast system is fully automated and computerized except the manual loading of feedstock. The operation requires 3 - 4 employees. The plant size should be about 20,000 square feet. The plant and installation cost varies from $5 million to $6 million. Based on three shifts, its annual production can be 5,000 tons.

5.5.4 Redmar Investors, Inc.

History

Redmar Investors, Inc. developed a process in which commingled plastics, wood waste, and other biomass may be combined to produce products which are building material related. The process was developed to produce a synthetic fuel in the form of "fire logs"and these are currently sold under the trade name of "Hearthbrite Firelogs". This same basic process is also used to manufacture landscape timbers, currently sold under the trade name of "Tuff Timbers". These products are described in Chapter 6.

The company became public in 1986 and was a New Jersey corporation which owned 100% of the issued stock of Windsor Synfuel Corp. and Filpat Manufacturing Company, Inc. in 1985. Windsor and Filpat were granted exclusive license to manufacture synthetic fireplace logs and building materials using the Redmar technology.
The manufacturing process for this system is considered proprietary information. The patent has been requested and will be reviewed.

Cost and Operation

The information concerning costs is also considered proprietary.

5.5.5 Co-Extrusion

Co-Extrusion is a process whereby two sets of different materials are extruded simultaneously to form a section consisting of layers. This process is common in the plastics producing industry for products such as sheets, panels and films which require the different properties represented by the two or more layers to allow the product to function properly. At the present time, commingled plastics waste are not being co-extruded but some manufacturers and brokers of process equipment believe this may hold some possibilities. One company which successfully markets a PET recycling system known as the Instamelt (see product literature in Appendix A.2) offers the following description of a potential scenario for this process.

Commingled plastics would be accepted at the plant in the form of regrind with mixed wastes present. A water wash working on the principle of separating the plastics by densities would be employed after the ferrous and non-ferrous metals, glass, and paper are removed. Commingled plastics will contain a small percent of polyvinyl chloride (PVC) and polyvinyl dichloride (PDVC) as well as several per cent polyethylene terepthalate (PET). These materials have a high density and will sink for removal in the lower section of the water wash . An auger or mechanical elevator could be employed to remove them from the bottom of the tank while the floaters ar easily removed from the top of the tank. The floaters consist of olefins (low density polyethylene, high density polyethylene, polypropylene, foam polystyrene, and foam plastics of all types). Since the foam lowers the density substantially, it is removed with the floaters. A pneumatic separation can be made to remove most of the foam material due to the extreme low densities.

Once the plastics have been hot water washed and centrifuged (centrifuging usually removes the surface water and renders the plastics dry enough for extrusion), the sinking materials could be utilized for extrusion into core products and the floaters co-extruded simultaneously onto the surface. The floaters , consisting of the olefin materials with additions of pigments and UV stabilizers, would give the product's surface the appearance of a prime colored material which the co-extrusion adds to the strength by making a sandwiched configuration as opposed to a mono-layer. This company believes that as in laminated wood and plywood, the layered material would be much stronger than the single material due to stress fractures being retarded by the interface bound to another substrate.

This company is currently developing a product consisting of a co-extruded stake developed for the agricultural industry. The co-extrusion consists of a core of ground up auto batteries and an outer layer of virgin polypropylene with carbon black added. The cost of these stakes, used primarily in vineyards, was reported to be 50% less than that of wooden stakes imported from Brazil and used extensively in this application. Various round profiles with hollow centers such as a typical pipe section have also been produced utilizing this technology.

The following is a patent review of a process which the inventor believes could be modified for co-extrusion of profiles with a commingled plastics inner core.

US patent, 4,249,875, Feb. 10, 1981, A Co-extrusion Apparatus and Method for Producing Multiple-layered Thermoplastic Pipe, was developed by Edward Hart and Raleigh N. Rutledge, both of big Spring, Texas. The patent was assigned to Cosden Technology, Inc., Dallas, Texas. The process comprises extruding a cylindrical stream of thermoplastic material, converting the cylindrical stream to an annular stream, applying at least one inner annular layer of thermoplastic to the inner surface of the annular stream, applying at least one outer annular layer of thermoplastic material to the annular stream, and extruding the resultant multiple-layered annular stream. Apparatus for producing this pipe includes a modular pipe die having inside and outside laydown means, flow equalizing means within each of the inner and outer laydown means to obviate layer imperfections, and adjustable means to control the concentricity of the outer layers. the invention finds particular application in the production of a thermoplastic pipe having an intermediate expanded core.

In summary, the technologies for recycling commingled plastics waste have been developed and are available for the recycling industry. More and more recyclers see the opportunities of recycling commingled plastics. However, it still remains a question whether the recycling of commingled plastics is economically feasible, and if not, how it might become feasible. Research and development continues to improve the various systems and it is expected that production rates will improve and the consistency of the products will increase. A more difficult question rests in the problem of creating steady, viable markets, once the products have been produced, and whether or not the security of a constant feedstock supply can be determined.

6.0 COMMINGLED PLASTICS PRODUCT EVALUATION

6.1 Introduction

The development of the processing of commingled post-consumer plastics waste was initiated in Europe. Posts, panels, and lumber profile type products have been made and sold with product properties being established as required. European technology is reported to be advanced from that of U.S. technology. West Germany, Japan, and Italy have technologies which reportedly are able to produce extruded or molded thin profile sheets and as well as panels and assorted molded shapes from commingled plastics waste. The study of European technologies was not within the scope of this report, however a few will be mentioned to illustrate the potential for gaining valuable information from a thorough study of these technologies.

1. AKW\Horstmann, Coburg, FRG.(6)

This recycling enterprise is sited next to a landfill and powered by the landfill methane recovery system. A polyolefin separation plant is also located here. From recovered post consumer plastics waste, around 65% of the polyolefin fraction is recovered and re-pelletized. The pellets are suitable for injection molding, extrusion, or thermoforming. Products currently made from this system include bottles, conduit covers, and pipe profiles.

2. Stadtereinigung Nord, Flensburg, FRG.(6)

This recycling enterprise combines collection, sorting, co-location with the landfill and composting plant, and the ET-1 System to produce standard lumber profiles from commingled plastics waste. Products currently sold are picnic table kits, compost bins, fencing, and marshland staging. A system for building sound attenuation walls for German expressways has been developed using panels and posts made from recycled commingled plastics waste.

3. Sorema Company, Como, Italy.(6)

This firm has over 140 installations of plastics recycling plants established world-wide with production capacities ranging form 100 to 2000 kg per hour. Predominant sources of feedstock include agricultural film or industrial wastes. Around 12 plants process post consumer plastics waste. Products produced from this technology include mulch film, electrical conduit, pipe profiles including irrigation pipe, and various flat extrusion sheeting.

4. Remaplan, Munich, West Germany.(6)

Using the Recycloplast technology, post consumer plastics waste are processed into products such as pallets, compost bins, cable reels, knock-down gaylords, temporary road surfacing tiles, grates, and gutters.

USA recycling companies are attempting to produce similar products but have not made the in-roads into markets with current products nor developed, in final form, the broad variety of end-products as may be found in Germany and Italy. Products currently produced in the United States from commingled plastics are used as substitutes for wood lumber, concrete, and metal and consist of large cross section profiles.

6.2 General Description of Products

The basic products from commingled plastics waste may be classified into two groups by their usages. The first group consists of the products which can be used in direct applications known as end products. The second group consists of products, granular in form, re-claimed from mixed plastics waste. This re-grind could be used for fillers in some materials such as concrete block and sandwich board. However, most of products being produced now in the USA are directly for end use. Those products are currently limited to posts, boards, poles, and lumber-like products limited to large cross sections. The basic products made by using various technologies are actually very similar except for their shapes. The product is generally formed from thermoplastics with contaminates included inside. The cross-section of commingled products may be square, round, rectangular, oval, triangular, "T" shaped or irregular depending on the applications for the finished products.

Products manufactured from commingled plastics waste, based on results from various tests or experiments, have the following general characteristics (3):

Positive Characteristics

- Durability (Lifespan is reported to be 400 -600 years)
- Corrosion resistance
- Toughness (elasticity)
- Moldability
- Better abrasion resistance than competitive products
- Workability to permit cutting as easily a wood
- Lighter weight than concrete, leading to easier installation in certain applications
- Physical properties which can be improved with the use of fillers or additives , if required
- Rot proof and termite\insect proof
- Splinter free
- Resistance to salt water and animal urine

Since there is no requirement of preservatives such as creosote, pressure treatment fluids, fungicides, insecticides, oils, and metal-based toxins, these products will not leach harmful substances into the soil. Use of these products mitigates landfill containment. Each post of a dimension of 6'6" by 4" is comprised of around thirty one gallon plastic containers, saves three cubic feet of landfill space and leaves one tree growing.(23)

Negative characteristics

- More expensive (sometimes up to 4-8 times the cost of treated wood)

- Restrictions of use imposed by building code requirements
- Larger thermal expansion than wood
- Poor performance in bending resulting from loading
- Poor heat resistance. Fire will cause them to melt and flame up if no flame retardants are incorporated.

Even though limited by their negative characteristics, the products still have broad applications in various fields. Table 6.2.1 lists the common applications.

6.3 Potential Uses for Building Products from Commingled Plastics Feedstock

The Building Construction Industry has provided a large market for plastics product applications for some time. Of all major plastics uses, building construction applications fall into the second largest category of use. Table 6.3.1 provides an overview of major categories of use for plastics products.

AGRICULTURE	LANDSCAPE/RECREATIONAL
Barrier Retainers	Flower Pots
Duck Boards	Flower and Tree Boxes
Electrical Fences	Golf Course Walk Ways
Erosion Control Timbers	Park Benches
Fruit Tree Supports	Picnic Tables
Gates	Playground Equipment
Horse Stalls	Sand Box Kits
Markers	Stadium Seating
Pig and Calf Pens	Storage Bins
Poultry Cage Construction	Trash Bins
Ranch Fences	Tree Guards
Stakes	

AGRICULTURE
- Barrier Retainers
- Duck Boards
- Electrical Fences
- Erosion Control Timbers
- Fruit Tree Supports
- Gates
- Horse Stalls
- Markers
- Pig and Calf Pens
- Poultry Cage Construction
- Ranch Fences
- Stakes

MARINE ENGINEERING
- Beach Erosion Control
- Board Walks
- Coast Erosion Protectors
- Dock Side Fenders
- Boat Docks
- Fishing Boat Wear Plates
- Lobster Traps
- Pier Impact Protectors
- Rub Rails
- Sea Walls
- Trawler Net Rollers

CIVIL ENGINEERING
- Barriers
- Bearing Pads
- Fences
- Road Delineators
- Traffic Direction Posts

LANDSCAPE/RECREATIONAL
- Flower Pots
- Flower and Tree Boxes
- Golf Course Walk Ways
- Park Benches
- Picnic Tables
- Playground Equipment
- Sand Box Kits
- Stadium Seating
- Storage Bins
- Trash Bins
- Tree Guards

CONSTRUCTION
- Car Stops
- Fencing
- Flooring Tiles
- Footings and Sill Plates
- Temporary Highway Surfacing
- Loading Dock Rails
- No-load Grating
- Markers
- Pallets
- Pipe Racks
- Planks
- Sign Posts
- Slab Separators
- Stair Treads
- Traffic Barriers\Bollards
- Truck Flooring
- Wire Racks

GARDENING
- Compost Enclosures
- Fences, Gates
- Retainer Wall
- Garden Boundary
- Landscaping Timbers

Table 6.2.1 General Applications of Commingled Plastics Products

	1986	1987
Packaging	12,480	13,620
Building Construction	9,936	10,647
Transportation	1,912	1,876
Appliances	985	1,080
Electrical/Electronic	1,806	1,954
Furniture	915	961
Toys	664	701
Housewares	1,212	1,270
TOTAL	29,868	32,100

Table 6.3.1 Major Plastics Uses (millions of pounds)

**Source: Modern Plastics, January, 1988

Increasing use of plastics applications in building construction is evident from the above table. The potential for materials substitutions of recycled plastics materials is high for an industry which is already quite dependent upon the use of plastics to produce cost effective projects.

As shown below in Table 6.3.2, the products made from commingled plastics waste have the potential to be developed for wide application in the construction industry. Particularly, the following products have been identified as having the potential of utilizing a large amount of commingled plastics waste in construction as substitutes for applications which presently use more traditional materials(3):

1. Treated Lumber
2. Landscape Timber
3. Horse Fencing/stable
4. Farm Pens
5. Roadside Posts
6. Pallets

Table 6.3.2 Six Potential Applications for Commingled Recycled Plastics Products

For each of the above categories, a partial increase in the percentage of these products made from commingled plastics waste would have the effect of reducing the plastics waste stream destined for landfill containment or incineration while promoting public awareness of the existence of these products. Penetration into these established markets is discussed in Chapter 7 of this report.

The following list is indicative of the potential scope of building components which show promise for the ability to be fabricated from recycled plastics. This list is not meant to be inclusive, but to give indication of the types of components which should be studied. Many of the contacted manufacturers claim to be working on a wide variety of construction related products at the present time, but the majority of this information is considered proprietary.

1. Retaining walls/sound attenuation walls
2. Partitions, de-mountable & fixed partitions
3. Pipe profiles, conduit, pipe covers
4. Landscape pavers
5. Window components
6. Geotextiles
7. Roofing tiles
8. Concrete formwork
9. Others

Table 6.3.3 New Applications for Recycled Plastics in Building Construction.

A brief description of each application listed in Table 6.3.3 is provided here.

Retaining Walls/Sound Attenuation Walls

Wall systems for highway applications and erosion control have been reportedly developed in West Germany utilizing posts and panels made from commingled plastics waste. As this technology for producing sheets and thin section panels is developed in the United States or imported from Europe, these applications should be studied for materials substitutions using recycled plastics.

Partitions, De-Mountable and Fixed, Including Toilet Partitions

Partitions of all types used in interior applications could be made with a commingled plastics core for desired profile thickness with an outer layer of virgin resin for uniform color. The technology for producing extruded or compression molded sheets would be necessary for this type of fabrication.

Pipe Profiles, Conduit, Pipe Covers

Co-extrusion technology should be studied for potential use in manufacturing pipe and conduit sections containing a middle layer of commingled plastics sandwiched to two outer layers of a virgin resin. A description of this technology is found in Chapter 5.0.

Landscape Pavers

Technology developed to produce plate like shapes could be employed to produce pavers for outdoor applications in a variety of shapes with the capability of being interlocking.

Window Components. Extruded sections of commingled plastics around which are wrapped virgin resin sections could be used in this application. The potential products in this application include window frames, sashes, stiles and reveals.

Geotextiles

Geotextiles for erosion control, stabilization, retention liners currently are being produced from recycled PET. However, it is possible that they can be made from commingled plastics waste, if technologies are improved to produce extruded sheets.

Roofing Tiles

The research is currently underway at the University of Florida to determine methods of producing roofing tiles from waste phosphate, asphalt, and commingled plastics waste. There is potential for utilizing varying portions of commingled plastics waste in a variety of roofing tile applications.

Concrete Formwork Applications

A system for flatwork forming made from HDPE is already on the market (33). It is designed to save form erection and stripping time and needs no nailing, double staking, or form release agents. Formwork boards come with end connectors and cam locks. Sections can bend in any direction to form outside or inside radii as close as a few inches by the cutting of a series of slits. This product has high potential to be made from commingled plastics waste and could at the present time be made from recycled HDPE with a small degree of contaminate polymers and other material present.

Other Applications

Other applications include grade stakes, cable and wire reels, gutters,leaders, down spouts, splash blocks, manhole covers, flooring additives, composite building panels, guard rail posts, pipeline casing insulators, sandwich panel constructions, hand rail cover profiles, base and cove shapes, etc.

Current existing building products produced from commingled plastics waste comprise a larger list than the previous one. In order to provide an overview of commingled plastics products currently produced and available on the market, their manufacturers, and their price ranges, Table 6.3.4 through Table 6.3.7 have been compiled from various recyclers' publications. More details on the products may be found in Appendix A.2 and A.3. Because prices continually vary due to external considerations, the following items are presented without being identified by company. All items and prices reflect the present state of conditions and are subject to change in the future. Therefore, each product price list will be identified by number only.

Company Address:	Products	Comments
Advanced Recycling Technology, Mid-Atlantic Plastics Systems, Inc. Roselle, NJ 07203 TEL (201) 241-9333 Fax (201) 241-3988	Stakes, boards, fences, road signs, playground equip., boatdocking, picnic table.	$0.75/kg or $0.34/lb (in Germany)
Belgium Recycling Company B.V.B.A. Middenweg 15 3590 Hamont-Achel Belgie TEL 011-621738 Fax 011-622025	Park tables and benches, fences, road posts, road signs	
Hammer's Plastic Recycling Corp. RR3 Box 182 Iowa Falls, IA 50126 TEL (515) 648-5073 Fax (515) 648-5074	Car stops, park benches, speed bumps, boat docks & pilings, landscape timbers, playground equipment, pallets, sign posts, stakes, bollards, pipe rack.	
Hearthbrite Industries, 12 Windsor Industrial Pk. P.O. Box 36 Windsor, NJ 08561 TEL. (609) 448-1500	"Tuff Timbers" steps, retaining walls landscape borders bulkheading various post applications	

Table 6.3.4 Commercial Recyclers

Company Address:	Products	Comments
Processed Plastics Company P. O. Box 68 Ionia, Michigan 48846 TEL (616) 527-6677	Benches, pallets, blocking, markers, docks & dock bumpers, picnic tables, seawalls, landscape timbers, boardwalks, fence & fence posts.	
Post Plastics, Inc. P. O. Box 333 Mulberry, FL 33860 TEL (813) 425-4058	Round posts, timbers, parking lot wheel stops.	
Restoration Plastics 35 Pearlstreet Malone NY 12953 TEL (518) 483-7867	Round posts, square posts, flat board, dock board.	
Superwood International Ltd., Corke Abbey, Bray, County Wicklow, Ireland TEL 353-1-823835 Fax 353-1-823835	Stakes, slatted floors, fences, gates, street & road furniture, delineators, markers, bollards, pallets, underground cable covers, coastal & river bank protection units.	Net profit in 1988: £605,000; 1987: £347,000.
The Plastic Lumber Co., Inc. P. O. Box 80075 Akron, OH 44308 TEL (216) 434-8989 Fax (216) 434-7905	Parking stops, speed bumps, curb edgings.	
Riverhead Milling, Inc. 6801 State Rd, Bldg. B Philadelphia, PA 19135 (215)-333-6616	Lumber and pieces for table kits	

Table 6.3.4 Commercial Recyclers (continued)

Commingled Plastics Products Currently Produced by Recyclers

ITEM	SPECIFICATION	PRICE (EACH) 1-9	10-25	26-50
PARK BENCHES (unassembled)	6'	$220.00	$210.00	$200.00
	4'	175.00	165.00	155.00
HI-BACK BENCHES (unassembled)	6'	$175.00	$165.00	$155.00
	4'	160.00	150.00	140.00
CAR-STOPS	6"x4.5"x6'			
	Blue	$ 34.00	$ 32.00	$ 30.00
	Gray or Yellow	30.00	28.00	26.00
	Brown or Black	28.00	26.00	24.00
SPEED BUMPS (Sleeping Policeman)		$ 99.00	$ 89.00	$ 79.00
BOLLARDS	6"x6"x33"	$ 60.00	$ 50.00	$ 40.00
MINI CAR-STOPS	3.4"x2.5"x18"	$ 10.00	$ 8.00	$ 7.00
LANDSCAPE TIMBERS (black only)	6"x8"x8'	$ 58.00	$ 55.00	$ 53.00
	6"x6"x8'	$ 48.00	$ 45.00	$ 43.00
	4"x4"x12'	$ 44.00	$ 40.00	$ 36.00
STOKBORD	4'x8'x0.5"	$ 76.00	$ 74.00	$ 72.00

Table 6.3.5 Price List for Products Made by Company A

ITEM	SPECIFICATIONS	PRICES	WEIGHT
UPRIGHT BENCHES	3'	$ 120.00	
(heavy duty)	4'	$ 180.00	
UPRIGHT BENCHES (extra heavy duty)			
	4'	$ 145.00	
	8'	$ 215.00	
FLAT BENCHES	3'	$ 78.00	
	6'	$ 132.00	
PICNIC TABLE	6'	$ 385.00	
CAR STOP	6'	$ 31.00	41.0 lb
ROUND POST	1.5"x6'	$ 2.20	4.0 lb
	2"x6'	$ 3.30	6.0 lb
	2-3/8"x6'	$ 5.50	8.0 lb
	2-3/8"x11'	$ 10.50	19.0 lb
	5"x8'	$ 39.60	66.0 lb
LUMBERS	1.5"x1.5"x8'	$ 3.65	7.0 lb
	2-3/4"x2-3/4"x8'	$ 13.10	25.0 lb
	3-1/4"x3-3/4"x8'	$ 16.30	32.0 lb
	3-3/8"x3-3/8"x8'	$ 17.20	33.5 lb
	4"x4"x6'	$ 20.25	39.0 lb
	4"x4"x8'	$ 27.50	52.0 lb
	4"x4"x12'	$ 54.00	78.0 lb
	2"x4"x8'	$ 13.25	25.0 lb
	2"x4"x10'	$ 16.80	30.0 lb
	2"x4"x12'	$ 19.90	35.0 lb
	2"x6"x8'	$ 22.00	40.0 lb
SHEETS	1"X3'X5'	$ 45.50	70.0 lb
	1-1/2"x2'x8'	$ 83.00	112.5 lb
	1-1/2"x4'x8'	$ 163.25	225.0 lb
	2"x4'x8'	$ 187.50	250.0 lb

Table 6.3.6 Price List for Products Made by Company B

ITEM	SPECIFICATION	PRICE	WEIGHT
ROUND POST	2-3/4"x78"	$ 2.50	10.0 lb
	3-1/4"x78"	$ 5.00	20.0 lb
	4"x78"	$ 6.25	25.0 lb
	5-1/2"x8'	$ 20.00	80.0 lb
TIMBERS	3-1/2"x7-1/2"x8'	$ 25.00	100.0 lb
	5-1/2"x7-1/2"x78"	$ 25.00	100.0 lb
PARKING STOP	6-1/2"x5"x5'10"		
	yellow, white	$ 15.50	50.0 lb
	black	$ 13.50	50.0 lb
	6-1/2"x4-1/2"x5'10"		
	yellow, white	$ 12.25	37.0 lb
	black	$ 10.25	37.0 lb

Table 6.3.6 Price List for Products Made by Company C

ITEM	SPECIFICATION	PRICE	WEIGHT
ROUND POST	2"x4'	$ 1.85	4.1 lb
	2"x6'	$ 2.78	6.2 lb
	3"x4'	$ 4.19	9.3 lb
	4"x4'	$ 7.43	16.5 lb
	4"x6'	$ 11.15	24.8 lb
LUMBER	2"x2"x4'	$ 2.39	5.3 lb
	3"x3"x4'	$ 5.35	11.9 lb
	3"x4"x4'	$ 7.11	15.8 lb
	4"x4"x4'	$ 9.49	21.1 lb
	4.25"x4.2"x4'	$ 10.71	23.8 lb
BOARD	6"x1"x8'	$ 7.09	15.8 lb
	6"x1.5"x8'	$ 10.69	23.8 lb
	6"x2"x8'	$ 14.22	31.6 lb

Table 6.3.7 Price List for Products Made by Company D

The following table illustrates a cost comparison of plastic lumber profiles with treated wood. The calculation results show that plastic lumber price is about 3 times of that of wood in term of price per lb and 8 times of that of wood in term of price per 1000 board feet.

Type of lumber: Southern yellow pine, #2
Pressure treatment: 0.40 C.C.A
Density after treatment: 36.4 lb/ft.^{3}

Nominal size:	2"x4"x8'	2"x4"x10'	2"x4"x16'	4"x4"x8'
Wholesale price: $/1000 board ft	$360.00	$360.00	$425.00	$360.00
No. of board ft: (nominal)	5.33	6.67	10.67	10.67
Cost ($/piece):	1.92	2.40	4.53	3.84
Volume (ft^3/piece):	0.292	0.365	0.584	0.681
Weight (lbs/piece):	10.63	13.29	21.25	24.79
Cost ($/lb):	$0.181	$0.181	$0.213	$0.155

Table 6.3.8 Lumber Price Calculation (12)

Plastic Lumber (data from Table 6.3.6)

Nominal size:	2"x4"x8'	2"x4"x10'	4"x4"x8'
Cost/piece:	$ 13.25	$ 16.80	$ 27.50
Board ft/piece:	5.33	6.67	10.67
Weight/piece(lbs):	25.00	30.00	52.00
Cost/1000 board ft:	$2486.00	$2518.00	$ 2577.00
Cost/lb:	$ 0.53	$ 0.56	$ 0.53

Table 6.3.9 Plastic Lumber Price Calculation

6.4 Progress in Testing of Commingled Plastic Products

Testing of commingled plastics products plays an important role in developing products, determining product properties, improving product qualities, and the setting of product specifications. Various tests on commingled plastics product have been conducted in the USA by a few research institutes in order to investigate mechanical properties for comparison with wood lumber, or to identify new applications.

At the Center for Plastics Recycling Research (CPRR), Rutgers University, mechanical tests of commingled plastics products were performed to obtain the product's specific gravity, compressive modulus, yield stress, and compressive strength (30). The feedstock for the tested products was obtained from either the post-consumer plastics waste stream or a mixture of plastics prepared to emulate

Sample Group #	Sample Designation	Material Composition	Specific Gravity	Compressive Modulus(psi)	Yield Stress (2% offset)	Compressive Strength (@ 10%)
A	005	100 % New Jersey Curbside Tailings (NJCT)	.994	89500	2578	3049
	006	Same as 005	.925	88900	2704	3159
	009	Same as 005	.919	90000	2729	3207
	020	Same as 005	.937	90000	2818	3253
B	007	60% HDPE Milk Bottl 15% Detergent Bottles 15% NJCT 10% LDPE Pellets	.883	114800	3256	3921
	008	Same as 007	.891	109700	3219	3800
	010	60% HDPE Milk Bottl 15% Detergent Bottles 12% N.J. Curbside Tailings 10% LDPE Pellets 3% Base Cups(for color)	.887	114400	3269	3920
	011	Same as 010	.903	107600	3247	3884
C	EPS Fines	50% HDPE Milk Bottl 50% Desified Expanded PS	.806	164000	4100	4120

Table 6.4.1 Test Results on Commingled Plastic Posts (30)

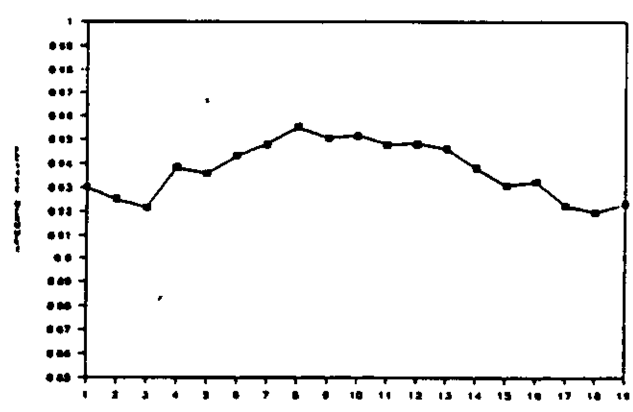


FIGURE 6.4.1

that of the post consumer waste stream. (see table 6.4.1). The product profile for the testing was chosen to be 2.5 inches square in cross-section and 95 inches in length. The results of the tests are summarized in table 6.4.1 and figure 6.4.1.

Figure 6.4.1 indicates that the specific gravity varied along the bar and was highest at the mid-section. The data in table 6.4.1 indicates that similar feedstock resulted in very closed product properties (sample 005, 006, 009, 020 or 007, 008, 010, 011). The adjusting of the mixture composition may increase the product's properties significantly. Sample group C is superior to group B and group B to group A. It was also found in CPRR's tests that all the products made by the ET/1 machine so far contain varying amount of cavities or voids inside. It was expected that the moisture in the feedstock might be responsible for the occurrence of these defects, which in turn decrease the product's mechanical properties.

In further testing, a sample known as NJCT (New Jersey Curbside Tailings) was formulated as waste feedstock to emulate the composition of typical post consumer plastics waste. The tests determined the compressive modulus to be 90,000 PSI. By adding polystyrene to the samples, it was discovered that the mechanical properties of the commingled product dramatically increased. The modulus was increased by 60% with an addition of only 10% PS. The addition of 20% PS produced an increase of 82% in the compressive modulus.(21)

Bennett (1988) has conducted a series of tests on commingled plastics lumber to better understand and assess its performance compared to wood lumber (3). The tests that were performed included:

- maximum pull-out resistance force of nails and screws in plastic and wood;
- the effects of heat on maximum pull-out resistance force for nails;
- railroad spike pull-out tests;

The data obtained from the tests are displayed in table 6.4.2 through table 6.4.4. The test results show that commingled plastics lumber possesses a higher nail holding strength than wood (table 6.4.2) by about 40% at normal temperature.

However, when heated to 149°F, the nail holding capability of plastic lumber reduced almost 44% from 155 lbs to 88.3 lbs while that of wood remained unchanged. The screw pull-out tests indicate that commingled plastics lumber has less screw holding strength than wood lumber. Although in the railway spike pull-out the commingled plastics timber turned out to have much lower holding capability compared to the creosoted timber presently being used for railroad ties, it might be possible to increase the plastic timber's spike pull-out resistance force significantly by designing a new type of spike (3).

Nail Pullout Test	Wood Pullout Force (lbs)	Recycled Plastic Pullout Force(lbs)	% Difference
Perpendicular to Grain(face)	112.33	157.00	41%
Perpendicular to Grain(side)	111.00	155.00	40%
Parallel to Grain	46.00	166.00	261%
Heated Samples 145°F (65°C)	116.00	88.30	-24.0%

** samples used were 2"x4" in dimensions;
** nails driven perpendicular to grain.

Table 6.4.2 Nail Pullout Tests (3)

Screw Pullout Test	Wood Pullout Force (lbs)	Recycled Plastic Force (lbs)	% Difference
Hand Driven #8-2" screws	713	360	-50.5%
Predrilled Holes		407	

Table 6.4.3 Screw Pullout Tests (3)

Materials	1st Time	2nd Time	3rd Time
Azobe	22,000 lbs	17,750 lbs	16,020 lbs
Oak	8,000 lbs	7,410 lbs	6,240 lbs
Recycled	1,253 lbs	1,067 lbs	977 lbs
Comments	Azobe: a wood found in the African tropical forests. ** Each spike set 3 times in same hole		

Table 6.4.4 Railway Spike Pullout Test (3)

The results of tests conducted at different research institutes on products made from commingled plastics waste revealed that the products' strength properties vary from sample to sample due to inconsistency in feedstock and varying degrees of moisture content. The non-uniformity in the properties prevent specifications for these products to be set at the present time. This, in turn limits the applications to non-critical usage. However, with the advances of the technologies on manufacturing commingled plastic products, It is expected that the products will become more consistent in their properties and find more applications in building construction market.

7.0 MARKETING FACTORS OF RECYCLED PLASTIC BUILDING PRODUCTS

7.1 Introduction

Products made from recycled commingled plastics are already on the world and U.S. markets. Some manufacturers in Europe derive their total income from the sale of products made from recycled commingled plastics. A major manufacturer in the United States reports supplying the City of Chicago with replacement lumber for playground equipment at the rate of 10,000 units or 1.5 million pounds in 1989. The extension of the contract is expected to produce 40,000 units or 5 million pounds in total.(24) In addition, many established companies deriving their income from more traditional and established recycling markets dealing primarily with the recycling of discrete resins, are in research and development for the recycling of mixed feedstocks which do not consist of a pure polymer type and may be contaminated with content residue. There are over 40 commingled plastics recycling systems currently installed on a worldwide basis. The annual capacity is approaching 100,000,000 pounds of post consumer plastics waste. By the end of 1990, an additional 30,000,000 pounds will be added to the capacity load on an annual basis.(16)

In determining the market potential of utilizing recycled commingled plastics in building construction applications, many factors must be considered. Market viability of products made from recycled commingled plastics depends upon the following considerations:

1. Cost of end-products compared with those made from traditional materials as affected by production rates and initial capital investment;
2. Consumer awareness of products and product acceptance in the market place;
3. The affect of value-added factors (such as long life span) to product acceptance;
4. The expansion of primary markets and the ability to create secondary markets ;
5. Indirect cost benefits associated with more efficient solid waste management practices;
6. Existence of a recycling infrastructure including the availability of a permanent feedstock.

This section will examine the major contributing factors of obtaining feedstock, transportation of feedstock to processing locations, product acceptance and the role of regulating bodies in promoting or discouraging initial product viability. Also considered will be the necessity for policy consensus by government to enhance the successful utilization of recycled plastics product substitutes for those made of tradition materials as well as the co-operative effort required between government and private enterprise to initiate production and expand primary markets for end-products.

7.2 The Role of Government Policy

Research and development of new products from commingled plastics wastes conducted by the private sector is being driven by the new focus of national attention on the affect of plastics disposal practices upon the quality of the environment and the increasing tax burden required of municipalities to finance waste management practices. As public pressure in the form of bond issue defeats and organized outcry against the siting of landfills and incinerators increases, both government and private enterprise are devoting more attention to studying ways to make recycling more profitable. The role government policy making will play in bringing the plastics recycling industry into economic feasibility will be an important factor in coordinating efforts among private industry,(including producers, brokers, recyclers), and local municipalities.

Government policy can also affect such important considerations as:

1. collection and sorting practices; both on an individual and collective municipality basis, and
2. product acceptance through the utilization of recycled plastics substitutes for more traditional materials in government procurement practices.

These elements, in turn, have the ability to influence:

3. education of the public to increase awareness of the availability of recycled products.

Government policy can also help ensure a permanent and steady supply of feedstock through the organization of co-operative efforts by local recycling programs,private recycling companies, and municipal solid waste management practices.

7.2.1 Economic Incentives and the Role of Marketing

The availability of economic incentives based on providing a climate favorable to business start-up for the recycling industry also lies within the provenance of government policy. When this is accompanied by a set of disincentives (such as represented by the Advanced Disposal Fee) for the use of plastic packaging of low ability to be recycled, the impact upon the market viability of recycled commingled plastic products is significant.

Choices of economic incentives should be studied both for the prioritization of alternatives and to create combinations of incentives to provide a positive framework for recycling business start-up. These might be in the form of direct or indirect tax structures. Direct tax structures could include price supports, grants, subsidies, or low-fee, long-term land leases strategically located for direct acceptance of post consumer waste feedstock. Indirect methods such as tax credits should also be studied. The goal would be to encourage outside capital investment in new technologies which have the potential to mitigate escalating costs of plastics disposal and extend the life of a non-renewable resource, and create new jobs and revenue for the location in which these businesses occur.

At this time, perhaps the most important incentive for creating a viable market climate for recycled commingled plastics products lies within government purchasing policy. This is because the major impediment to the viability of those recycled commingled plastics products now available is a factor of low public awareness. This becomes an advertising and marketing problem. By specifying the use of commingled plastics products in the non-critical use categories and publicizing this practice, public awareness of such products can grow along with the new technological advances and expanding number of applications which will be proffered by private recycling companies in the future. The effort by the City of Chicago and a private producer of recycled commingled plastics end-products (described in the introduction to Chapter 7) is a good example of a cooperative effort to bring the problems of waste disposal, recycling, and end-product awareness and acceptance to the public's attention.

7.2.2 Impact of Consumer Awareness Concerning Negative Aspects of Plastics Disposal Methods

Only a few years ago, the major plastics producers showed no budget for recycling. This coincided with a relatively low consumer awareness of the solid waste management crisis and other issues related to the quality of the environment. However,in 1989, the industry will spent around 40 million dollars on recycling projects. Driven by fears of losing major markets in plastic products due to increasing public reaction against the method in which these products are disposed, many large corporations are creating large advertising budgets to publicize their new recycling pilot programs. While this dollar amount may seem extensive on the surface, the Recycling Coordinator at Exxon Chemical, a company which annually produces two billion pounds of resin per year, reports that if all industry recycling programs are successful, plastics recycling will be increased to only 1%. (32) This indicates that the driving force behind the recycling programs designed by corporate plastics producers and users is more public relations oriented than actual waste disposal problem oriented. Currently, these well-publicized recycling programs, while positive in creating potential new recycling handling systems and greater public awareness, might have a negative impact in lulling the consumer into a feeling of safety in the indiscriminate purchasing of plastics products. Private industry should encourage more participation of all producers and users while increasing programs geared toward making recycling feasible in terms of economic return and greater efficiency of solid waste management practices.

The public's new-found awareness of the state of solid waste management practices in the United States has prompted another significant impact on plastics use and disposal in the form of outright product bans. Growing nsumer fears of the negative aspects of purchasing plastics des ' for immediate disposal (such as virtually all plastics packagin, is the force behind the rapid appearance of these new product ban laws. In certain locations, specific plastics have been actually banned from use and many major markets are in danger of disappearing overnight. An example of this is the disposable diaper business. Nebraska has recently passed a disposable diaper ban and legislation is pending in Oregon and California. Proctor and Gamble, Inc. rep---d 1.6 billion dollars earned in 1988 from the sale of diapers alone, which they have no interest in seeing legislated away.(31) Another example of this occurrence is found in ortland, Oregon where a ban on polystyrene foam in the form of fast food coffee cups and sandwich clamshells is now in place.(31) The Council for Solid Waste Solutions, Washington D.C., reports that six states and 31 localities have adopted such legislation banning the use of polystyrene in fast food packaging. This source also reports that in just two weeks, enough polystyrene packaging is thrown away by McDonald's franchises to fill the twin towers of the World Trade Center. Currently, McDonald's has around 250 million annually on polystyrene packagir .31) Additionally, the auto industry spends $500 million annually on disposal packaging and more to burn it. Therefore, the enormous rates of generation and use associated with certain products seem to be partially to blame for creating adverse public reactions. These examples illustrate the potential negative economic impact which might be created by such product bans upon private industry.

These laws concerning plastics bans and product modification are affecting the nature of the feedstock which might be available to recyclers. In states which have mandated that certain products such as plastic grocery bags or disposable diapers be "bio-degradable", a situation is created in which the feedstock of commingled plastics, as represented by that flowing into the post-consumer solid waste stream, becomes affected by a certain percentage of waste plastics which cannot be recycled and whose destination can only be incineration or landfill containment.

To illustrate the scope of involvement of governmental policy making on the nature of the commingled plastics waste feedstock, consider the following facts. Over 2,000 new laws regulating policy for solid waste management have been passed by legislatures on all levels in the past year. (6) Within this number, plastics are specifically targeted in the form of taxes on packaging and bio-degradability. (6) These restrictions will have the natural outcome of raising the cost of producing plastic products. The costs will be passed onto the consumer. A logical result will be a paradigm shift in the awareness of the consumer in the purchasing of products which come in packages not suitable for recycling as opposed to those which have recycling potential. Plastics producers are concerned with this diminishing consumer confidence in the environmental safety of such purchases.

In Florida, a law requiring an Advanced Deposit Fee will go into effect October 1, 1992. This law requires manufacturers to attach a one cent per container charge on plastic, glass, aluminum and plastic coated paper which cannot be recycled at a 50% rate. If this goal fails to be met by a certain product by the year 1995, a 2 cent deposit on such a product will be required. A recent study commissioned by the Florida Legislature advises retailers to attach a similar fee. (36) This is intended to create in the consumer a greater awareness of the cost of disposal of each item they might buy. Once the consumer begins to accept the responsibility for the cost of disposal, their choices will undoubtedly become more critical concerning non-recyclable items. This law could have an indirect affect of making available a larger amount of recyclable plastics packaging for use as feedstock in recycling processes. Therefore, methods to recycle discrete polymer types as well as mixed polymers should continue to be evaluated and data collected for use in cost analysis studies.

To date, the most stringent "bottle" legislation passed may be found in the State of Maine's "bottle law" approved by referendum in 1976 and reaffirmed in 1979 after voters blocked an industry-backed repeal campaign. This law bans non-returnable containers for beer and soda and requires consumers to pay a deposit for each can or bottle. The deposit becomes refundable upon return of the container by the consumer. Under laws passed in 1989, this will be expanded to include the following:

A. Bringing more than 48 "no deposit" containers into the state will cost an individual $20.00 per container and all liquor bottle shall carry a $ 0.15 charge.

B. All throw-away non-dairy beverage containers shall be banned.

C. By July 1. 1991, plastic six-pack straps will be banned.

These examples, when considered in the light of the number of laws currently on the books concerning solid waste management, as it directly relates to product and packaging, indicate the growing threat to plastics producers as well as the state of emergency of the conditions of landfill containment of all solid waste. Yet, plastics production rates are rising and products made from plastics continue to be critical to the economic viability of entire industries such as food packaging, medical supplies, and the automobile industry. Increasing reliance of society upon plastics creates the necessity of seeking alternative means of disposing or recycling this material.

7.2.3 The Role of a National Policy

Plastics wastes are a portion of the total solid waste stream and as such, their disposal methods are subject to the same pressures which affect the remainder. The Environmental Protection Agency has proposed an agenda consisting of four goals to be used as guidelines for industry and municipalities. In the year 1992, the EPA proposes:

1. The total amount of waste generated should be reduced by 26% through such means as reduced packaging.

2. The overall recycling rate should be increased to 25%.

3. Waste-to Energy plants should increase the percentage fo remaining solid waste from 9% to 20%.

4. Landfills should be reserved to accept that which cannot be burned or recycled.

While these policies are not law, they represent a strong direction in which local, state and federal governments are being pressured to follow. However, the EPA is not vested with the power to ensure the enforcement of these directives and admits that manufacturers have no direct incentive to design products which fit effectively into waste management programs because they are not responsible for the cost of such programs. (32) Because of legislation such as The Advanced Disposal Fee in the State of Florida, this cost is directly passed on to the consumer. This, in turn, will create pressure on manufacturers to utilize methods of production and labelling which will help abate consumer displeasure of shouldering the burden of the cost of disposal.

More importantly, the advent of a variety of product bans, "bottle legislation", and disposal fees independently designed by states and local municipalities will create a need for a national policy which might provide a certain consistent framework for such elements as recycling rates, product composition, product labelling, and preferred disposal practices in order to standardize the constraints which accompany the purchase and disposal of plastics in both durable goods and packaging. This will be necessary to maintain the economic viability of private industry associated with the production and use of plastic resins as they attempt to comply with an overwhelming variety of restrictions and conflicts.

7.2.4 The Role of Regulatory Agencies

Other regulatory bodies will play a role in the efficiency of recycling plastics waste into viable products. Regarding testing and defining standards for use of recycled products, certain standard definitions and controls must be established. An example of an early effort is the March 1990 scheduled publication by the D20 Plastics Recycling Committee of ASTM of a guidance document on the proper use of recycled materials. Central to the information in this effort is a set of consensus definitions of all terminology related to recycling plastics. This consensus represents co-operative efforts among resin producers, processors, manufacturers, and solid waste management officials. The ASTM document will also encompass such considerations as objectives, specifications, specification revisions, use of performance standards, quality assurance, and identification and labelling of plastics, contaminants, fillers, and pigments. Key provisions address revisions to existing standards. The first states that if a standard does not specifically restrict the utilization of recycled plastics, they then might be substituted. The second concerns the justification of a restriction of use. If such a restriction exists, it should be justified according to performance tests or be rescinded. (40) Once the work of establishing standards for grades and types of plastics including recycled plastics is accomplished, market opportunities for innovative products should flourish.

Once testing and standardization has occurred, specifications can be written. This will place these products in position for building code review and acceptance. After this long process is completed, the task of market place acceptance will come to the forefront. However, the extension of these recycled products into the areas beyond those of "non-critical use" will require each of these steps.

7.3 Sources of Available Feedstock

There are two main sources of material for plastics wastes recycling:

1. the industrial waste stream and
2. the post consumer solid waste recovery process.

The plastics production rate in the United States is estimated to be around 60 billion pounds of resins produced annually with sales of plastics products exceeding $150 billion per year. By the year

2000, U.S. output of plastics is estimated to be up 25% to 76 billion pounds. (36) In terms of costs, plastics for which recycling markets have been created are actually the second most valuable materials in the solid waste stream, claiming $75 to $200 per ton to aluminum's $1,000 per ton. (36) Currently it is estimated that 0.01% of plastics waste is recycled.

The economic viability of plastics recycling, both from post-consumer wastes sources and industrial wastes sources, begins with a simple formula of feedstock pricing. Commingled plastics wastes utilized as feedstock must ultimately be sufficiently lower in cost than virgin resins. The price of virgin resins is directly linked with the price of oil. This also affects the price of recycled plastics as they become more valuable or less valuable as oil prices fluctuate.

7.3.1 Collection and Sorting Alternatives

Another factor in feedstock pricing involves the direct and indirect costs connected with collection, transportation, and processing. Escalating landfill construction costs and limited location opportunities also indirectly affect economic evaluation is the costs of disposal vs. the costs of recycling are considered. Other cost factors to consider are those related to continued maintenance of landfills which are expected to escalate with more stringent EPA laws.

The task of collection and sortation begins first with the consumer. The consumer is charged with the responsibility of separating the plastics out from the remainder of the solid waste stream and making them available for pick-up. Since curb-side recovery of plastics now centers entirely upon PET and HDPE bottles, many other plastic products consisting of polymers which also have potential for recycling continue to be remanded to the landfill or the incinerator. It should be noted, however, that a certain amount of containers comprised of polymers other than HDPE and PET inevitably end up among collected PET and HDPE. This creates a problem at the point of sortation at the recovery location. These must be extracted and disposed of by traditional means.

The inability on the part of consumers to recognize plastic packaging by polymer content is an impediment to the recycling of other polymers. The Society for Plastics Institute has proposed that national standards be set to define a plastic package by resin type. Even though there are many families of polymers, most packaging can be categorized into six major classes. These are:

PET:	polyethylene terephthalate
HDPE:	high density polyethylene
V:	vinyl
LDPE:	low density polyethylene
PP:	polypropylene
PS:	polystyrene

A category of "other" could be added to this list to encompass miscellaneous materials.

The State of Michigan has just passed such an act which states that "on or after January 1, 1992, and container composed predominantly of plastic resin and having a relatively inflexible finite shape or form that directly holds a substance or material and has a capacity of eight ounces or more, shall have a label indicating the plastic resin used to produce the product." Appendix A.1 provides a copy of this recent legislation which follows the guidelines for product labelling suggested by The Society for Plastics Institute. (25) This resin code modelled after that suggested by the SPI is similar to those which are now law in 18 states. (6)

There are two basic kinds of systems in which recycled commingled plastics waste products might be turned into end products:

1. Municipality owned and operated.
2. Cooperative effort between the municipality and private enterprise.

Essentially, a county can be in the business of disposing wastes by either:

A. Diverting a portion of those wastes into the manufacturing of end-product or

B: Providing a portion of those recoverable wastes to brokers who remove them from the county for re-use in the manufacturing of another end-product, C: A combination of the above concepts.

There is no known program in which the municipality has the capability of producing end-product from wastes. If facilities which could produce end-products from the plastics waste stream from which PET and HDPE have been removed were added to municipal recycling programs, additional revenues would have to come from the sale of products for which viable markets have been established. This would not be a desirable alternative at this time because municipalities would bear the burden of creating stable primary markets for the products they produce.

The second scenario is currently the established method for gaining revenue from the sale of recyclable material. Several counties in the United States, such as Dade County in Florida, have materials recovery facilities (MRF) which recover recyclable materials for sale to brokers. When a recycling program is initiated, the cost to collect the recyclable material is an added cost to the cost of disposal. The CPRR, Rutgers University, believes that these costs can be offset by the revenues garnered from the sale of recyclables and the avoidance of the cost of landfill. If a MRF is located near the county landfill and the waste stream undergoes sortation for recovery of recyclables, revenues may be captured from the sale of materials from the MRF while available space in the landfill is extended for critical use.

The following tables were compiled from data obtained at the CPRR from pilot programs in New Jersey. They illustrate the relationship of cost benefits of recycling compared with traditional methods of disposal. These costs were based upon the sale of recyclable materials to brokers who sell the material to recyclers and direct sale of materials to recyclers. The study emphasizes that the percent capture ratio from each household is critical to the economic feasibility of a recycling program. Capture ratios from the study area show Rhode Island obtaining 65% and New Jersey 85%. At the 65% to 85% capture ratio, the cost to recycle are equal to the cost of landfill containment if these costs are around $45 to $50 per ton.

COMPONENT	% IN MSW	SELLING PRICE (cents/lb)	REVENUE %
Newspaper	6	1.0	10
Glass Bottles	8	2.0	24
Plastic Bottles	2	6.0	19
Steel Cans	2	0.5	2
Aluminum Cans	1	40.0	45

Table 7.3.1 Contribution to Collecting & Sorting Revenues(27)

	NO RECYCLING	RECYCLING WITH PLASTICS
Collection	2925	3339
Landfill	2925	2520
Sorting	0	495
Revenue	0	(732)
Net Cost	5850	5622

(65,000 Tons of MSW\YR, in Thousand Dollars)

Table 7.3.2 Collection/Sortation Economics (27)

This data was compiled using $45.00 per ton as the cost of landfilling and generation rates for a typical community of 100,000. (27)

The important point to derive from this study is the necessity of collecting accurate data for solid waste management costs related to traditional methods of disposal to produce a break-even analysis of incorporating any kind of recycling program. Without these data, a vital part of the cost analysis is missing. This means that in relation to commingled plastics waste recovery and subsequent production of end-products from this source, the cost avoided by diversion of these materials from the landfill or incinerator must be factored into the economic viability of the product. Most U.S. manufacturers of recycled commingled plastics end-products receive the feedstock at no cost because it is "donated" by the municipality or plastics user. The burden of collecting, sorting, and size reduction is not borne by the manufacturer. Therefore, in plastics recycling, the revenue which may be derived by the municipality will be from the sale of extracted PET and HDPE to brokers with the cost of providing commingled plastics feedstock to manufacturers offset by those mitigated by decreased landfill or incineration of the resultant plastics waste.

7.3.2 Transportation

The factor which makes plastic packaging so desirable to consumers and so undesirable in terms of solid waste management is its low bulk density. It is this characteristic which creates a costly transportation problem in transferring used packaging wastes from a collection point to a point of processing. How and when to decrease bulk density of plastic wastes is a key issue in profitability. At the present time, curbside recovery programs involve pick-up of HDPE and PET bottles on designated days. The volume of bottles in their whole state requires numerous trips to the sorting point. Some garbage trucks are equipped with mechanical means of crushing the bottles at the point of initial curbside recovery. The material in whole form or crushed is then transported to a point of sortation. After sorting by hand, recovered whole beverage bottles, are usually crushed and baled. A second step of grinding and/or shredding for transportation to a secondary recycling operation may occur. In either form, the material is then transported away from the place of sortation.

This means that so called "avoidance factors", such as the escalating costs of transportation and tipping fees incurred by municipalities and indirectly passed on to the average citizen must be taken into account. Tipping fees are reported to be as high as $100 per ton in some parts of the United States. Currently, FLorida cities spend around $257 million year for solid waste management.(22) This represents a cost to cities of $42.00 per person. The tipping fees have no cost structure built into the system to support the enormous capital investments which will be required to upgrade existing landfills and create new ones. In 1987, Florida had 170 active landfills, down from 500 active landfills reported in existence in the late 1970's.(22) By the year 2000, the disappearance of available landfill containment may cause tipping fees to rapidly escalate as the cost of new construction is added to the cost of transporting solid wastes far away from dense, populated counties to areas less populated with more available land.

The costs of transportation and the salaried personnel required to effectively operate this system also significantly contributes to costs. Trucks which haul garbage cost between $90,000 and $100.000 to purchase. These, too, must be maintained. The cost of fuel is subject to the economic and political conditions which affect gas and oil prices. Fewer trips to the landfill would result in lower costs associated with tipping fees , fuel, maintenance, and number of salaried personnel. The large volume represented by the plastics waste stream is a significant contributor to the number of trips required to handle landfill containment of solid wastes. A standard plastic soda bottle weighing very little, displaces around 7 pounds of other garbage. Therefore, minimizing the length and number of trips required to bring plastics wastes to the point of the recycling manufacturer should be a goal in the overall strategy of recycling. This requires cooperation between local municipalities and the private recycling enterprise to ensure proper location and method of transportation to the recycler in order to make the entire process more cost efficient. Regarding processors of commingled plastics wastes, proper location of the manufacturing facility would ensure that transportation costs would be at a minimum, whether borne by the municipality or the recycler. This, in turn, would limit the initial cost structure of end-product units.

7.3.3 Sources of Feedstock

The most desired source of feedstock for processing into recycled products at this time remains that of the industrial waste stream. The ability to easily identify the source material and the degree of cleaning required for processing are factors which promote recyclability and increase the market value of end products.

However, nearly all recycling applications require some treatment of the feedstock before it may be processed into secondary application.

Almost all plastic fabricating operations generate a significant amount of scrap originating from trim operations and the production of "seconds" in which some mistake in production is involved. Much of this can be placed back into primary recycling. An example of this is found in the production of six-pack can straps which are prepared by extrusion followed by die cutting. Approximately 15% to 20% finds its way into the final product. In fact, the economic viability of this product relies upon repeated recycling of this material, reported to be up to six or seven repetitions. This is the limit of cycles that may be accomplished without a significant loss of properties or introduction of contamination.

It is quite common to base the economic viability of plastic product production upon the ability to reprocess a significant portion, reported as between 15% to 30% of wasted feedstock , as a blend with virgin resin or the major source for a particular product. (26) However, once the minimum number of repetitions of recycling in-house have been completed, there remains a significant amount of scrap waste which requires disposal due to its uselessness for the initial product manufacturing. It is at this point that this scrap material must either be disposed of by traditional methods or made available for recycling into end-products destined for non-critical use applications. It is estimated that an average of around 5% of each type of plastic resin production operation becomes post industrial waste annually. (8)

Thus, even "pure" plastic waste scrap must be disposed of in landfill containment or incineration after the life cycles of its property viability are spent. The quantity and availability of industrial scrap will directly affect the viability of recycling commingled plastics. Since industrial scrap is traditionally cleaner and, in many cases, purer than post consumer wastes, processing costs are affected by saving steps and time required for cleaning.

An example of a viable and relatively clean form of industrial plastics waste is found in the manufacturing of PET bottles. Frequently mistakes are made in the production of a bottle creating a large amount of industrial seconds. The mistake could be as small as a group of bottles to which the wrong label has been attached. Industrial seconds consisting of mis-labeled PET beverage bottles are not usable to soft drink bottlers.

This would constitute a feedstock that held virtually no contaminants as the normal cycle of filling the bottle with syrup and discarding it with a portion of remaining syrup which then increases in certain toxic microbial actions is pre-empted. As a one-product line, the resin utilized would be relatively homogeneous compared with the variety of resins found in post-consumer wastes. The attachment of the label in conjunction with the adhesive make these bottles relatively unattractive to the primary producer who must effectively remove virtually every trace of foreign material for viable reprocessing. But to the commingled recycler, this kind of material is highly desirable because a lesser amount of source separation and cleaning would be required. This type of feedstock is, by its nature, less costly to process. Research should be conducted which locates by type and amount the sources of post industrial plastics waste in the State of Florida which would be available for recycling by commingled plastics processing technology but is presently disposed of by incineration or landfill containment.

The most critical source of plastic wastes is found in the post consumer waste stream. This source presents the most problems associated with recycling and represents the source of the most negative impact upon the environment. Aside from scattered efforts to recover PET and HDPE bottles in curbside collection, virtually all waste plastics are landfilled or incinerated. It has been reported that approximately 35% of the annual production of plastics product consists of packaging, with essentially all of this amount finding its way eventually into the waste stream. (26) With packaging now almost 50% of the plastics waste stream fraction, and this amount expected to increase, considering the post consumer waste stream as a viable feedstock source for recycling is becoming more important. Since plastics found in the post consumer waste stream are of such a variety of mixed polymers with a high degree of contamination from content residues and other materials incorporated into the plastic product, this portion must be recycled with technology designed for processing such a feedstock.

7.4 The Role of HDPE and PET Markets

Economically healthy markets are already in existence for HDPE and PET. At the present time, most experts assume that PET and HDPE are the only two polymers that may be successfully separated from the waste stream . For this reason, the role of PET and HDPE markets must be examined.

Established markets for HDPE and PET resins will continue to pull these polymers out of the post consumer waste stream. HDPE and PET in recycled pelletized form sell for approximately 50% less than the virgin resin. This price does not include the collection and sortation which would be performed by municipalities. With those added costs, the price rises to around 20 % higher than the virgin resin. In states where there is bottle legislation, consumers pay a certain per cent deposit which is refunded when the bottle is returned. These nine bottle deposit states provide most of the PET available to brokers for recycling. (31) From CPRR estimates, current recovery of Pet beverage bottles represents about 20% of the total PET bottle production in the United States. These estimates should be increasing as a result of new collection programs coming on line all over the country. Perfect recovery of all PET beverage containers is expected to amount to less than 5% of the entire plastics waste stream which, in turn, would represent less than 0.4% of the total MSW stream. The recovery of all beverage containers, including HDPE bottles, would approximately double these figures. (19)

Clean, flaked PET can carry a price of around $0.25 per lb. Flaked PET can be converted into pellets for around $0.05 per lb. and therefore sold for around $0.30 per lb. Virgin PET, pelletized, currently sells for about $0.56 per lb. HDPE, sells for around $0.17 per lb. while the cost of virgin resin is now around $0.40 per lb. Plastic bottles, both PET and HDPE, currently command around $0.06 per pound. (12) Because of the desirable marketability factors associated with these two resins, it is expected that these markets will increase. Primarily, their high marketability stems from the fact that PET and HDPE are easily recognized by the consumer or anyone engaged in hand separation and the products made from them are relatively homogeneous in polymer type.

Recycled PET finds its main market in fiberfill, the insulation of ski jackets. In 1985, it was reported that 80% of the 100 million pounds of PET (which came primarily from states with deposit legislation) was recycled into fiberfill. The remainder was utilized in a variety of other products. At that time is was estimated that a market potential for recycled PET was greater than 1.3 billion pounds, considerably higher than the amount being recycled today.(28) Other applications include industrial strapping for pallet loads, unsaturated polyester molding compounds for sinks, shower stalls, corrugated awnings, and exterior panels for automobiles. These applications incorporate other fillers such as fiberglass and marble dust. Additional applications include polyols for manufacturing foam for home and commercial freezer insulation, furniture cushions,paint and industrial coatings, audio cassette cases, engineering plastics for appliance handles, housing and casing, and chemical conversion into monomers. (26)

HDPE generated as waste predominantly from milk bottles, is used to make such items as plastic lumber profiles, drainage pipes, flower pots, bristles for paint brushes, traffic barriers, and base cups for soft drink bottles. Many types of processing systems for commingled plastics utilize a significant amount of HDPE in their feedstock. The items mentioned above can therefore be made from a feedstock source which has had a minimal amount of separation such as that emanating from municipal solid wastes. It is reported that the appearance of these items is not as good as if it were made from pure HDPE. (26) The separation of PET and HDPE from the post consumer waste stream and the industrial waste stream has an affect upon the marketability of the remaining commingled plastics waste stream.

The markets for HDPE and PET as well as their recycling rates are described in the following tables.

POLYETHYLENE TEREPHTHALATE - PET - Recycling Projections

Major Markets (million lbs.)	1987 Actual Sales	Potential Recycled %	Potential Recycled Volume	Projected 1993 (11% annual growth) Potential Sales	Projected 1993 (11% annual growth) Recycled
Polyester Thermoplastic (PET)					
Blow Molding					
Soft-drink Bottles	740	0	0	1,384	0
Custom Bottles	135	10	14	253	25
Extrusion					
Film	470	10	47	879	88
Magnetic recording film	75	0	0	140	0
Ovenable Trays	25	0	0	47	0
Coating for ovenable board	12	0	0	22	0
Sheeting (for blisters, etc)	7	10	1	13	1
Strapping	28	40	11	52	21
Exports	175	10	18	327	33
Total PET	1,667		90	3,118	168
Polyester, Unsaturated					
Reinforced Polyester					
Molded	785	2	16	1,468	29
Sheet	190	2	4	355	7
Surface Coating	18	0	0	34	0
Export	10	0	0	19	0
Other	312	0	0	584	0
Total Unsaturated Poly.	1,315		20	2,460	36

Reinforced Polyester, Unsaturated					
Aircraft/aerospace	33	0	0	62	0
Appliance/business	90	2	2	168	3
Construction	393	2	8	735	15
Consumer	130	0	0	243	0
Corrosion	326	0	0	610	0
Electrical	55	0	0	103	0
Marine	350	2	7	655	13
Transportation	195	2	4	365	7
Other	50	0	0	94	0
Total Reinforced Unsaturated Polyester	1,622		21	3,034	38
Polyurethane - Rigid Foams					
Building Insulation	445	2	9	832	17
Refrigeration	119	2	2	223	4
Industrial Insulation	65	2	1	122	2
Packaging	50	2	1	94	2
Transportation	64	2	1	120	2
Other	32	0	0	60	0
Total Polyurethane	775		15	1,450	28
Textile					
Filament Yarn	1,180	10	118	1,409	141
Staple and Tow	2,369	10	237	2,829	283
Total Textile	3,549		355	4,238	424
Grand Total	8,928		500	14,299	695

Table 7.4.1. PET Recycling Projections (4)

HIGH DENSITY POLYETHYLENE - HDPE - Recycling Projections

Major Markets (million lbs)	1987 Actual Sales	Recycled %	Recycled Volume	Projected 1993 (7% annual growth) Sales	Recycled
Blow Molding					
Bottles					
Milk	740	0	0	1,111	0
Other Food	278	0	0	417	0
Household Chemicals	895	10	90	1,343	134
Pharmaceuticals	184	0	0	276	0
Drums (>15 gal.)	110	5	6	165	8
Fuel Tanks	54	0	0	81	0
Tight-Head Pails	78	10	8	117	12
Toys	70	5	4	105	5
Housewares	45	0	0	68	0
Other Blow Molding	235	0	0	353	0
Total Blow Molding	2,689		108	4,035	151
Extrusion					
Coating	42	0	0	63	0
Film (<12 mil.)					
Merchandise Bags	162	0	0	243	0
Tee-shirt Sacks	106	0	0	159	0
Trash Bags	76	0	0	114	0
Food Packaging	88	0	0	132	0
Deli Paper	13	0	0	20	0
Multiwall Sack Liners	45	0	0	68	0
Other	96	0	0	144	0
Pipe					
Corrugated	152	25	38	228	57
Water	63	0	0	95	0
Oil & Gas production	76	0	0	114	0
Industrial/Mining	54	0	0	81	0
Gas	118	0	0	177	0
Irrigation	42	50	21	63	32
Other	55	0	0	83	0
Sheet (>12mil.)	210	10	21	315	32
Wire & Cable	124	0	0	186	0
Other Extrusion	35	10	4	53	5
Total Extrusion	1,557		84	2,337	125
Injection Molding					
Industrial Containers					
Dairy Crates	61	10	6	92	9

Other Crates, Cases, Pallets	139	10	14	209	21
Pails	410	10	41	615	62
Consumer Packaging					
Milk-bottle Caps	26	0	0	39	0
Other Caps	63	0	0	95	0
Dairy Tubs	147	0	0	221	0
Ice-cream Containers	82	0	0	123	0
Beverage-bottle Bases	124	50	62	186	93
Other Food Containers	47	0	0	71	0
Paint Cans	36	10	4	54	5
Housewares	242	0	0	363	0
Toys	84	5	4	126	6
Other Injection	250	10	25	375	38
Total Injection Molding	1,711		156	2,568	234
Rotomolding	122	10	12	183	8
Export	915	0	0	1,373	0
Other	830	10	83	1,246	125
GRAND TOTAL	7,824		441	1,742	662

Table 7.4.2 HDPE Recycling Projections (4)

The activity level of recycled PET and HDPE is important for two reasons. First, the technologies associated with the processing of these two polymers is closely related to that of commingled plastics recycling technologies. Some of the end-products made from HDPE, whether from virgin resins or recycled resins, have potential to be manufactured from a mixed feedstock.

Secondly, the removal of these two polymers significantly affects the properties of the commingled plastics resultant by producing a feedstock that is lacking in these two elements. This could create a need for polymer additives to produce appropriate chemical and physical properties in the final product. Application of the final product is a critical factor in determining the use of additives. Since all commingled plastics final products are designated for "non-critical" uses, there is much flexibility in the range of chemical and physical properties. Perhaps more important is the idea that the majority of feedstocks available for commingled plastics recycling will likely have undergone a separation process in which the more valuable PET and HDPE have been removed. Processors utilizing this kind of feedstock will have to consider the affect of this on end-products and perhaps find additional sources of waste polymers to be utilized as additives to improve properties.

7.5 Creating Primary Markets

Primary markets must be established to absorb the rate of end-product made from materials emanating from the plastics solid waste stream. The first product applications must be substitutions for those made from traditional materials. Evaluations of inroads which could be made into established markets should be made for all potential substitutions. Primary focus in the studying of recycling wastes into other end products has been in the area of collection systems. Market development should be designed to evaluate industry's capacity to absorb the currently available products. Without the capacity to utilize the products efficiently, markets could become saturated, prices would fall, and the entire system could collapse.

Primary market areas of non-critical use should be thoroughly studied for market penetration capability of recycled materials. In a market study conducted by Dr. Robert Bennet for the Center for Plastics Recycling Research, Rutgers University, it is reported that in 1990, around 80 billion board feet of wood were used in the manufacturing of pallets. If this product were made from recycled plastics, then around 37 billion pounds could be utilized. If only one per cent market penetration of recycled plastics occurred, approximately 37 million pounds could be used.

	Wood	Mixed Plastics
Market Size (1990)	7.4 billion lbs (>300 million pallets)	37 billion lbs
Estimated Penetration		1%
Estimated Markets		370 million lbs

Table 7.4.3 Market Opportunities for Recycled Commingled Plastics in Pallet Construction (4)

In another example, the market for landscape timbers alone consisted of 12 million units sold in the United States in 1988. If "timbers" made from recycled plastics were substituted, approximately 1/2 billion pounds of mixed plastics waste could be utilized.(4)

Primary market areas in building construction with designated uses of non-critical should be carefully identified and evaluated according to ease of transition from traditional materials to recycled. With the assignation of appropriate percentages of market penetration, a comprehensive depiction of the extent of available primary market potential could be developed.

7.6 Impediments to Product Acceptance

Recycled products have previously endured a poor image from producers and users because of the perception that recycled content would produce an inferior product. Now that a shift in public opinion has occurred so dramatically in the last few years, a product advertising itself as containing recycled material is capitalizing on a market edge. This is a rare example of the disappearance of a significant product impediment through fundamental changes in public opinion.

Impediments for recycled product acceptance emanate from the following concerns:

1. product inconsistency due to early stages of technology development;
2. the inability to expand into secondary markets in construction because of non-compliance with building codes;

of these commercial technologies including the municipal\private joint venture, tax incentives and disincentives, the goal of government procurement practices, and mitigation of escalating costs of solid waste disposal methods may be studied on a case basis as a variety of these ventures have been tried and are in operation in West Germany, Belgium, Italy, and Japan.

Potential Funding Agencies:

U.S. Environmental Protection Agency

Plastics Recycling Foundation

Council For Solid Waste Solutions

BCIAC

Duration: 9 months

NOTE: A true financial feasibility study which produces a business plan can not be conducted without the benefit of the above information being established. A financial feasibility study requires the co-operation of a task force comprised of municipal officials, State government officials, and a particular commercial technology willing to provide what is primarily considered proprietary information. The benefits for each segment would prompt the participation by all.

e. The Principal Investigators for this study are faculty members in the School of Building Construction at the University of Florida. Their experience in architecture and engineering plus previous research in, and exposure to, recycled material applications will provide the appropriate expertise in assessing the building construction industry for potential utilization of recycled plastics. Equally necessary for studying construction applications is a thorough knowledge of the various Building Codes which govern and constrain the industry and the materials which it is allowed to use. This includes not only the structural properties of the materials, but also their fire resistive characteristics.

OUTLINE OF MAJOR ACTIVITIES

1. Major Activities

a. Catalog survey to assess the use of recycled plastics in construction applications in the US, Europe, and Japan.
b. Creation of an outline of Building Construction systems for use in materials analysis.
c. Breakdown of materials and products versus Building Construction systems.
d. Evaluation of materials and products for substitution of recycled plastics via a rating scheme.
e. Ranking of products and materials by technical and financial feasibility of substitution.
f. Determination of manufacturers of candidate products for substitution.
g. Contact with manufacturers and research staffs of companies which produce the candidate products.
h. Evaluation of feedstock and other technical requirements for substitution of recycled plastics for traditional materials.
i. Report on research.

2. SUMMARY:

The research proposed in this outline will provide a major compilation of end-use applications and create a link between these potential applications and the emerging technologies required to implement these products. The evaluation of financial and technical constraints, which are important obstacles to be overcome, will provide critical information required to implement strategies which give industry the incentive to transition from traditional materials to recycled plastics. An experienced, knowledgeable team of researchers from the faculty of the University of Florida will insure a high quality useful body of knowledge is produced.

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A.1 State of Michigan, Enrolled House Bill No. 5805

Act No. 414
Public Acts of 1988
Approved by the Governor
December 24, 1988
Filed with the Secretary of State
December 27, 1988

STATE OF MICHIGAN
84TH LEGISLATURE
REGULAR SESSION OF 1988

Introduced by Reps. Kosteva, Scott, DeBeaussaert, Gire, DeMars, Emmons, Hart and Varga

ENROLLED HOUSE BILL No. 5805

AN ACT to require the labeling of certain plastic products; to provide for the powers and duties of certain state departments and officials; and to prescribe penalties and remedies.

The People of the State of Michigan enact:

Sec. 1. As used in this act:

(a) "Degradable" means capable of being broken down by biodegradation, photodegradation, or chemical degradation into component parts within 360 days under exposure to the elements.

(b) "Department" means the department of natural resources.

(c) "Label" means a molded imprint or raised symbol on or near the bottom of a plastic product.

(d) "Person" means an individual, sole proprietor, partnership, association, corporation, or other legal entity.

(e) "Plastic" means any material made of polymeric organic compounds and additives that can be shaped by flow.

(f) "Plastic bottle" means a rigid plastic container with a capacity of 16 ounces or more that has a neck that is smaller than the body of the container.

(g) "Plastic product" means a plastic bottle and any other rigid plastic container.

(h) "Rigid plastic container" means any container composed predominantly of plastic resin and having a relatively inflexible finite shape or form that directly holds a substance or material and has a capacity of 8 ounces or more.

(i) "PETE" means polyethylene terephthalate.

(j) "HDPE" means high density polyethylene.

(k) "V" means vinyl.

(*l*) "LDPE" means low density polyethylene.

(m) "PP" means polypropylene.

(n) "PS" means polystyrene.

(o) "OTHER" means multi-layer.

(p) "D" means degradable.

recycled paper

A.2 Industry Directory: Producers of End-Use Recycled Plastics and Producers of Commingled Plastics as Manufacturing By-Product

HAMMER'S
PLASTIC
RECYCLING CORP.

A Manufacturer of
Recycled Plastic Products

HAMMER'S PLASTIC RECYCLING CORP.

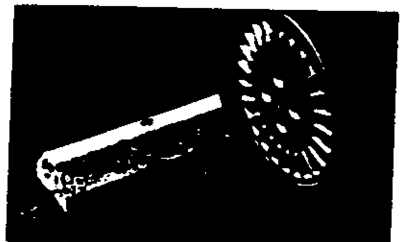
A Manufacturer of Recycled Plastic Products

Plastic waste contributes significantly to the growing waste problem in th United States. **Out of the entire solid waste stream, plastics represents 8% by weight but almost 30% by volume!** With a majority of our land projected to approach full capacity as early as 1992, recycling becomes increasingly necessary as disposal sites close, tipping fees escalate and pu awareness increases regarding polluting effects of plastic waste. **HAMME PLASTIC RECYCLING CORP. has a solution to address these enorn problems.**

HAMMER'S manufactures a variety of exciting products that are cost competitive, high-quality alternatives to concrete, wood, and metal, and a made from **100% recycled plastic.**

HAMMER'S owns a number of United States' **patents,** four of which are used in the recycling and manufacturing of these plastic products.

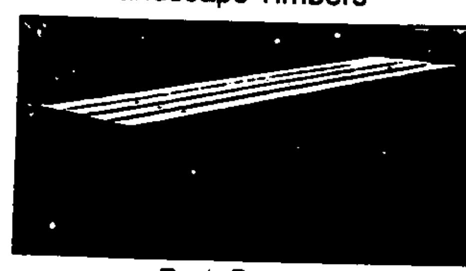
HAMMER'S is currently recycling mixed or commingled plastic waste material at an annual rate in excess of 4,000,000 pounds. Our products inc CAR STOPS (plastic curbs used principally in parking lots), PARK BENCHES, SPEED BUMPS, BOAT DOCKS & PILINGS, LANDSCAPE TIMBERS, PLAYGROUND EQUIPMENT, PALLETS, SIGN POSTS, STAKES, as well as various industrial custom moldings.



Car Stop

Landscape Timbers

Speed Bump



Park Bench

In the past, one of the big obstacles to plastic recycling has been the need t separate the different types of plastics before cleaning and processing. HAMMER'S unique recycling method reduces this need for elaborate separation: **HAMMER'S is processing mixed plastic waste now!** In additio our system uses both post-consumer and post-industrial commingled plastic and up to 15% of non-plastic waste. HAMMER'S agrees with some experts who predict that by the year 2000, as much as 25% of all plastic used in manufacturing finished products will come from recycled plastic.

HAMMER'S HISTORY . . .

HAMMER'S was formed in 1978 as a manufacturer and supplier of products to the agriculture industry. In 1981 we expanded our agricultural product line to include distribution and sale of imported products manufactured from recycled plastic.

HAMMER'S formed PLASTIC RECYLING, INC. in 1984 to design and build a production facility to recycle mixed-plastic waste into commercially viable products.

In 1987, PLASTIC began processing mixed-plastic and manufacturing products from commingled plastic material. In 1988, PLASTIC won the State of Iowa Governor's Award for best exemplifying the achievements and contributions industry makes each year to Iowa and its communities.
In March 1989, HAMMER'S PLASTIC RECYCLING CORP. was formed to provide a vehicle to take this concept nationwide.
HAMMER'S continues to expand its business of recycling plastic waste by manufacturing and selling products of commingled plastic.

HAMMER'S PLASTIC RECYCLING CORP. has headquarters and manufacturing facilities in Iowa Falls, Iowa. Our unique molds and processes are protected by a number of American and international patents. Our automated production lines are used to manufacture Car-Stops, Speed Bumps, Landscape Timbers, Pilings, and other large profile products.
The company also possesses patented equipment for the manufacturing of custom-molded products and new products in the test marketing stages. These lines dramatically reduce the cost of custom molded products principally because of HAMMER'S unique ability to design and manufacture inexpensive molds. Future plans include the acquisition of other equipment which will allow increases of up to 50% of output capacity and the ability to recycle various homogeneous plastic resins.
HAMMER'S is aggressively expanding its recycling operations into regions where legislation and public programs favor or require recycling of plastic waste. The company pursues business arrangements to implement the recycling methods and production techniques developed in Iowa Falls' prototype facility. HAMMER'S considers agreements with local governments, large corporations, and other private entities where assistance in financing, assured supply of waste plastic, and support in the marketing of end products is available. A typical satellite facility will have the capacity to process **10 million pounds** of plastic waste, 8 million pounds of which are used to produce end products. Additionally, the company is going to continue its development of cleaning and processing plastic waste which is sold to other plastic manufacturers. Once completed, all facilities will have the capacity to clean and resell an additional 2 million pounds annually that would otherwise end up in a landfill.
The problem of burying our plastic waste is an immediate and catastrophic problem which affects the United States right now. HAMMER'S PLASTIC RECYCLING CORP. offers a viable alternative to municipalities in order that we save our landfill space. It is our goal to make plastics a community resource, rather than a burden on our precious environment.

TYPES OF PLASTICS AND EVERYDAY APPLICATIONS

ABS (Acrylonitaile-Butadiene-Styrene): Telephones. business machine housings. power tool housings, pipe and fittings.

Acetal: Combs. butane lighter bodies. (Bic) ball point pen barrels. soap dispensers. garden hose nozzles.

Acrylic: Skylights, commercial signs, auto taillights, sunglass lenses. bank security barriers.

EVA (Ethylene-Vinyl Acetate): Produce bags, pet food pouches, dry soup bags, auto bumper pads. swimming pool hose.

HDPE (High Density Polyethylene): Milk and soft drink crates, caps, pipes & profiles, grocery bags, 55-gallon drums, gasoline tanks, toys, and detergent bottles (Joy).

LDPE (Low Density Polyethylene): Bread packaging, frozen food bags, toys, paint can lids, milk bottle caps.

LLDPE (Linear Low Density Polyethylene): Film. piping, wire and cable insulation. trash can liners. dry cleaning garment bags.

Nylon: Hair brushes. chain saw housing. bicycle wheels. fish line. auto engine fans. ice skate supports. frozen food pouches.

PB (Polybutylene): Hot and cold water pipe. fire sprinkler piping. food and meat packaging films. hot fill containers (Thermos).

PBT (Polybutylene Terephthalate): Steam iron handles. hair dryer housings. oven handles and switches, LED displays. lamp sockets.

PET (Polyethylene Terephthalate): Beverage bottles (2-liter Coke). mouthwash jars (Scope), peanut butter jars. wine bottles. salad dressing bottles.

Polycarbonate: Compact disks. auto head lamps, 5-gallon water bottles. baby formula bottles. traffic light signal lenses. unbreakable beverage glasses.

Polyester or LCP (Liquid Crystal Polymers): Chemical pumps. electronic components. coil bobbins. electrical sockets. dual ovenable cookware (Tupperware).

PP (Polypropylene): Battery cases. trim and air ducts in automobiles. yogurt (Dannon) and margarine tubs. medicine bottles. yarns used in fabrics in luggage and shoes. upholstery and car seats.

PS (Polystyrene): Video cassettes. audio/visual equipment. TV's. cabinet doors. packaging for compact disks. vials. egg cartons. packages for fast food items (McDonald's).

PVC (Polyvinyl Chloride): Heavy-walled pressure pipe. surgical gloves. crystal clear food packaging. house siding. garbage disposals. skylight frames.

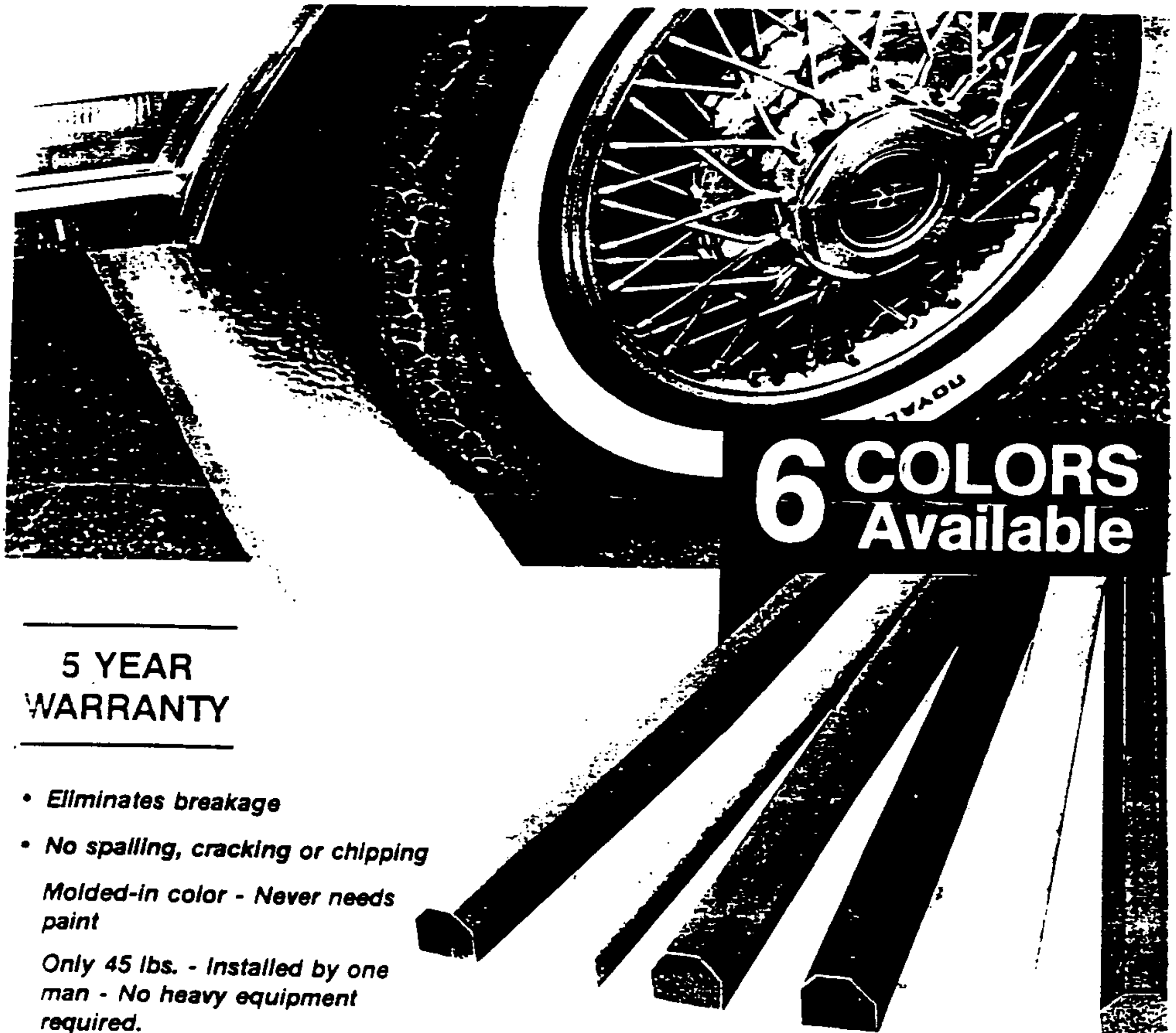
PVDC (Polyvinylidene Dichloride): Saran films. cosmetic packaging. unit dose packaging of pharmaceuticals. meat. cheese and poultry packaging.

NOTE: Hammer's has recycled each of the above plastics.
Commingled refers to any combination of these plastics.

For more information. call or write to:
Hammers Plastic Recycling Corp.
RR3 Box 182. Iowa Falls. IA 50126
(515) 648-5073
FAX (515) 648-5074

The solid plastic parking stop!

Made of 100% recycled plastic . . . in colo



5 YEAR WARRANTY

- ***Eliminates breakage***
- ***No spalling, cracking or chipping***

Molded-in color - Never needs paint

Only 45 lbs. - Installed by one man - No heavy equipment required.

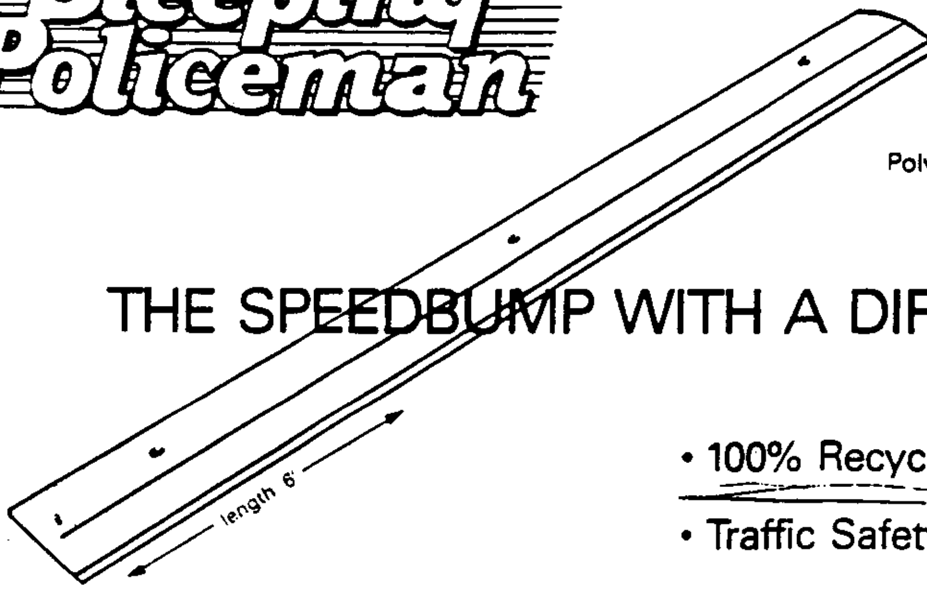
The lightweight, attractive Car-Stop is a unique product for parking areas. This tough, rugged parking stop reduces parking facility problems. The full-depth color resists fading and eliminates painting. Car-Stop will replace concrete for all parking areas . . . commercial, industrial, institutional, public or private. Car-Stop, with its excellent advantages and 5 year warranty, is a sound investment for your parking location.

Distributed by **BREWER COTE OF FLORIDA INC.**

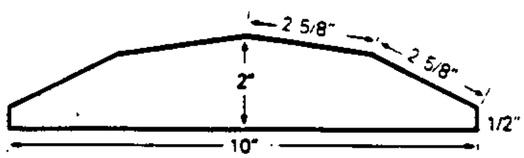
Circle 9 on Reader Inquiry Card

Sleeping Policeman

Polymer Products' Sleeping Policeman®



THE SPEEDBUMP WITH A DIFFERENCE!

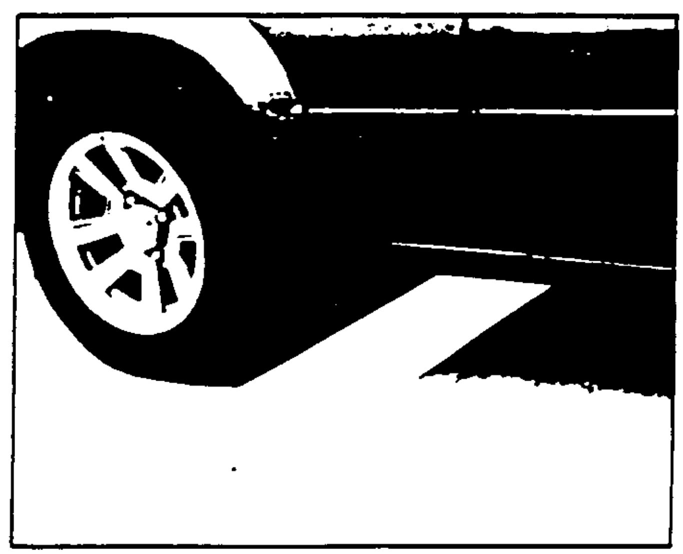


- 100% Recycled Plastic
- Traffic Safety Yellow
- Maintenance Free
- Chemical Resistant
- Corrosion Proof
- Moisture Resistant

The Sleeping Policeman® is designed for interchangeability. If traffic patterns change, it can be moved to a new location. If winter snows are in the forecast, the Sleeping Policeman® can be taken up, stored until spring, then simply place it back in its original position.

The Sleeping Policeman® does not require painting to improve its visibility, even at night. It is not affected by road chemicals, oil, salt, sunlight, or ozone attack.

The Sleeping Policeman® is affixed to the pavement with three lag bolts. Installation is fast and easy using the simplest tools.



Designed to reduce traffic speeds to 10-15 mph.

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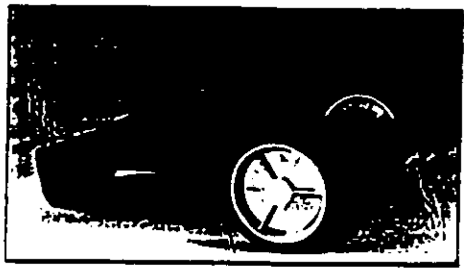
6850 Riviera Drive
Coral Gables, FL 33146
(305) 661-7647

BREWER COTE OF FLORIDA INC.

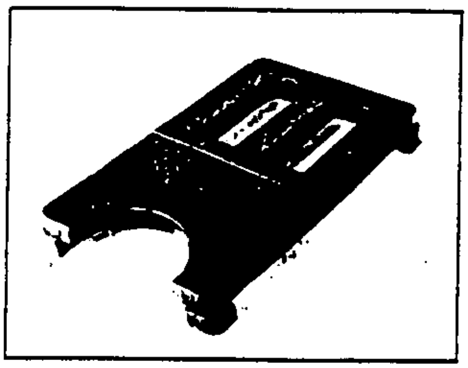
Marketing Office
P.O. Box 5261
Lakeland, FL 33807
(813) 646-8596
FAX 1-813-646-8597

Sleeping Policeman

Custom Industrial Moldings Are Our Business!



Base assembly for moving industrial machinery.



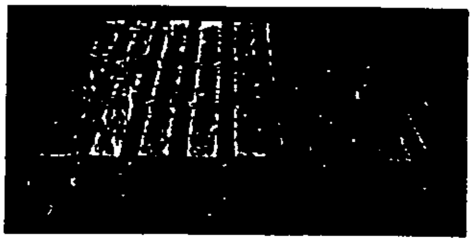
Stationary base for industrial equipment.

Let
Hammer's Plastic Recycling
custom design
parts for you!

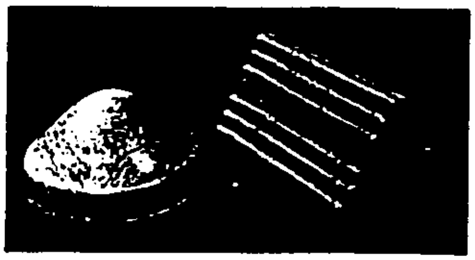
For more information, call or write to:
Hammer's Plastic Recycling Corp.
RR3 Box 182. Iowa Falls. IA 50126
(515) 648-5073
FAX (515) 648-5074

Thick Wall

Custom designed industrial products made from 100% recycled plastic



Pallet



Terminal cap for light pole — Wheel Chock

HAMMER'S PLASTIC RECYCLING CORP

Thick Wall 100% Recycled Plastic

Q: *Is tooling too costly to replace your short run parts with plastic?*

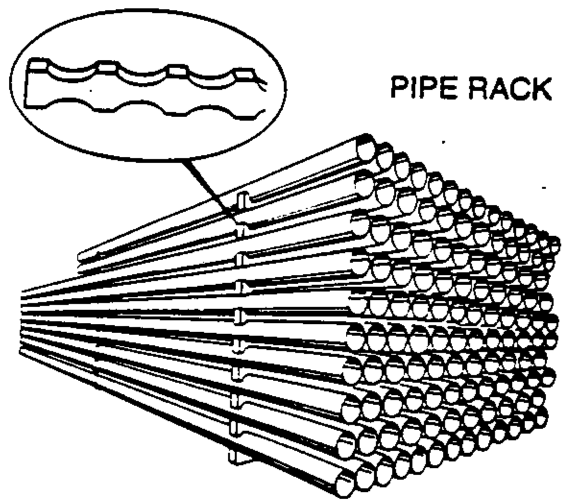
A: *Call Hammer's Plastic Recycling Corp.*

Our "Thickwall"™ molding process lowers part costs. Tooling costing hundreds, not thousands, make even the short runs feasible.

Hammer's Plastic Recycling Thickwall™ technology is a breakthrough for today's industry.

Rugged, durable plastic Thickwall™ moldings will satisfy all your changing needs. A wide variety of applications, from OEM parts to material handling uses, can be designed and molded to adapt to your special needs. Corrosion resistant and maintenance free Thickwall™ moldings are available in many different shapes and sizes. With Thickwall™ tooling even a short run is made cost effective.

Manufactured under one or more of the following patents: 4,626,189
4,738,808
4,797,237
4,824,627



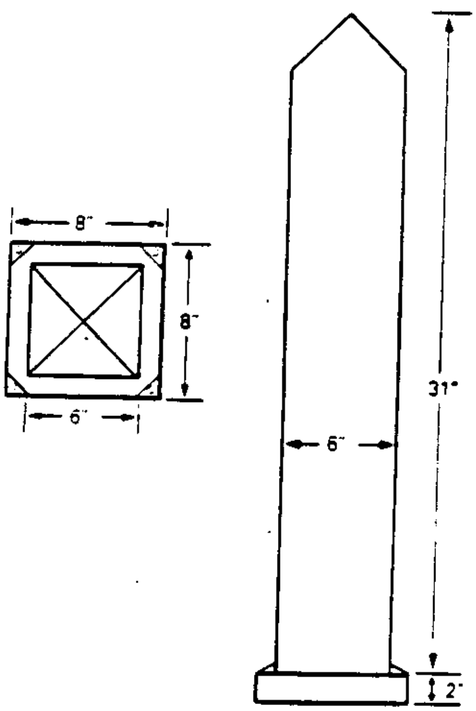
- Rust Proof
- Corrosion Resistant
- Maintenance Free

BOLLARDS

Traffic yellow through-out for high visibility, <u>even at night</u>.

May be used in a variety of applications to control unwanted traffic, temporarily or permanently.

May be used in parking lots, roadways, construction sites, and parks.



Manufactured under one or more of the following patents: 4.626.189 4.797.237 4.738.808 4.824.627

For more information, call or write to:
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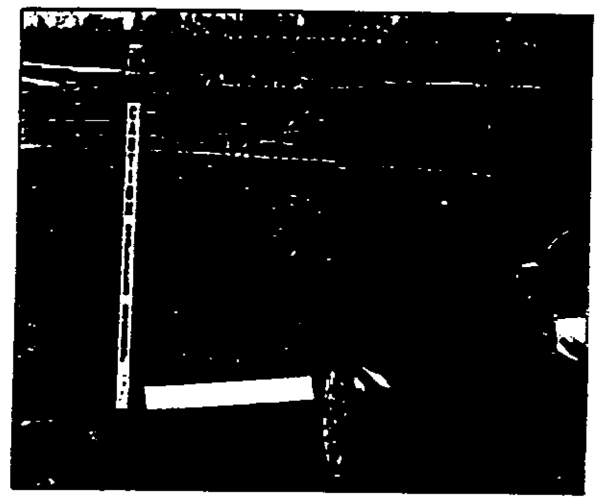


The Speedbump with a difference

HAMMER'S PLASTIC RECYCLING CORP
A Manufacturer of Recycled Plastic Products

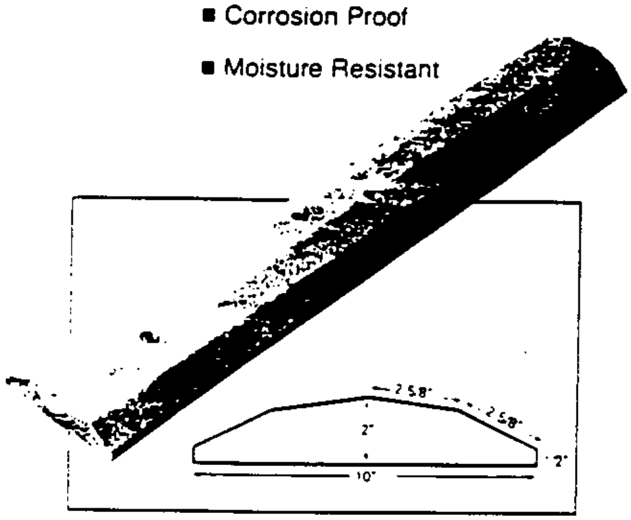
Sleeping Policeman *100% Recycled Plastic*

The Sleeping Policeman® is designed for interchangeability. If traffic patterns change, it can be moved to a new location. If winter snows are in the forecast, the Sleeping Policeman® can be taken up, stored until spring, then simply place it back in its original position.

The Sleeping Policeman® does not require painting to improve its visibility, even at night. It is not affected by road chemicals, oil, salt, sunlight, or ozone attack.

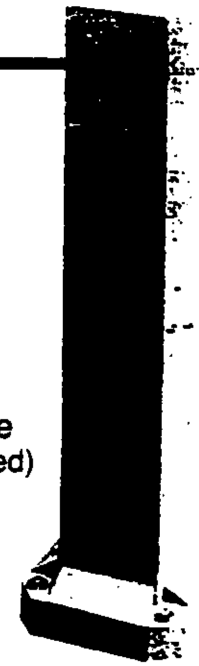
The Sleeping Policeman® is affixed to the pavement with three lag bolts. Installation is fast and easy using the simplest tools.

- Movable
- Traffic Safety Yellow
- Maintenance Free
- Chemical Resistant
- Corrosion Proof
- Moisture Resistant

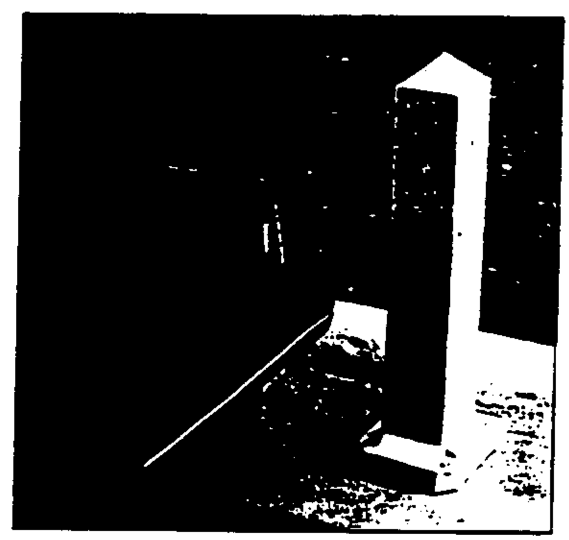


BOLLARDS
For Traffic Control

- Traffic Safety Yellow
- Decay Proof
- Rust Proof
- Can Be Anchored At Base Corners (hardware furnished)
- Moisture Resistant
- Maintenance Free
- 100% Recycled Plastic



Designed to limit access in a variety of applications.



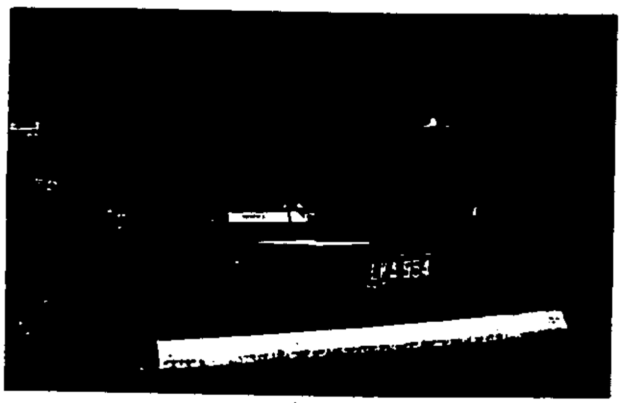
Car Stop *100% Recycled Plastic*

The solid recycled plastic parking stop!

The lightweight, attractive Car-Stop is a unique product for parking areas. This tough, rugged parking stop reduces parking facility problems. The full-depth color resists fading and eliminates painting. Car-Stop will replace concrete for all parking areas... commercial, industrial, institutional, public or private. Car-Stop, with its excellent advantages and 5 year warranty, is a sound investment for your parking location.

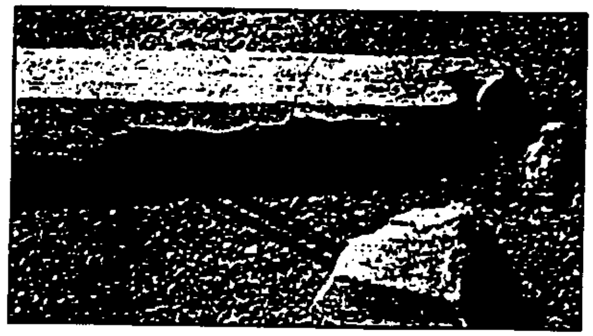
Available in 5 colors!

Blue Yellow Brown
Black Grey



Manufactured under one or more of the following patents: 4,626,189 4,797,237 4,738,808 4,824,627

Eliminate the danger of exposed reinforcing rods from concrete parking stops.

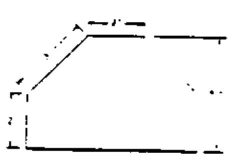


5 YEAR WARRANTY

- *Eliminates breakage*
- *No spalling, cracking or chipping*
- *Molded in color — Never needs paint*
- *Only 45 lbs. vs. 230 lbs. with concrete No heavy equipment required*
- *An environmentally sound investment made from recycled plastic*
- *Resistant to gas, oil, salt, sunlight and chemicals*

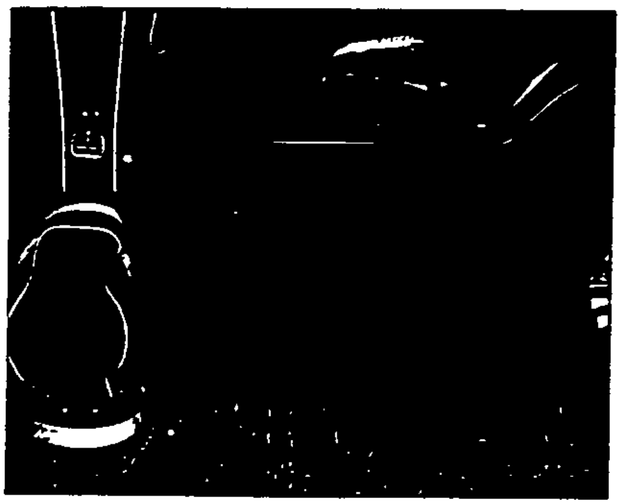
SPECIFICATIONS

*HEIGHT .... 4 ½" LENGTH .... 72"
*WIDTH .... 6" WEIGHT . 45 lbs. (Approx.)
**COLORS .... Standard — Black and Brown
Options — Handicap Blue, Safety Yellow, Grey
Securing Holes Countersunk [illegible] diameter
SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE



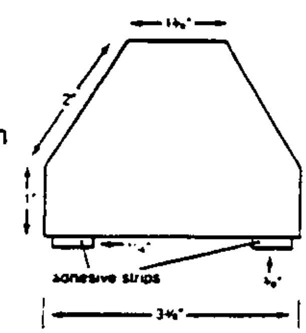
Mini Stop

For home use in garages



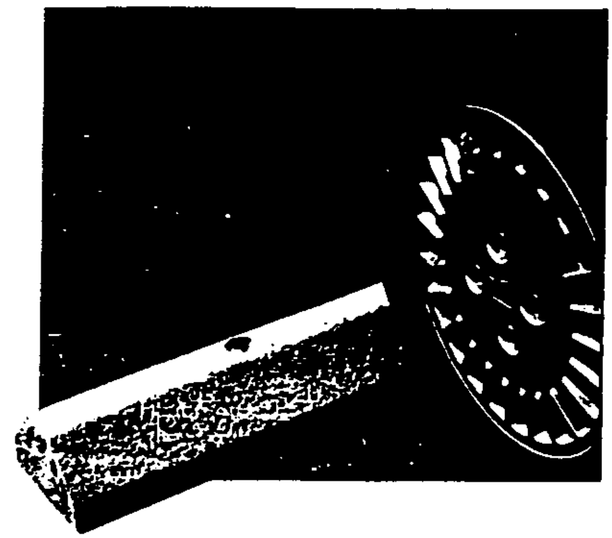
SPECIFICATIONS: Length 18" Height 2½"
Color — Black

- 100% Recycled Plastic
- Environmentally sound
- Easily fixed in place with adhesive mountings
- Designed as check warning
- 5 Year warranty against breakage in normal use



For more information, call or write to:
Hammer's Plastic Recycling Corp.
RR3 Box 182, Iowa Falls, IA 50126
(515) 648-5073
FAX (515) 648-5074

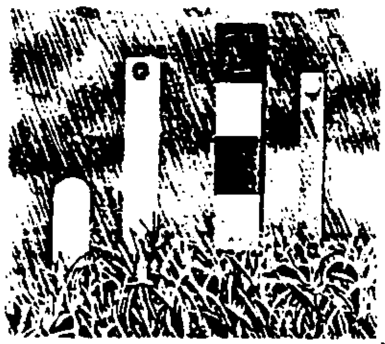
Car Stop



The solid recycled plastic parking stop!

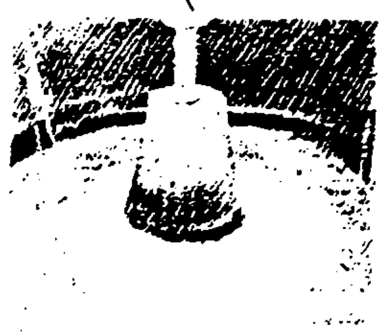
HAMMER'S PLASTIC RECYCLING CORP.

SUPERWOOD INTERNATIONAL LTD.



PRODUCT

WASTE PLASTICS



PROCESS

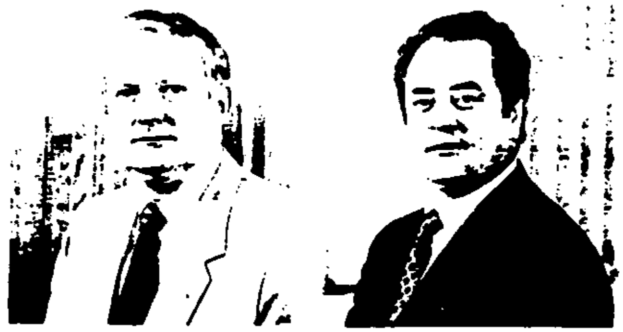
WIDE PRODUCT RANGE

PROVEN TECHNOLOGY

COMPREHENSIVE FRANCHISE/ LICENCE PACKAGE

HIGHLY PROFITABLE

THE SUPERWOOD STORY



SUPERWOOD LTD was co-founded by R.J. Bunyan and F.J. Desmond Finnegan in Dublin in 1980 and commenced operation in 1981.

The company acquired the exclusive Irish rights to manufacture and market products produced by the Klobbie process patented by Lankhorst Touwfabrieken B.V., the inventors of the process in the mid-seventies.

SUPERWOOD LTD. Irish owned, and depending exclusively on this process, has developed the process and created a wide range of products of varying size and colours, with many different uses, which it markets to municipal, industrial and agricultural customers.

In 1984, the company completed a major extension to its factory, doubled its productive capacity and commenced an extensive Research and Development programme.

SUPERWOOD INTERNATIONAL LTD. was incorporated in 1984 by the original promotors of SUPERWOOD LTD. and purchased the exclusive worldwide marketing and manufacturing rights to the Klobbie process.

Over a seven year period of design and operational development by SUPERWOOD LTD, the Klobbie process has been commercialised. SUPERWOOD INTERNATIONAL LTD manufactures the improved plant and machinery and markets it as the SUPERFLOW process.

A holding company SUPERWOOD HOLDINGS plc of which the above companies are wholly owned subsidiaries, was floated on the Irish Stock Exchange in November 1987.

The following is the published trading record of the SUPERWOOD Group

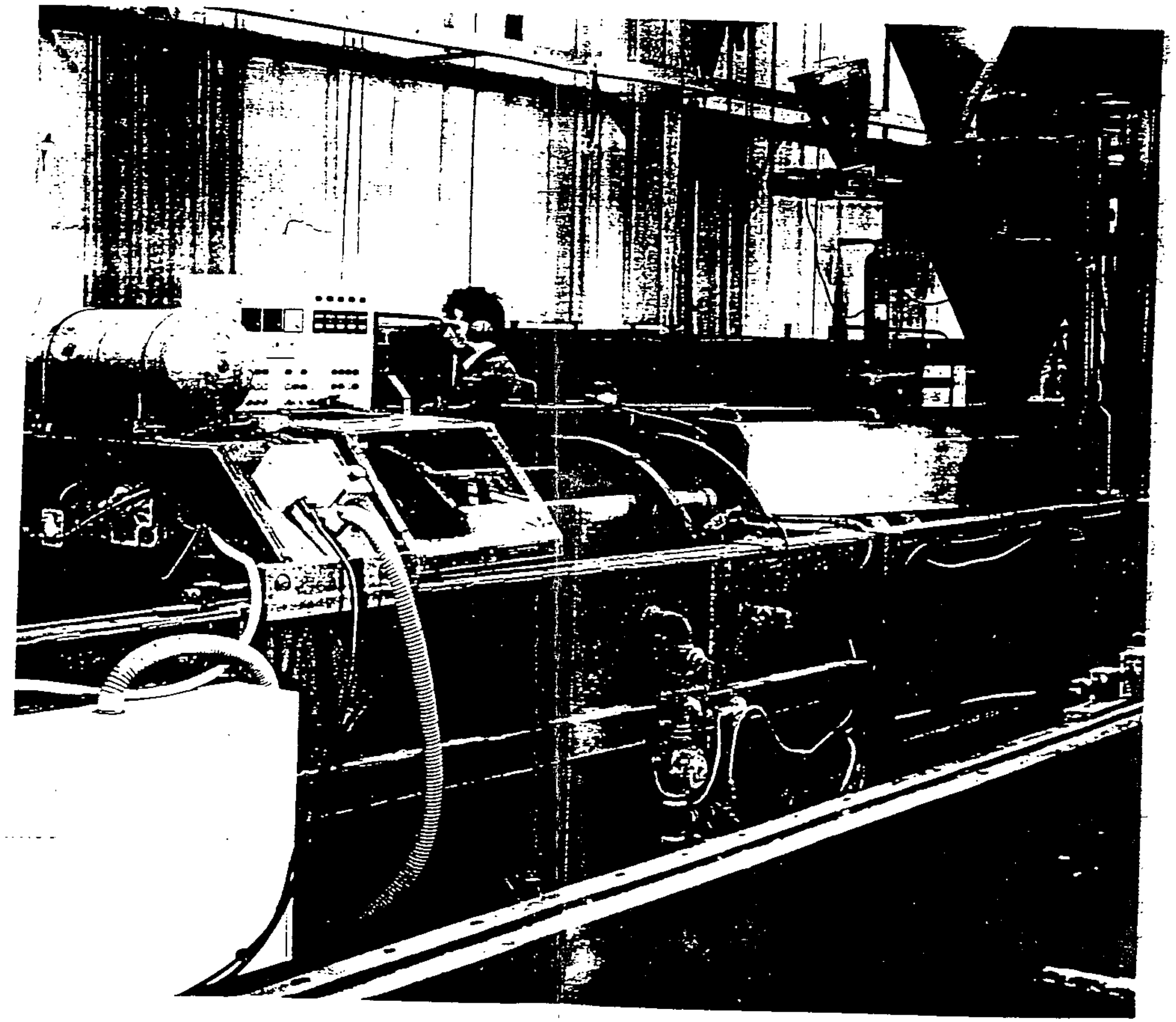
Y.E. 31.5	Turnover £000's	Net Profit £000's
1983	188	25
1984	252	[illegible]
1985	581	[illegible]
1986	621	142
1987	1,279	[illegible]
1988	2,000*	25*

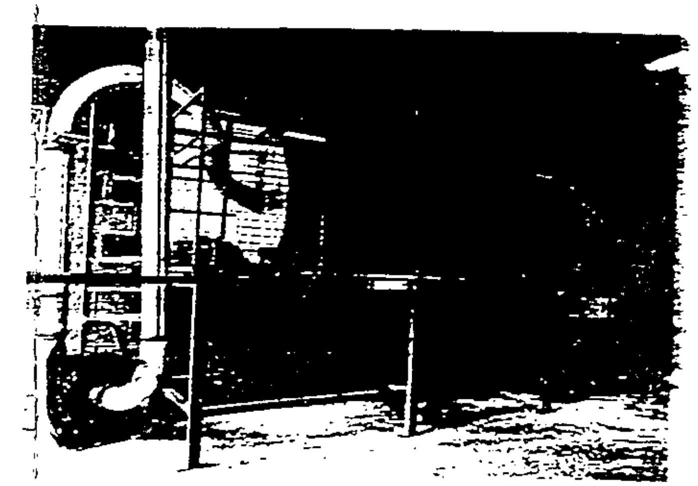
* Forecast.

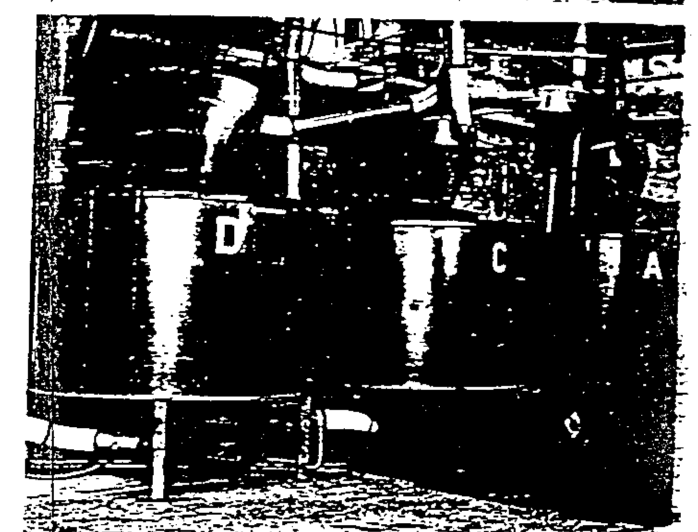
THE SUPERFLOW PROCESS:

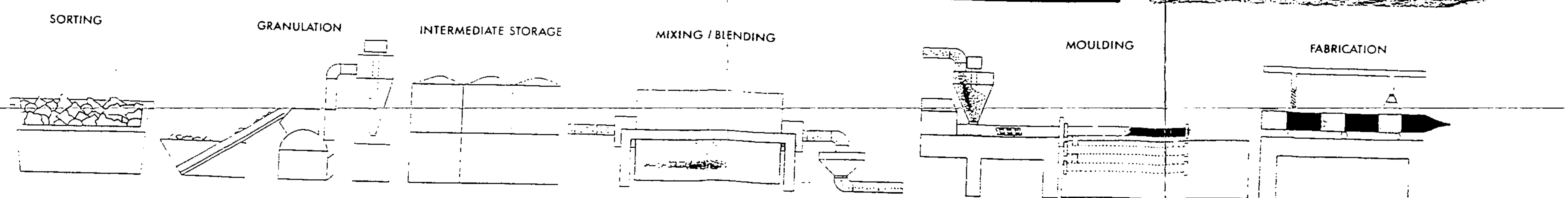
The Superflow Process consists of an extruder, which is a large steel screw in a steel barrel. The extruder is driven by a large electric motor and the friction caused by the rotating screw melts the plastic. The plasticised material is forced out through an orifice into a steel mould. The process then changes from extrusion to low pressure flow moulding. Ten moulds of similar or different cross section but of the same length, are mounted horizontally on a carousel in a large tank of water. The moulds rotate about a horizontal axis and at top dead centre position, each mould is filled in turn by the extruder. The other moulds are cooled under water while the top mould is being filled. After each moulding has been cooled in the tank of water, the moulding is ejected pneumatically. The water in the cooling tank is a closed system and is circulated through a chiller. The cooling of the moulding results in a shrinkage which allows it to be ejected from the mould. The sequence of operations are performed pneumatically and electrically and there are no hydraulic operations. The sequence of events is controlled by a microprocessor, which is programmed to carry out the various operations required.

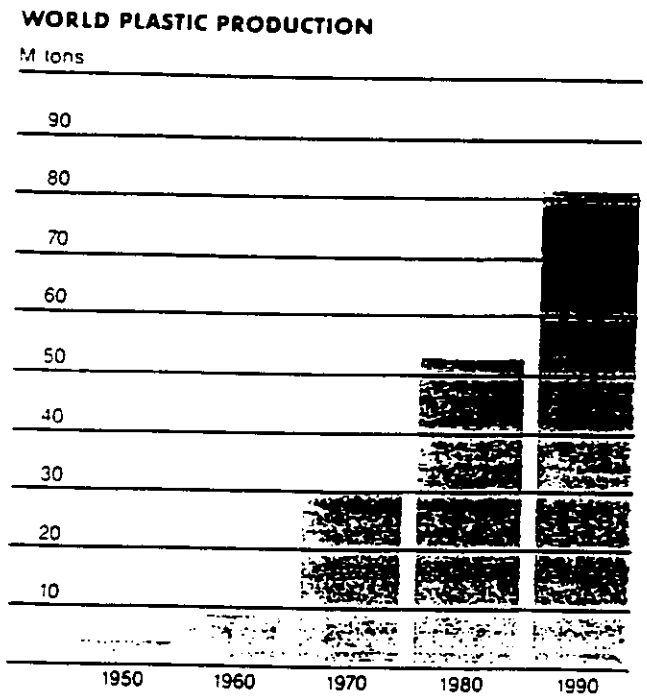
The Superflow Process can be operated manually, semi-automatically, or automatically, depending on the characteristics of the raw material and the mould configuration. The moulds are relatively cheap, being made from standard steel tube, box section or welded steel plate. The addition of blowing agents and/or fillers can vary the characteristics required in the end product to be marketed. A force feed drive may be used to feed the extruder with material of light density, i.e. film.

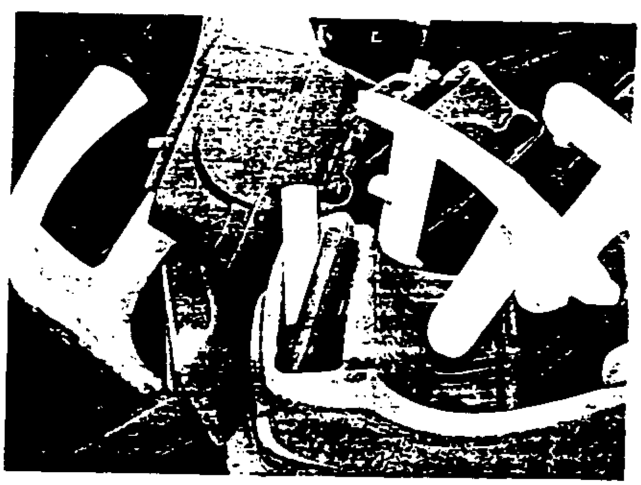












RAW MATERIALS:

The raw materials for the Superwood products are mainly thermoplastics, high and low density polyethelenes and polypropelenes. Other thermoplastics such as PET and ABS can be processed but under certain control. PVC may only be present in small proportions without special additives being added.

SOURCES:

Manufacturers of plastic articles, i.e. film, bags, tableware, syringes, toys, book bindings, trays, various domestic articles, e.g. containers and bottles.

Milk suppliers who produce their own plastic milk bottles and who have redundant and broken milk crates.

Beverage companies who use plastic bottles and containers, and who have broken beer crates. Large volumes of below standard articles, e.g. piping, ducting, plastic joints, disposable plastic medical goods.

In addition, every manufacturer of plastic articles has head waste from starting up the machine and after shutdown.

Manufacturers, distributors, and retailers have huge quantities of plastic packaging, including shrink-wrap, to be disposed of. Plastic processors, have large volumes of contaminated or sub-standard granules to dispose of from time to time.

PURCHASING PATTERNS:

Experience over seven years shows that normal patterns of purchasing raw materials are unlike normal commercial operations. Superwood normally takes supplies of material which someone else wants to dispose of. Factors such as the space occupied by the waste at manufacturer's premises, local dumping prohibitions, the cost of disposal, fire insurance conditions and attitude to waste determines the purchasing patterns and price. Basically, Superwood must be able to take the waste when it is offered. This can involve regular collections or periodic ones, and requires a large storage area to accommodate the waste. A large stock must also be held to provide against any sudden shortage.

AGRICULTURAL

Agricultural products, including stakes, slatted floors for calves and sheep, electric fence posts, gates, gate posts etc.

THE PRODUCT – SUPERWOOD

The Superflow process can produce basic solid plastic elongated product such as posts, poles, stakes, boards and a variety of similar shaped products.

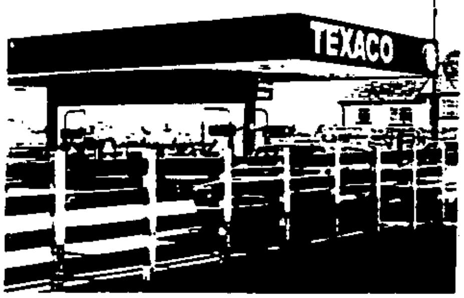
The products can vary in diameter from 12mm to 150mm or they can have a square cross section from 25mm × 25mm to 125mm × 125mm or they can have a rectangular cross section from 50mm × 25mm to 150mm × 75mm.

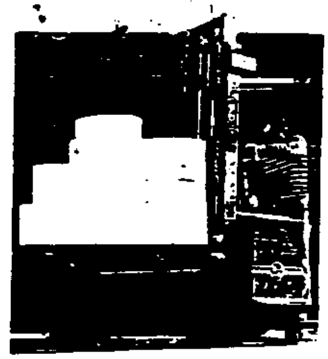
The length of the product can vary from one metre to four metres.

The structural properties of Superwood will depend on the characteristics of the raw materials. Blending the different polymers in certain proportions will enhance the ultimate physical properties of Superwood. The additions of fillers such as fibreglass, woodflour, chalk and other plastics can significantly alter the characteristics of Superwood.

Superwood – better than wood – is rot proof and impervious to fungus, insects, water, brine and whey. It has no grain, no knots and does not splinter. It can be nailed, screwed, sawn, planed and sanded. It does not require painting for outdoor uses, but it can be painted a specific colour if required, using a special painting process devised by Superwood Ltd. A method of coating a mixed colour plastic with a one colour plastic has also been developed.

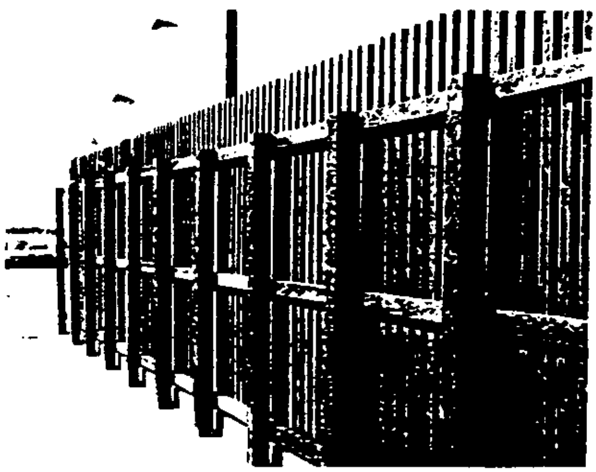
A complete range of road traffic furniture has been developed by fabrication techniques. Animal flooring, fencing and pallets are assembled from the basic products.

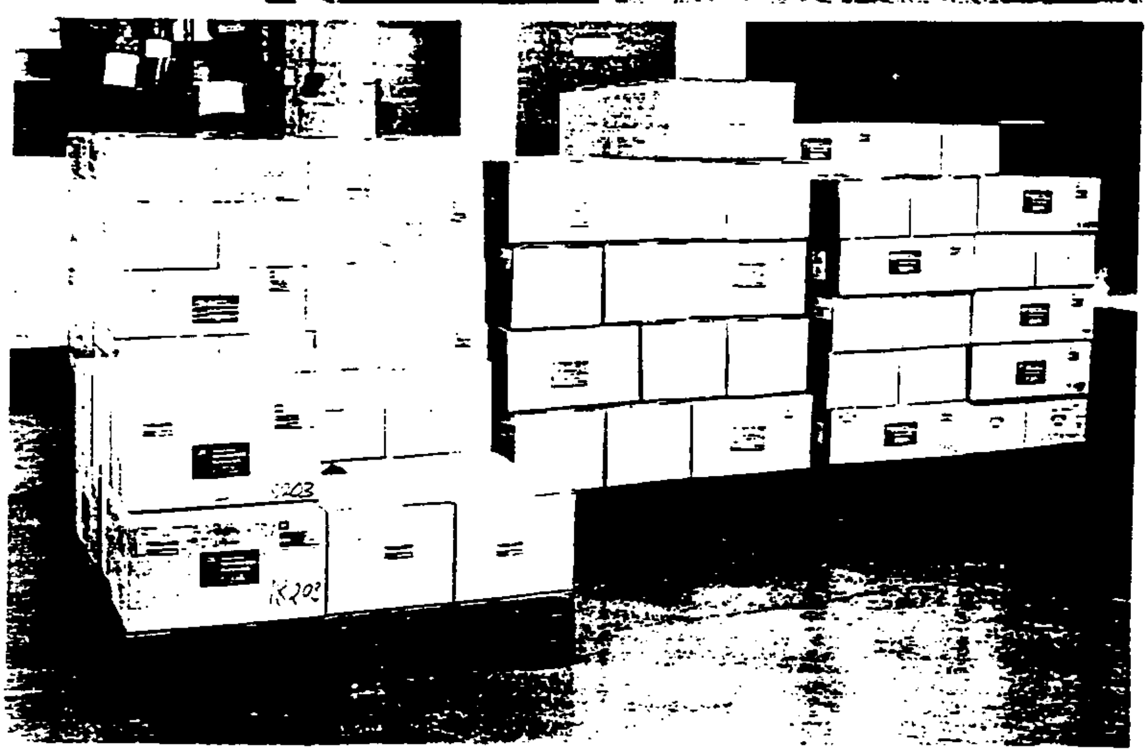


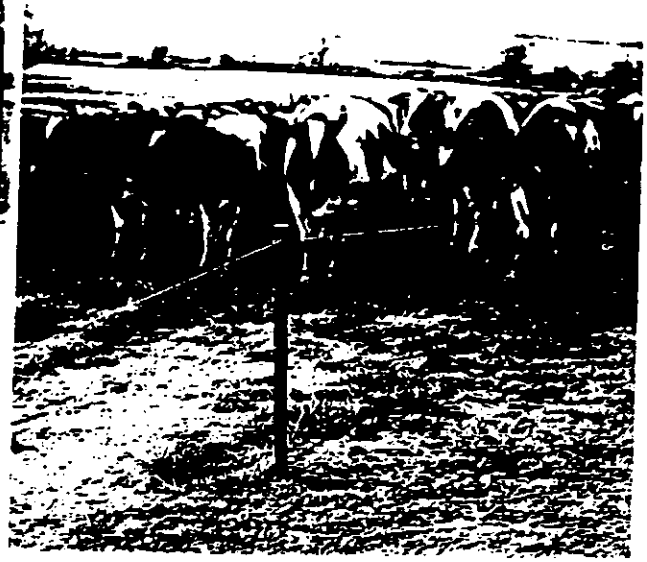


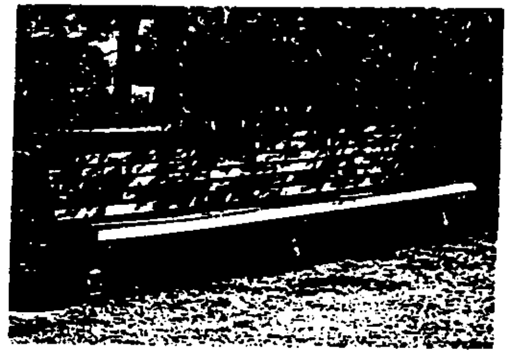
INDUSTRIAL

Industrial products, including pallets, underground cable covers, coastal and river bank protection units, trailer flooring and fencing, including palisade, picket, post and rail, snow posts and DIY kits.



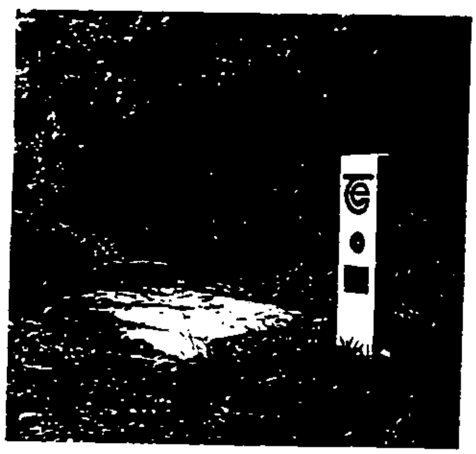


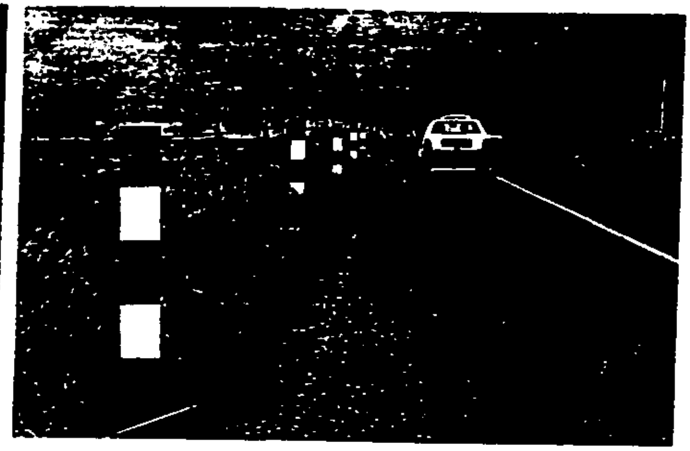


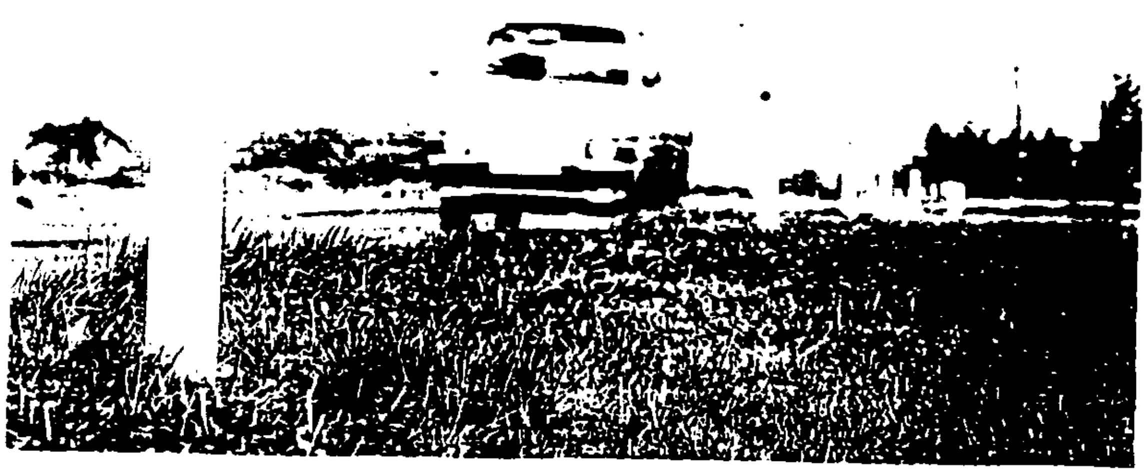


MUNICIPAL

Street and road furniture, including delineators, junction markers, hazard markers, motorway vergeposts, locating posts, bollards, poles, crash barriers, marker posts for sanitary, water, telecommunications, electrical and gas services, planters, tree guards and benches.







SUPERWOOD©

Solid Plastic Roadside Marker Posts

HAZARD MARKER

1.2m(4') black posts with white bands and tapered ends. Recessed corner cube reflector or mounted rectangular tape on metal backing, on the front and rear.

DIMENSIONS

Height: 1.2m(4')
Width: 100 & 150mm (4" & 6")
Depth: 25mm(1")

FEATURES

Recessed reflectors and tape are fitted with anti-theft screws. All markers have a retaining peg as optional. 6 models and only 3M reflective materials used.

MOTORWAY VERGE POST

1.5m(4'5") pointed white Superwood post, with blue metal plate, 1100sq.cm.(173sq.ins) on the front face and folded to roadside edge. There is a red reflective 3M strip below this, 150sq.cm.(23sq.ins), with a telephone symbol stamped on the roadside edge.

DIMENSIONS

Height: 1.5m(4'5")
Width: 100mm(4")
Depth: 50mm(2")

FEATURES

Mounted with galvanised anti-theft screws and the ground level is marked with a blue metal strip. Retaining peg or housing available. 3 models.

KEY TO PHOTOGRAPH
[illegible] TOP LEFT
1–6 Black hazard markers with white stripes 4" high x 4" wide [illegible] with 3M reflective tape on metal backing [illegible] corner cube reflectors.

7–9 Motorway & 'A' road verge posts 1.35m high with 3M reflective disc plus telephone symbol and directional arrows.
10–13 Black hazard markers with white stripes 4" high x 6" wide x 1" thick with 3M reflective tape.
14–16 Blue locating posts with corner cube reflectors plus road number and locating numerals.

JUNCTION MARKER

1m(3'3") white post with tapered (long or short) end and 60mm (2.4") single corner cube green recessed reflector on one side and white recessed reflector on the other.

DIMENSIONS

Height: 1m(3'3") or any height.
Width: 80&100mm (3.2" & 4")
Depth: 40&50mm (1.6" & 2")

FEATURES

Recessed reflectors are fitted with anti-theft galvanised screws and a retaining peg is optional. 4 models.

DELINEATOR

1m(3'3") white post with tapered (long or short) end and one or two 60mm(2.4") corner cube reflectors, recessed.

DIMENSIONS

Overall Height: any height
Width: 80&100mm (3.2" & 4")
Depth: 40&50mm (1.6" & 2")

FEATURES

Reflectors are recessed using spreading plastic rivets or non-retractable galvanised screws. A retaining peg is optional and any colour or size reflector is available.

KEY TO PHOTOGRAPH
FRONT RIGHT
1–5 Delineators and blank white post 1m high x 80mm x 40mm with corner cube reflectors, (any colour).
6–8 Delineators 1m high x 100mm x 50mm with corner cube reflectors, (any colour).
9 Black post 2m high with corner cube reflectors.
10–11 Delineators 889mm high x 80mm x 40mm with pointed base for easy driving using a mallet or driving dolly.
12 Blank white post 1.05m high x 100mm x 50mm

REMAINING FRONT PHOTOGRAPH
Bottom Centre Road Furniture in use

LOCATING POST

1m(3'3") blue post with tapered (long or short) end and 60mm (2.4") corner cube reflector, red on one side and white the other, recessed into the post. Locating numerals in sequence and the road number are hot foil stamped into the post, on the right hand side.

DIMENSIONS

Height: 1m(3'3")
Width: 80mm(3.2")
Depth: 40mm(1.6")

FEATURES

Recessed reflectors are fitted with anti-theft galvanised screws and a retaining peg is optional.

KERB REFLECTOR

195mm(7.7") Superwood with 2 red 60mm(2.4") corner cube reflectors, recessed.

DIMENSIONS

Width: 100mm(4")
Length: 195mm(7.7")
Depth: 25mm(1")

FEATURES

Superwood is pre-drilled for mounting

POLE/BARREL REFLECTOR

150mm(6") length of black Superwood with 60mm(2.4") corner cube reflector, recessed.

DIMENSIONS

Height: 150mm(6")
Width: 80mm(3.2")
Depth: 40mm(1.6")

FEATURES

Superwood is pre-drilled for mounting and the reflectors are fitted with anti-theft galvanised screws. Any colour reflector available.

WALL REFLECTOR

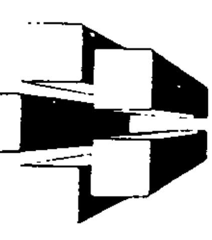
300mm(11.8") triangular Superwood section with 60mm(2.4") corner cube recessed reflector, available in any colour, in one side only or both sides for junctions.

DIMENSIONS

Length: 300mm(11.8")
Base
Width: 85mm(3.4")
Depth: 42mm(1.7")

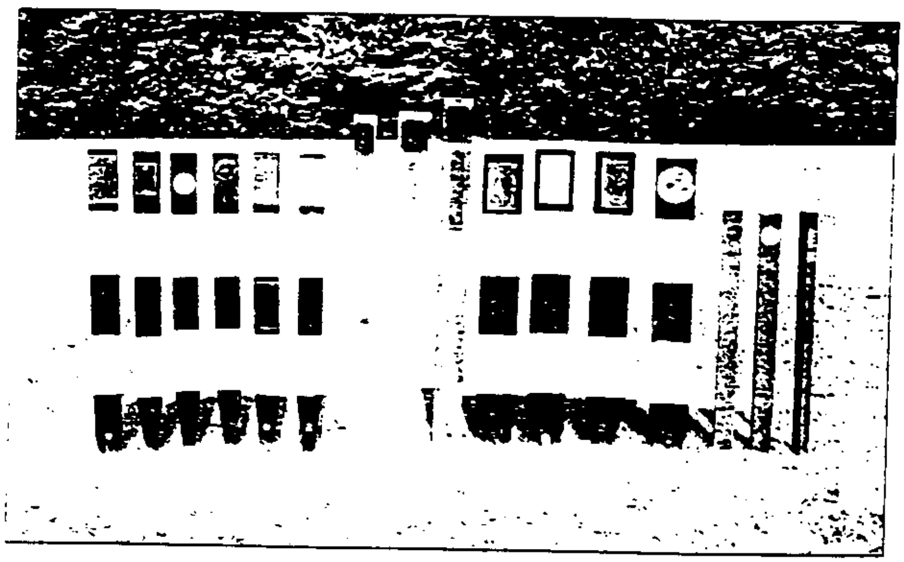
FEATURES

Superwood is pre-drilled for mounting and is available in black, white and brown.



SUPERWOOD LTD
[illegible]
Tel. 03535 803913 [illegible]
[illegible] 33322 [illegible]

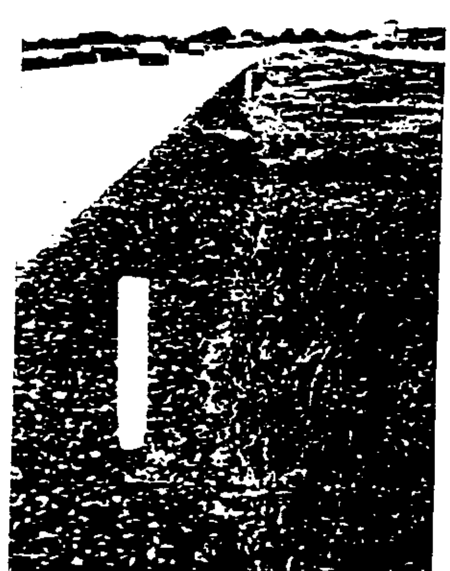
Solid Plastic Roadside Marker Posts ... today's alternative to traditional materials



Superwood solid plastic motorway verge posts, hazard markers, delineators and junction markers are:

- TOUGH, DURABLE, CHEAP
- WILL NEVER ROT OR CORRODE
- HAVE NO KNOTS OR SPLINTERS
- HOLD THEIR COLOUR
- DO NOT BECOME BRITTLE
- NEED NO MAINTENANCE

They will withstand human and mechanical abuse, especially motorway and roadside [illegible] thrown up by fast traffic. They [illegible] significantly better than other hollow plastic products and no expensive timber [illegible] necessary (thereby [illegible] pilferage). The Superwood [illegible] are the ideal replacement for the timber roadside [illegible] been used for [illegible] [illegible] and [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] be driven into [illegible] mallet or a driving [illegible]



The best of specified materials are used, eg. 3M reflective tape and all the products conform to The Traffic Sign Regulations and General Directions 1981 while also having Dept. of Transport and Dept. of the Environment approval.

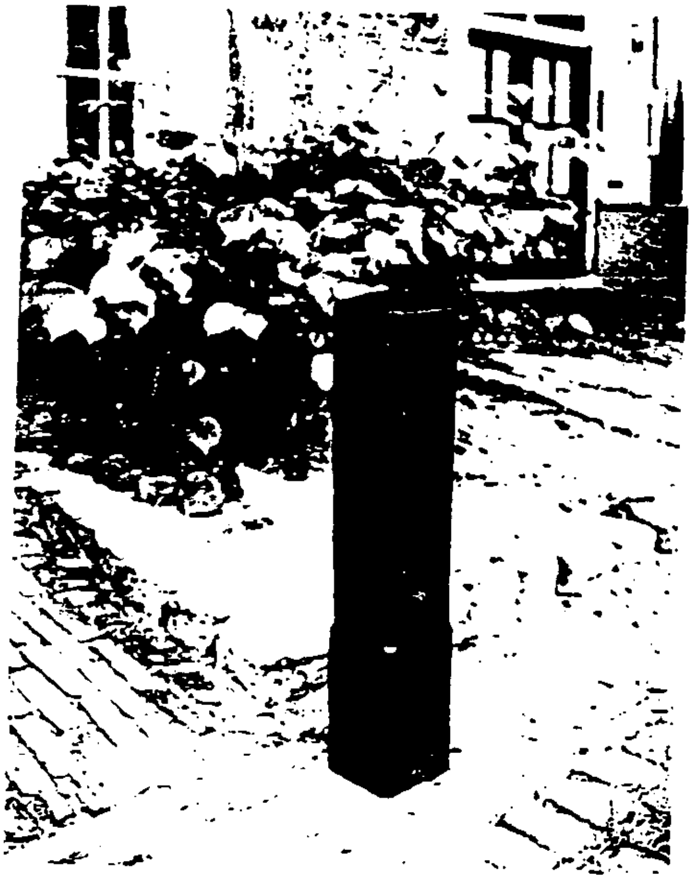
The products have been used extensively in the UK, Northern Ireland and the Republic of Ireland for the past four years.

All posts can be personalised with the road name and sequential locating numerals hot foil stamped into the plastic eliminating the [illegible] [illegible] plates and the worry of the weathering of the adhesive used on the other hollow plastic products which results in the reflective tape falling off.

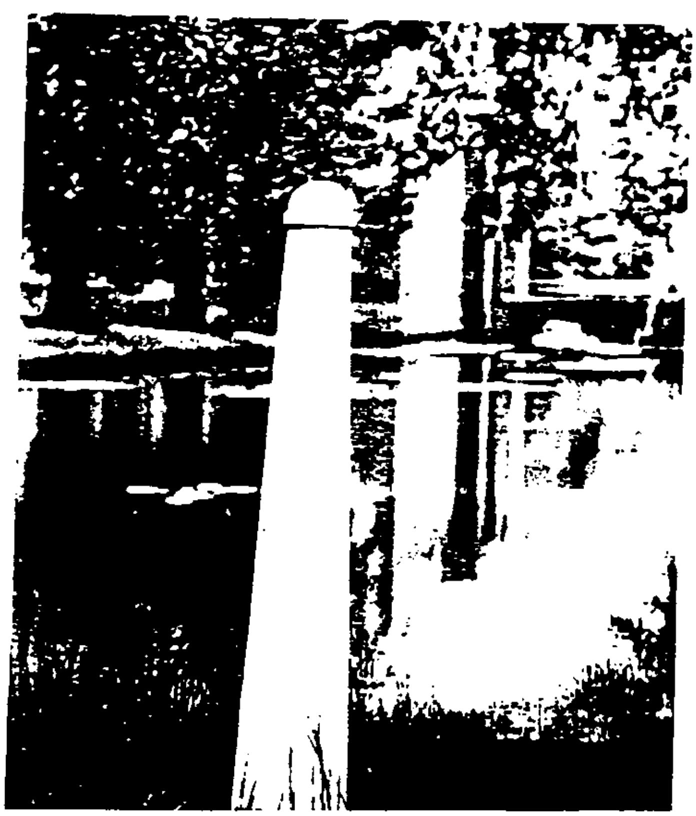
Superwood solid plastic roadside posts make a real contribution to road safety and help reduce the accident rate because [illegible] and survive [illegible] hollow plastic [illegible] [illegible] more [illegible] [illegible] stations [illegible]

So Superwood ... today's alternative for today and tomorrow

BELGIUM RECYCLING COMPANY B.V.B..



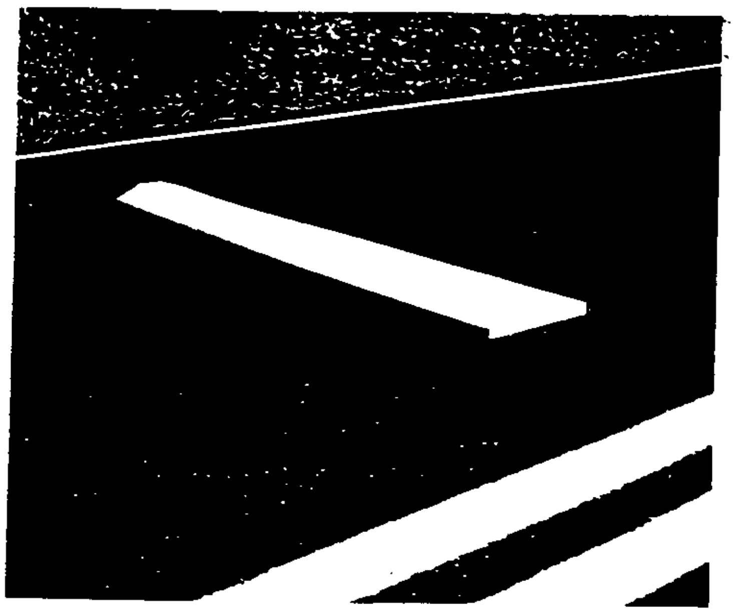
MIXED PLASTIC PRODUCTION SYSTEMS...



AND IT'S PRODUCTS

PLASTIC SPEED BUMPS & CURB EDGINGS

PLC PLASTIC SPEED BUMPS & CURB EDGINGS possess all the material, installation and maintenance features of our Parking Stops to help provide lower cost yet more attractive parking facilities



SPEED BUMPS

EASY TO INSTALL

Using none of the heavy installation equipment required with asphalt bumps PLC SPEED BUMPS go down easily with lag bolt fasteners.

CONVENIENT MOBILITY

PLC PLASTIC SPEED BUMPS are easily moved to accommodate changing traffic patterns or to avoid snow plow damage.

CURB EDGINGS

[illegible]

This quality low cost product can be the answer for your parking lot curb problems

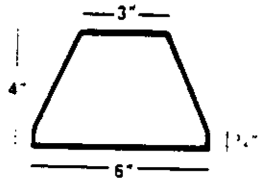
[illegible]

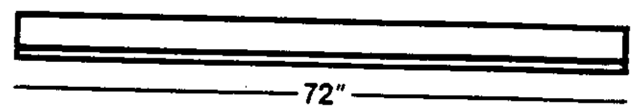
Dimensioned [illegible] asphalt [illegible] PLC MOUNDED CURB [illegible] cost [illegible] [illegible]

All PLASTIC LUMBER COMPANY PRODUCTS are easy and inexpensive to install...An installation brochure is available upon request.

PLASTIC PARKING STOPS

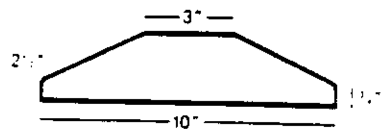
Standard colors of yellow, white and handicap blue are always in inventory. Specialty colors and color matching to corporate colors are available upon request.

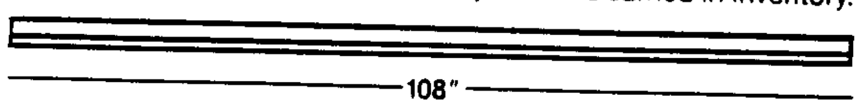




SPEED BUMPS

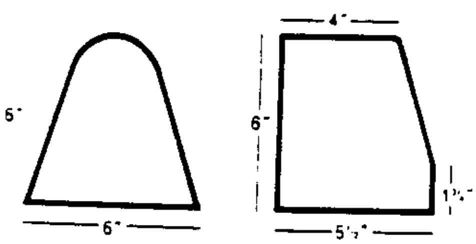
Safety Yellow is carried in inventory.

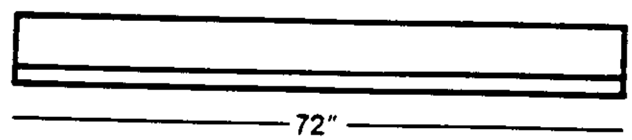




CURB EDGINGS

Asphalt black is carried in inventory.





5 YEAR WARRANTY

If you discover a defect in a Plastic Paving Maintenance Product, normal wear and tear excepted, The Plastic Lumber Company, Inc., will replace the Plastic Paving Maintenance Product at no charge to you provided: (1) you return the item to be replaced to The Plastic Lumber Company, Inc., in Akron, Ohio, within sixty (60) months from the date of purchase, and present proof of purchase and (2) you installed the Plastic Paving Maintenance Product as directed. Replacement product will be shipped FOB from the nearest distribution center.

ALL IMPLIED WARRANTIES ON PLASTIC PAVING MAINTENANCE PRODUCTS, INCLUDING IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, ARE LIMITED IN DURATION TO SIXTY (60) MONTHS FROM THE DATE OF THE ORIGINAL PURCHASE OF THE PLASTIC PAVING MAINTENANCE PRODUCT. IN NO EVENT WILL THE PLASTIC LUMBER COMPANY, INC., BE LIABLE FOR DIRECT, INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES RESULTING FROM ANY DEFECTIVE PLASTIC PAVING MAINTENANCE PRODUCTS. THE WARRANTY AND REMEDIES SET FORTH ABOVE ARE EXCLUSIVE AND IN LIEU OF ALL OTHERS, ORAL OR WRITTEN, EXPRESS OR IMPLIED.

For more information call or write us:

THE PLASTIC LUMBER COMPANY, INC.
P.O. BOX 80075
AKRON, OHIO 44308-0075
216 762-8989

FAX 216 434-7905

PRINTED ON RECYCLED PAPER

Plastalloy™

Plastalloy™ products are alloyed from post-use plastics. They are free from rot, splinters and cracking. Plastalloy™ products will not absorb moisture or harbor bacteria. They are solid, colorfast, and will offer years of maintenance free life. There are many uses and advantages of Plastalloy™ products. please talk with our representative concerning your particular needs.

Buy Recycled Products.
They're Worth Our Environment

Don't throw away a good thing.
RECYCLE! Michigan

PLEASE CONTACT:

PROCESSED PLASTICS COMPANY

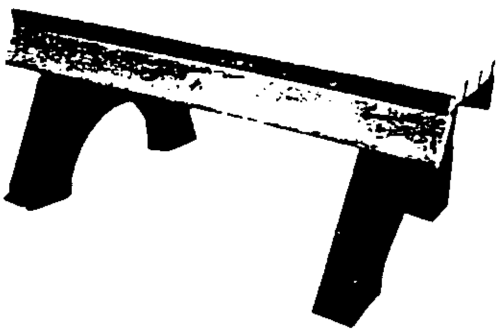
P.O. BOX 68 IONIA, MICHIGAN 48846

(616) 527-6677

Plastalloy™

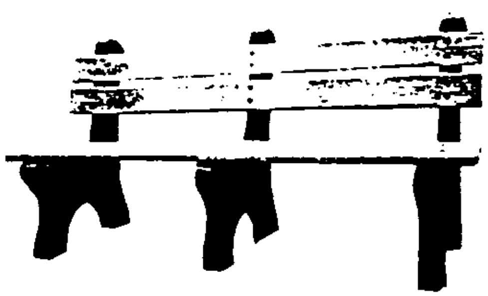
a product of
PROCESSED PLASTICS COMPANY
Ionia, MI 48846
(616) 527-6677

"RECYCLED PLASTIC PRODUCTS"

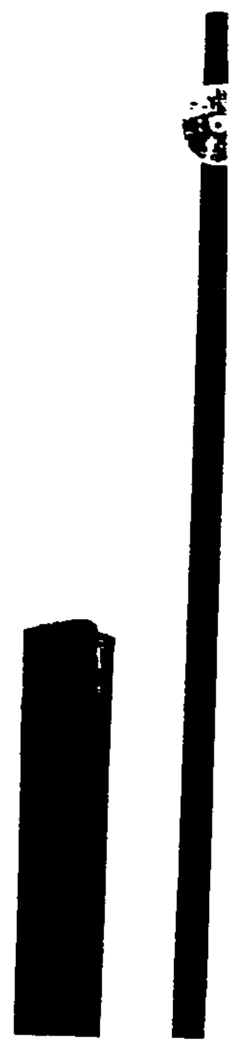


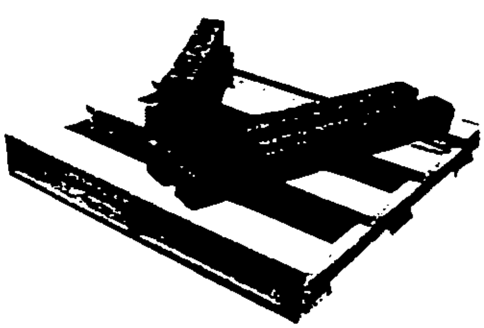
BENCHES
- Locker Rooms
- Parks
- Backyards
- Golf Courses
- Outdoor Activity Areas

PALLETS and BLOCKING
- Tool & Die Shops
- Foundries
- Chemical Suppliers & Manufacturers
- Machinery Builders
- Steel Suppliers
- Trucking — lumber, steel, equipment . . .



MARKERS
- Parking Lots
- Trails
- Drive and Driveways
- Golf Courses
- Roadways
- Restricted Areas





OTHER USES & APPLICATIONS
- Docks and Dock Bumpers
- Picnic Tables
- Seawalls and Grognes
- Boardwalks
- Landscaping
- Fence and Fence Posts

PROCESSED PLASTICS COMPANY

[illegible]

PLASTALLOY
TECHNICAL INFORMATION

Plastalloy is made from commingled plastic thus it has a general range of physical properties. The plastics are blended to produce the desired and most optimal characteristics possible for the end use of the product.

Density - 55 to 60 pounds per cubic feet.

Compressive Strength - 3,500 pounds per square inch.

Nail Holding Ability - 40% to 50% greater than wood at ambient temperatures.

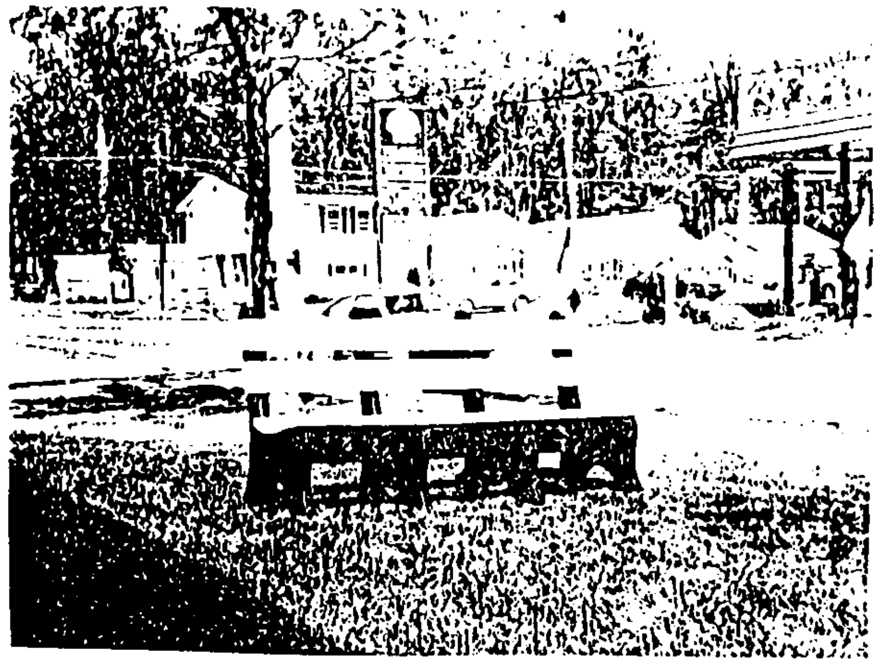
Unaffected By:
- Rot
- Insects
- Fungus
- Organic Solvents at ambient temperature.*
- Acids and alkalis at temperatures up to 150°F

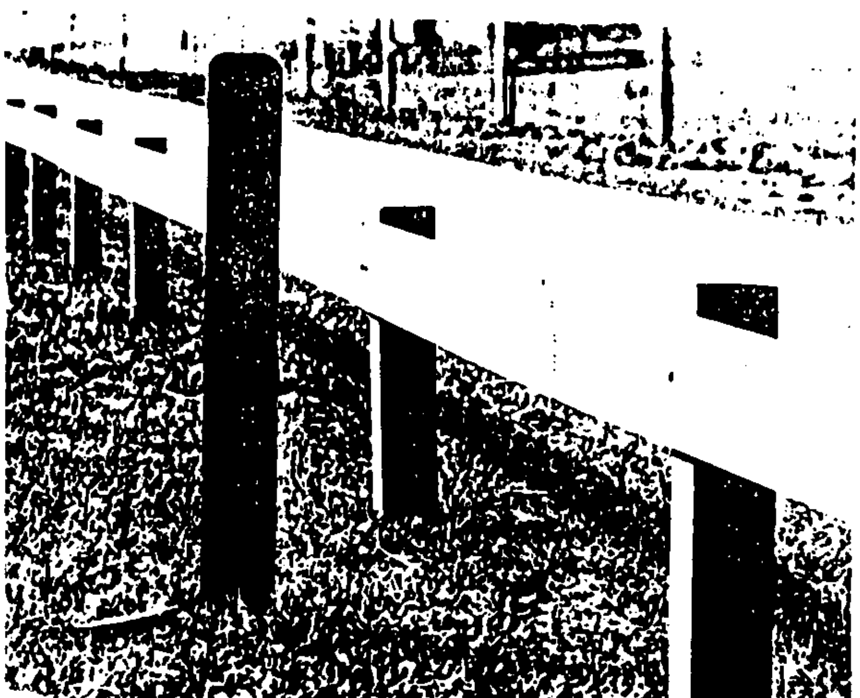
Electricity - will not conduct (insulator).

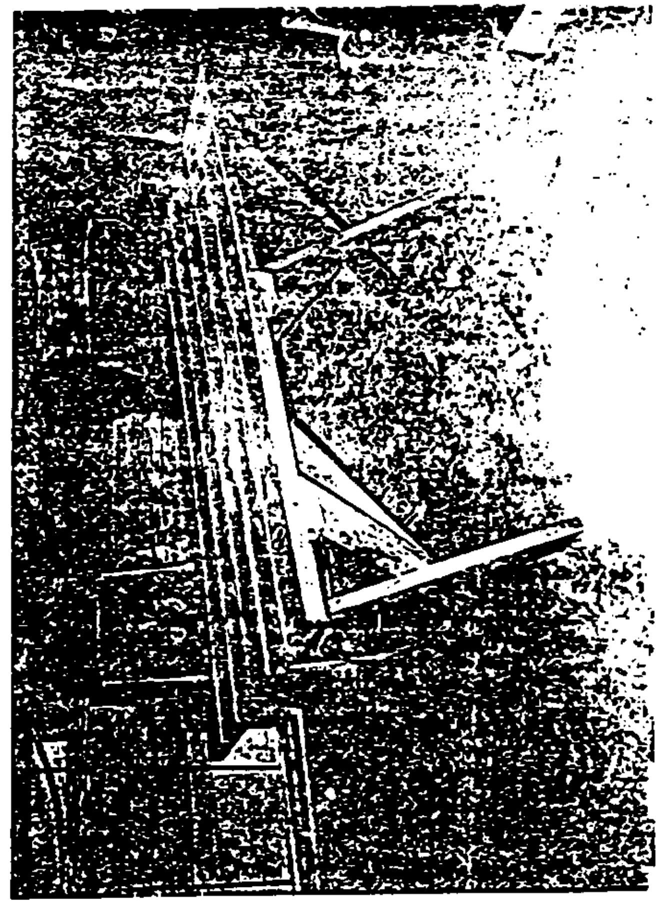
General Characteristics - resembles dense wood and may be drilled, screwed, sawn, bolted, nailed, etc. (Will not splinter.)**

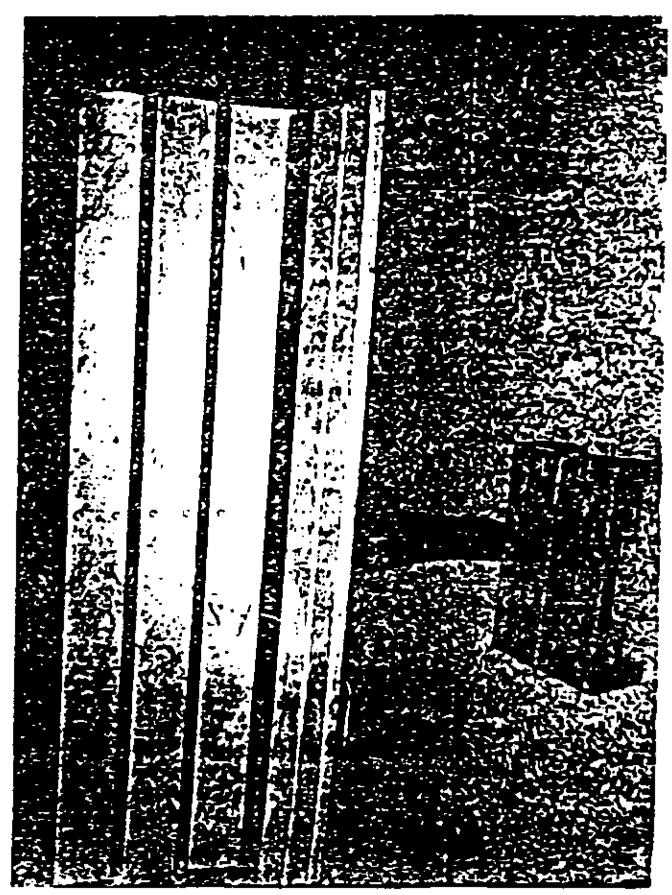
* May not be suitable for some solvents, test before using.
** Most fastners work best when holes are pre-drilled.

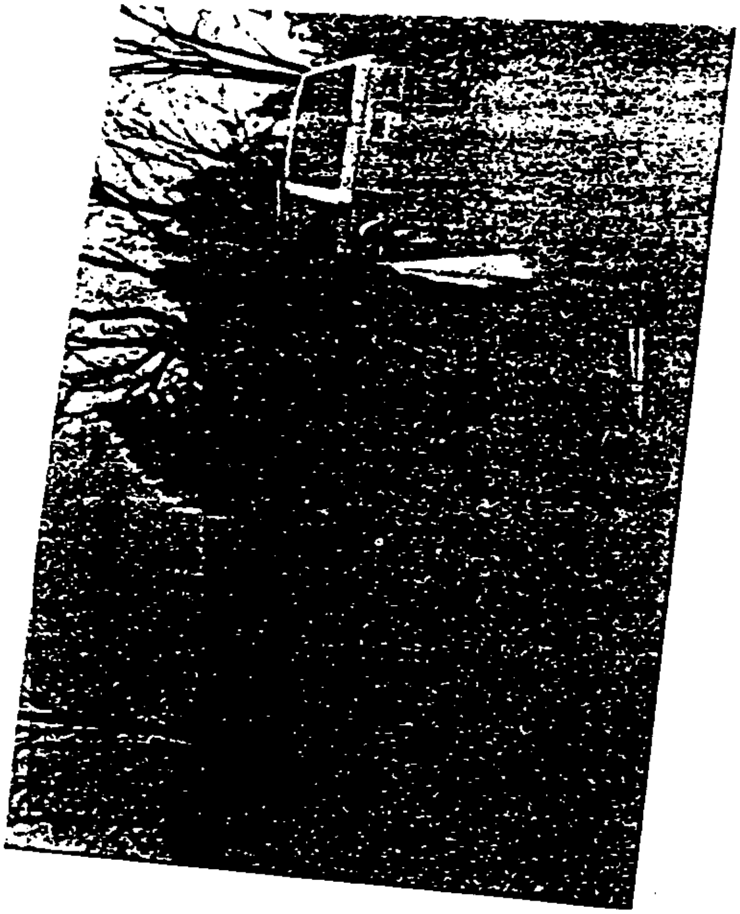

PROCESSED PLASTICS
MORTON

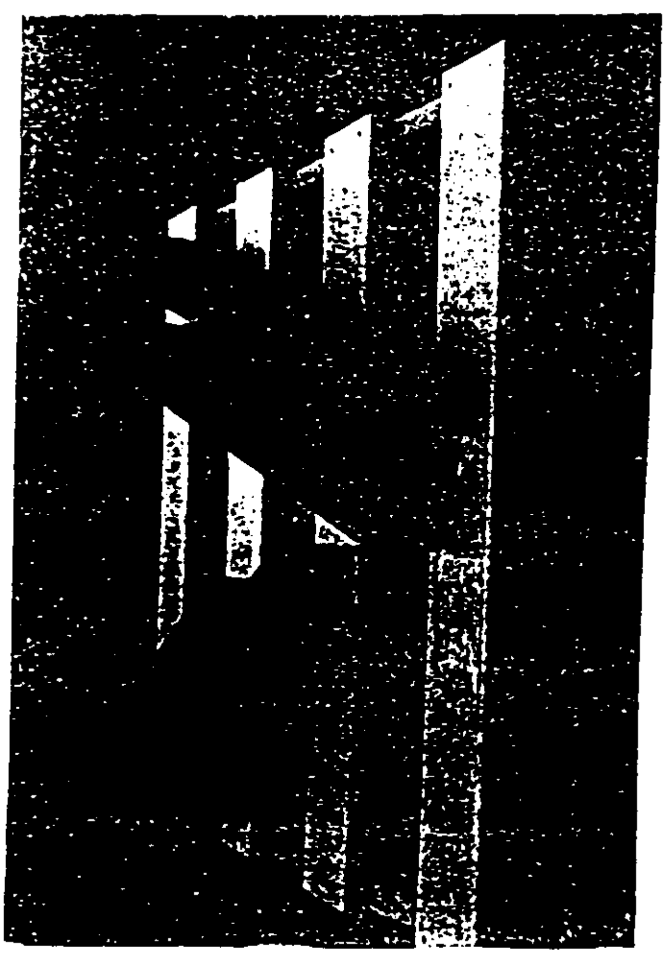


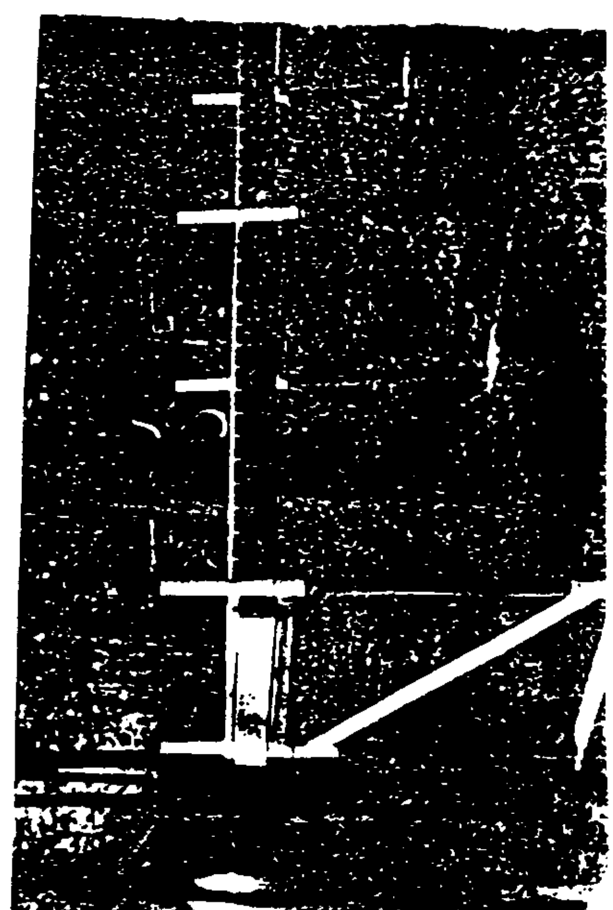






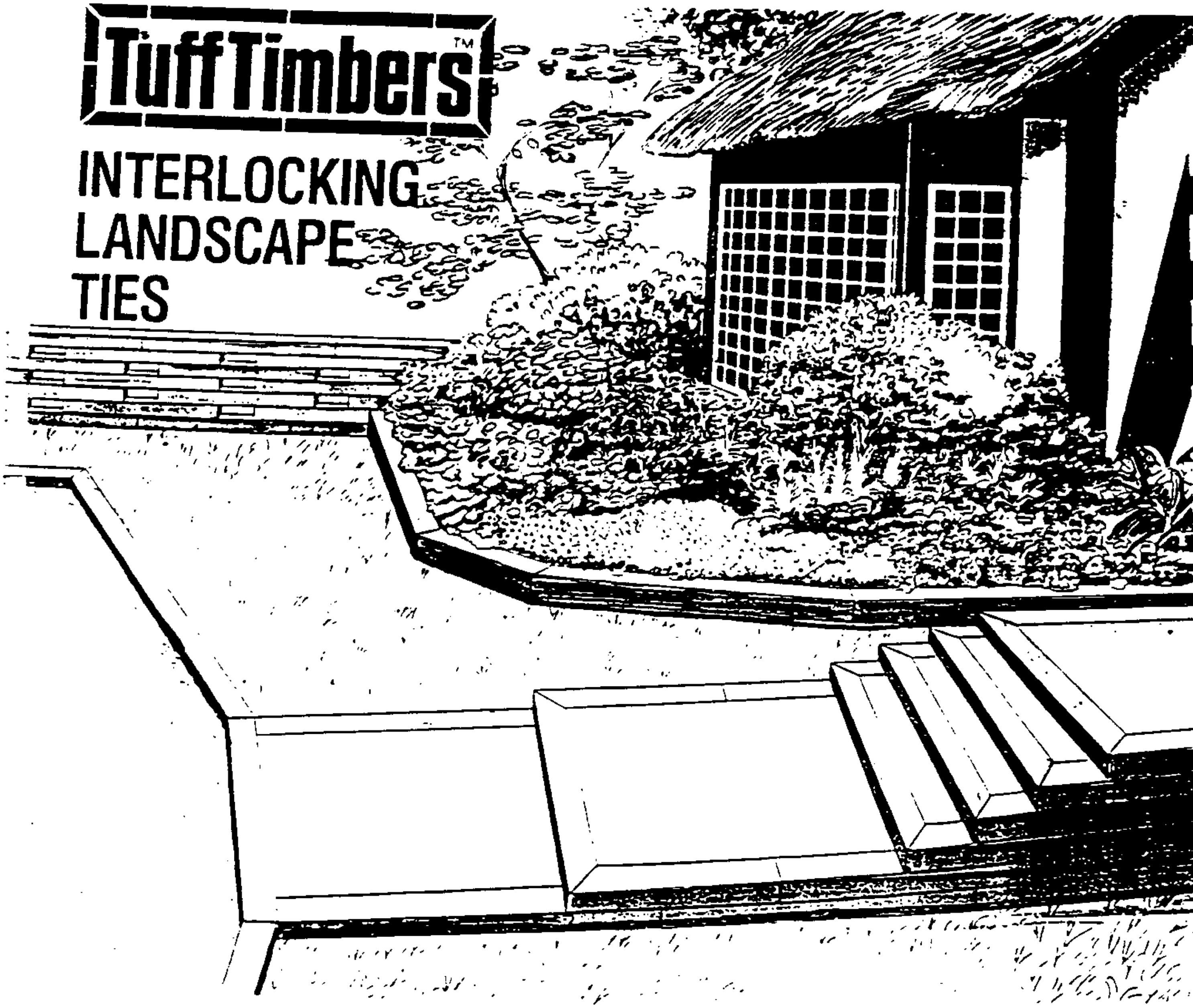






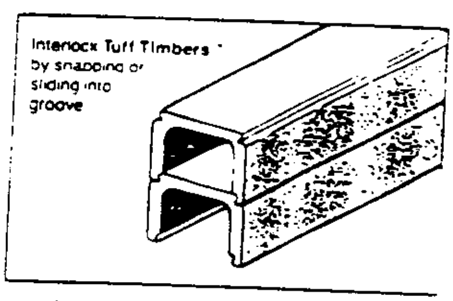
TuffTimbers™

INTERLOCKING LANDSCAPE TIES



Beautify Home and Garden With Easy-To-Use, Versatile Tuff Timbers™ Interlocking Landscape Ties

Tuff Timbers™ Interlocking Landscape Ties are the revolutionary alternative to treated exterior wood products. These ties snap or slide together, requiring no tools or special skills.



The wood tone finish can be retained for a natural look, or can be painted. In addition, Tuff Timbers™ can be ■ sanded ■ planed ■ sawed ■ nailed ■ screwed ■ painted ■ drilled or ■ bolted. The standard lengths, when combined with right and left corners and end caps, form a system with limitless applications for home, garden and lock. Durable, waterproof and nontoxic, Tuff Timbers™ are a revolutionary home building product — unsurpassed for strength, beauty and versatility.

Lifetime Guarantee Against Rot, Decay, Warping, Cracking and Insect (Termite) Infestation

Tuff Timbers™ are guaranteed against those elements which plague traditional, and often more expensive, wood ties. They will withstand ground contact indefinitely and are guaranteed against rotting, warping, cracking and insect (termite) infestation. Hearthbrite Industries, Inc. will replace any timber or corner piece exhibiting these problems ... FREE, exclusive of labor and shipping costs.

DURABLE

Tuff Timbers™ are the strongest and most durable product of their kind on the market today. They never need to be treated, as many exterior wood products require, thanks to the patented plastic polymerization process employed by Hearthbrite Industries, Inc.

WEATHERPROOF

The patented polymerization process has made **Tuff Timbers™** impervious to heat, cold and moisture. From Wisconsin to Florida, Texas to Tennessee, US-made **Tuff Timbers™** are the ideal choice for home and garden improvements.

WATERPROOF

Tuff Timbers™ are waterproof in salt or fresh water, and completely weatherproof. This makes them the ideal building material in any climate. **Tuff Timbers™** absorb less than one percent salt or fresh water. In fact, where normal wood absorbs 5.63% water, **Tuff Timbers™** take in a nominal 0.43%!

SAFE, NONTOXIC

The patented process used in the manufacture of **Tuff Timbers™** products was developed by Hearthbrite utilizing real wood fibers, recycled natural materials and nontoxic thermoplastics. Traditional landscape ties are treated with arsenic derivatives requiring extraordinary safety precautions in its use, construction and disposal.

DIMENSIONALLY STABLE

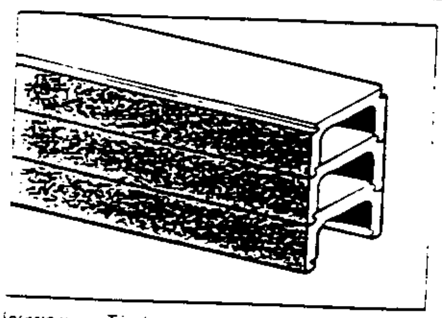
Tuff Timbers™ will not swell due to temperature or moisture variations. Subsequently, they will maintain their dimensional stability for easy construction and uniform appearance. Traditional landscape ties can vary by as much as half an inch.

LIGHTWEIGHT

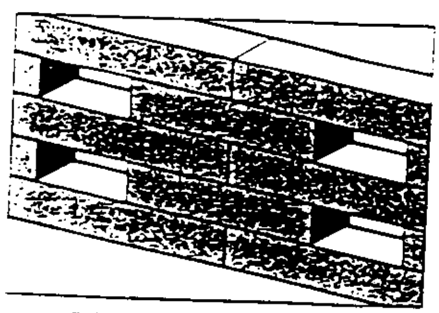
These amazing timbers are also lightweight (20 lbs per 8' length) making them easy to use in tough conditions — like building a dock, or creating a retaining wall. Home and garden beautification becomes a family project when all members of the family can easily handle the materials.

ECONOMICAL

All purpose **Tuff Timbers™** cost less than most traditional treated wood ties, and last indefinitely. Low priced promotional ties, and most treated landscape ties, are not rated for below ground contact, and their cost is in direct relation to the degree of treatment.



Interlocking **Timbers** stack to create walls, borders

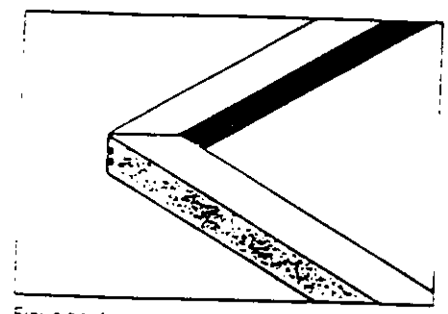


...ed Tuff Timbers ... create attractive lattice effect in fences

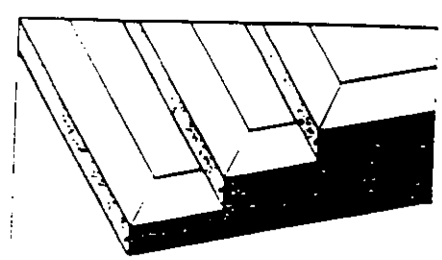
DOZENS OF USES

- *WALLS*
- *FENCES*
- *BORDERS*
- *STEPS*
- *LANDSCAPE AND NURSERY TIES*
- *RETAINING WALLS*
- *DECORATIVE WALLS*
- *FLOWER BED BORDERS*
- *GARDEN BORDERS*
- *WALKWAYS*
- *BULKHEADING*
- *PLANTERS*
- *SANDBOXES*
- *MAILBOX POSTS*

THE USES OF THE VERSATILE TUFF TIMBERS™ INTERLOCKING LANDSCAPE TIES ARE LIMITED ONLY BY YOUR IMAGINATION



Finish border treatments with mitered Tuff Timber™ CORNERS.



Stairs: Tuff Timber™ steps and retaining walls are guaranteed for a lifetime

TERMS OF LIFETIME GUARANTEE

Tuff Timbers™ are Guaranteed for Life Against

- Rot or decay
- Warping or cracking
- Insect (termite) infestation

Hearthbrite Industries, Inc. will replace FREE any **Tuff Timber™** which rots, decays, cracks, warps or becomes infested with insects. FREE replacement does not include shipping or labor charges. A written **LIFETIME GUARANTEE** will be send upon receipt of Proof of Purchase (cash register receipt and UPC code from label) along with our handy Instructional and Idea Manual, explaining the many uses of Tuff Timbers™ **Interlocking Landscape Ties.**

SIZES

[illegible]

Tuff Timbers

Hearthbrite Industries, Inc.
.2 Windsor Industrial Par...
P.O. Box 36, W... N...
(609) 448-1500

Tuff Timbers™

Easy-To-Use INTERLOCKING LANDSCAPE TIES

1 TIE—3½" x 5½" x 4 FEET RIGHT CORNER

DURABLE • WEATHERPROOF • WATERPROOF • SAFE, NONTOXIC
USE ABOVE OR BELOW GROUND

LIFETIME GUARANTEE

AGAINST

[ ] Rot or Decay
[ ] Warping or Cracking
[ ] Insect (Termite) Infestation

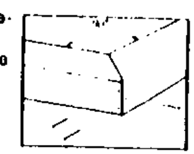
Hearthbrite Industries, Inc will replace FREE any Tuff Timber™ which shows evidence of these problems. A written LIFETIME GUARANTEE will be sent upon receipt of proof of purchase

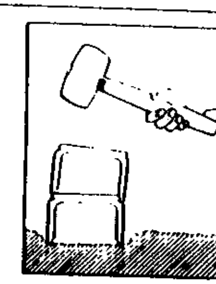
EASY TO USE:

1. Lay Tuff Timbers™ down on flat surface, or directly into the ground

2. Interlock Tuff Timbers™ by snapping or sliding into groove. Once the Timbers are interlocked, they will stay in place without fasteners. Fourpenny galvanized nails may be used if desired.

3. Tuff Timbers™ Corners create precise borders. Lay out right and left corner pieces, facing one another. Bring the angled corners together leaving no air space. Corners may be nailed, drilled, screwed or bolted into place. Continue interlocking Tuff Timbers™ as before.





Tuff Timbers™ Can Be: • Sanded • Planed • Sawed • Nailed • Screwed • Painted • Drilled • Bolted

Hearthbrite Industries, Inc.
12 Windsor Industrial Park • P.O. Box 36 Windsor, NJ 08561 • (609) 448 1500

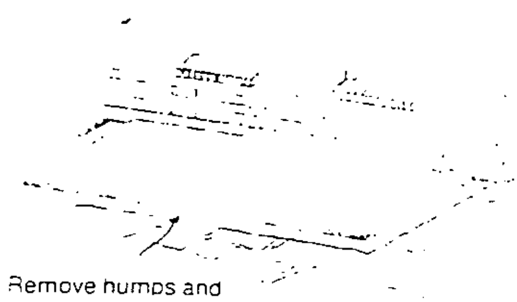
0 50352 11272

Step 1

Determine linear feet required to border the area you desire to edge. For each additional layer, simply add one times the linear footage determined. Tuff Timbers™ are sold in 4, 6 and 8 foot lengths with 4 foot right and left corner sections.

Step 2

Tuff Timbers™ may be placed directly in contact with the ground or may be set into concrete if greater permanence is required. We recommend that you prepare the ground by digging a shallow trench (1" deep is sufficent) and keep the contact surface as near straight and level as possible. This will facilitate much easier use of the interlocking system (See FIG. A)



Remove humps and maintain same level all around contact surface.

FIG. A

Step 3

Fit the bottom layer of Tuff Timbers™ into the prepared area. Be sure to allow at least two feet of length from outside of corners (See FIG. B). Tuff Timbers™ may be saw cut with any hand or circular saw. Do not destroy drop off pieces as these may be used on successive layers.

NOTE: If drainage is desired, simply allow a maximum $\frac{3}{8}$" gap at each butt joint in this layer.

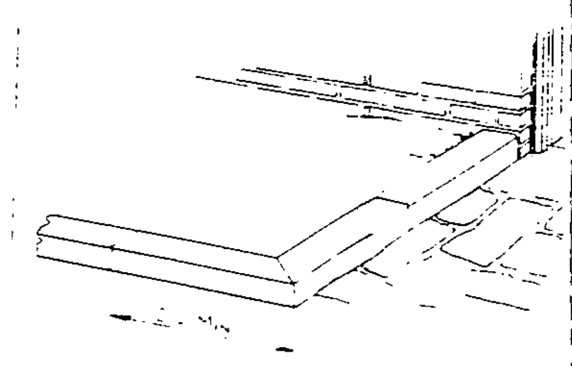


FIG. B

Step 4

After setting the bottom layer in place and setting corners at 90°, nail the corners at the outside points using 4d galvanized finishing nails (See FIG. C). Pre-drilling is not necessary but may be helpful in guiding the nails into place.

Use 4d galvanized finish nails. Locate ¼" in from corner—care must be taken that fastener penetrates squarely into mating Tuff Timbers™.

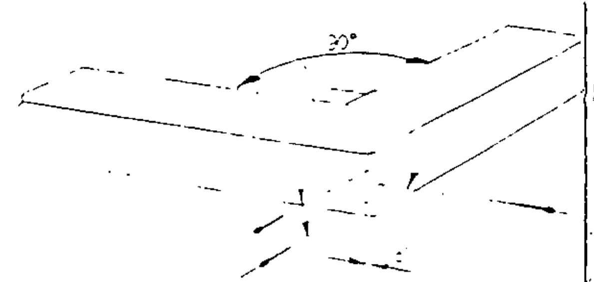


FIG. C

Step 5

The second layer and each successive layer may be installed easily by following a few simple rules.

1. Always maintain a minimum of one foot overlap of butt joints in each preceding layer where possible.

2. Always maintain a minimum two feet of corner section length when possible. For example: if the bottom layer has a corner section length of two feet then the next layer's corner section should be a minimum of three feet long or up to four feet long (minimum corner section 2 feet + minimum overlap of 1 foot = 3 feet.) If the bottom corner section is 3 feet long then the next layer's corner section may be either 2 feet long or 4 feet long (See FIG. D)

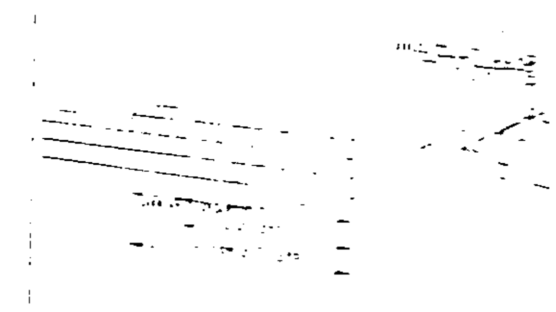


FIG. D

3. Interlocking can be accomplished by either sliding or "snapping" each successive layer into place. We have found it simplest to place the piece in position on top of the lower layer with one side in the groove. Then simply strike the opposite edge straight downward, working from one end to the other until it is

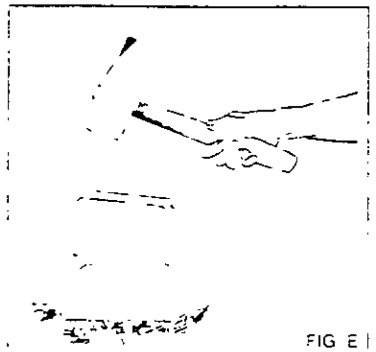


FIG. E

fully seated (See FIG. E). Do not strike Tuff Timbers™ directly with a steel hammer. Use a heavy rubber or wooden mallet or use a piece of scrap wood between the hammer and Tuff Timbers™. The Tuff Timbers™ will snap into place quite readily and can still be easily adjusted into position.

4. Always cap any open ends to prevent nuisance animal nesting. Use Tuff Timbers™ end caps for this purpose.

Step 6—Painting

Tuff Timbers™ may be painted with any good exterior grade paint. We recommend using oil-based paints when possible.

Tuff Timbers™ may be left natural if you desire. They will fade in color to a neutral gray identical to weathered wood.

We do not recommend staining.

DOZENS OF USES

- *WALLS*
- *FENCES*
- *BORDERS*
- *STEPS*
- *LANDSCAPE AND NURSERY TIES*
- *RETAINING WALLS*
- *DECORATIVE WALLS*
- *FLOWER BED BORDERS*
- *GARDEN BORDERS*
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- *BULKHEADING*
- *PLANTERS*
- *SANDBOXES*
- *MAILBOX POSTS*

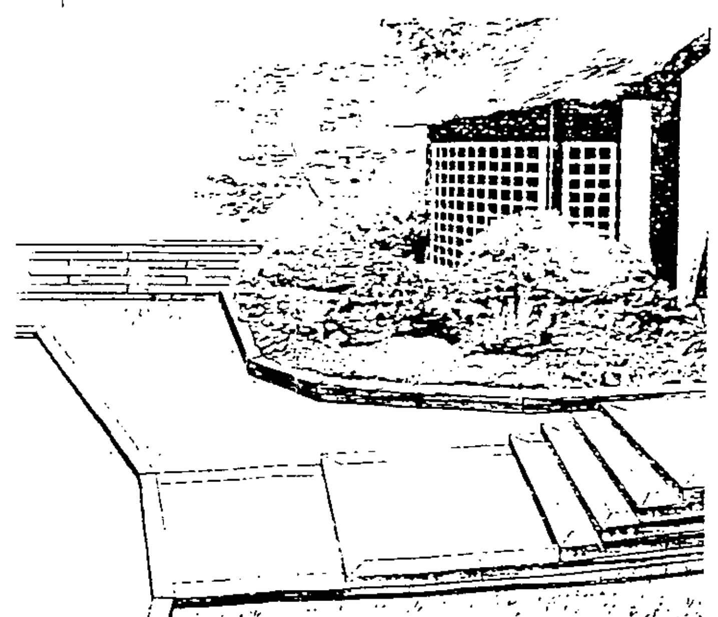
*THE USES OF THE VERSATILE **TUFF TIMBERS™ INTERLOCKING LANDSCAPE TIES** ARE LIMITED ONLY BY YOUR IMAGINATION.*

Tuff Timbers

Hearthbrite Industries, Inc.
12 Windsor Industrial Park
P.O. Box 36, Windsor, NJ 08561
(609) 448-1500

Tuff Timbers

INTERLOCKING LANDSCAPE TIES



HOW-TO-USE GUIDE

Hearthbrite Industries, Inc.

12 Windsor Industrial Park • P.O. Box 36 • Windsor, New Jersey 08561 • (609) 4

PROPERTY DATA SHEET

HEARTHBRITE COMPONENT BUILDING MATERIALS
1 5/8" X 1 3/8" X 33"

DENSITY

14.546 - 14.933 G/CU IN
55.30 - 56.77 LBS/CU FT

COEFFICIENT OF LINEAR THERMAL EXPANSION

5.277 - 6.518 X 10 - 5 IN/IN/°C

WATER ABSORPTION. CHANGE IN LENGTH (SWELLING)

1.02 - 1.31%

WATER CONTENT

.43 - .89%

TENSILE SHEAR, STEEL WITH WATER BASED ADHESIVE

40.8 LBS/SQ IN
U.S. TESTING COMPRESSIVE STRENGTH 52,500 LBS
U.S. TESTING FLEXURAL STRENGTH (3' SPAN) 7,420 LBS

COMPONENTS

WOOD FIBER -- HARDWOODS (OAK AND MAPLE)
PLASTIC -- LOW DENSITY POLYETHYLENE RECYCLED PLASTIC BAGS

COMPARATIVE SCREW AND NAIL PULL-OUT TESTS

1. PULL-OUT TEST #10 TAP SCREW 1" LONG:

SPRUCE	HEARTHBRITE
140 UNITS	180 UNITS

2. PULL-OUT 1" SHEET METAL SCREW:

SPRUCE	HEARTHBRITE
360 UNITS	600 UNITS

3. PULL-OUT 8-PENNY NAIL:

SPRUCE	HEARTHBRITE
260 UNITS	560 UNITS

4. PULL-OUT 8-PENNY SCREW NAIL:

SPRUCE	HEARTHBRITE
125 UNITS	330 UNITS

1/5/88

RIVENITE™

1989 PRICE LIST

PRODUCT CODE	SIZE	APPROX LBS/FT
EM1010	2.5" Round	2.15
EM1020	3.5" Round	4.0
EM1030	4" Round	5.05
EM1040	6" Round	11.85
EM2010	1.5x3.5	2.2
EM2020	1.5x5.5	3.4
EM2030	3.5x3.5	5
EM2035	5.5x5.5	12.10
EM2040	3.5 Decorative	2.9
EM3010	Tree Edging	3.4
EM3020	Tree Kit	35
EM1140	6" Cored Round	9.5
EM2135	5.5"x5.5" Cored	9.79
EM1141	6" Flat-side Round	9.86
EM2050	Parking Bumper	12.43
EM2150	Parking Bumper-Cored	9.08

MADE IN THE USA USING 100% RECYCLED M

MANUFACTURED BY RIVERHEAD MILLING, INC., PHILAD

Riverhead Milling, Inc.

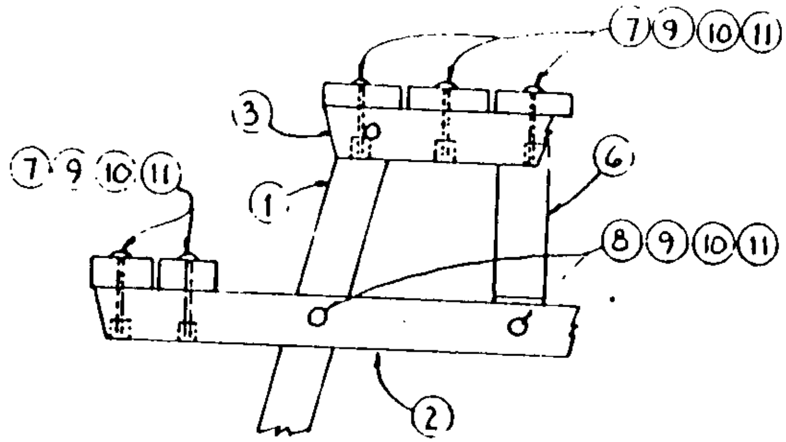
Better Products Through Recycling

Rivenite Park Tables
Materials List

Item	Qty	Description		Source
1	6	Rivenite 4 x 4 x 2'-5½"	Legs	S
2	3	Rivenite 4 x 4 x 4'-10"	Seat Supports (5'-1½")	S
3	3	Rivenite 4 x 4 x 2'-5"	Table Supports (2'-6")	S
4	5	Rivenite 2 x 6 x 8'-0"	Table Top	S
5	4	Rivenite 2 x 4 x 8'-0"	Seats	S
6	2	Rivenite 4 x 4 x 3'-2¼"	Diagonal Braces	S
7	27	Carriage Bolts - ½"ø x 5" Long - Zinc Plated		PBP
8	16	Carriage Bolts - ½"ø x 7" Long - Zinc Plated		PBP
9	43	½"ø Hex Nuts - Zinc Plated		PBP
10	43	½"ø Lock Washers - Zinc Plated.		PBP
11	43	½"ø Flat Washers - Zinc Plated		PBP
		Note!: If 2x4 top is required add 4 - ½"ø x 5 Carriage Bolts w/ nuts. L.W's & F.W's.		

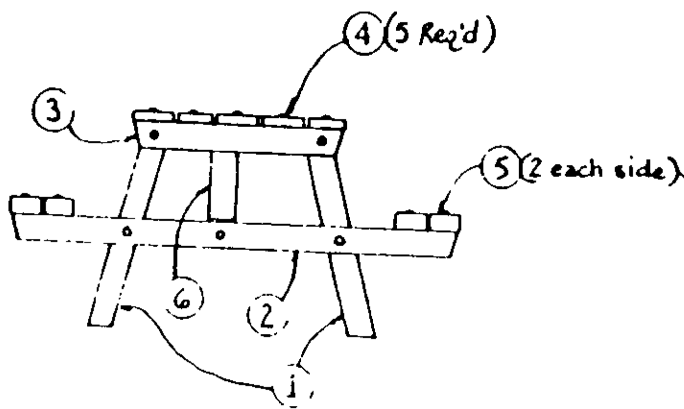
5601 State Road Bldg. B
Philadelphia, PA 19135
215-333-6616

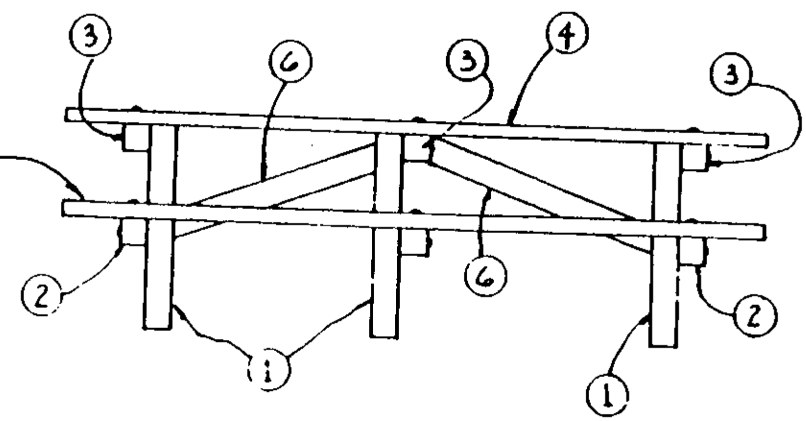
Dwg. A-001



Notes:

1. Item numbers are identified on Dwg A-001
2. Be sure to use specified bolts - 5" Long bolts for 2x4 and 2x6 joints - 7" Long bolts for 4x4 joints.





	Riverhead Milling Inc. 6801 State Rd. Phila., PA 19135
10-4-89	Rivenite Park Tables

A.3 The ET-1 Technology

ADVANCED RECYCLING TECHNOLOGY LTD

THE ET/1 SYSTEM

FROM

ADVANCED RECYCLING TECHNOLOGY

U.S.Agents:
Mid-Atlantic Plastics Systems, Inc.
Roselle, NJ 07203
TEL (201) 241-9333
FAX (201) 241-3988

ADVANCED RECYCLING TECHNOLOGY S.A. LTD. (ART) was founded by a team of international experts in the field of solid waste processing and recycling, especially plastic waste from all sources, including municipal wastes.

After a number of years of research and trials, and the development of several prototype processing systems, ADVANCED RECYCLING TECHNOLOGY S.A. LTD. has perfected and is manufacturing a new, original and patented process for the direct recycling of mixed contaminated post consumer plastic wastes into useful articles. This process is based on the ET/1 extrusion/molding machine.

General Arrangement Drawing Showing 2 Recycling Units
ET-1/8400 Drawing No. 92209

1. Conveyor-Raw material

2. Shredder B/15 R

3. Conveyor-Shredder material
   3.1 Upper Magnet
   3.2 Magnetic Drive-Drum
   3.3 Distributor-heavy and light (film) material

4. Grinder M/45/70

5. Silo for grinded material MVA/43
   5.1 Feeding screw with hopper, for hand feed
   5.2 Volumetric extraction screw

6. Conveyor for film scrap

7. Cutting and densifying unit R/A/600

8. Silo for densified material
   8.1 Feeding screw with hopper, for hand feed
   8.2 Volumetric extraction screw

9. Mixer MV/43

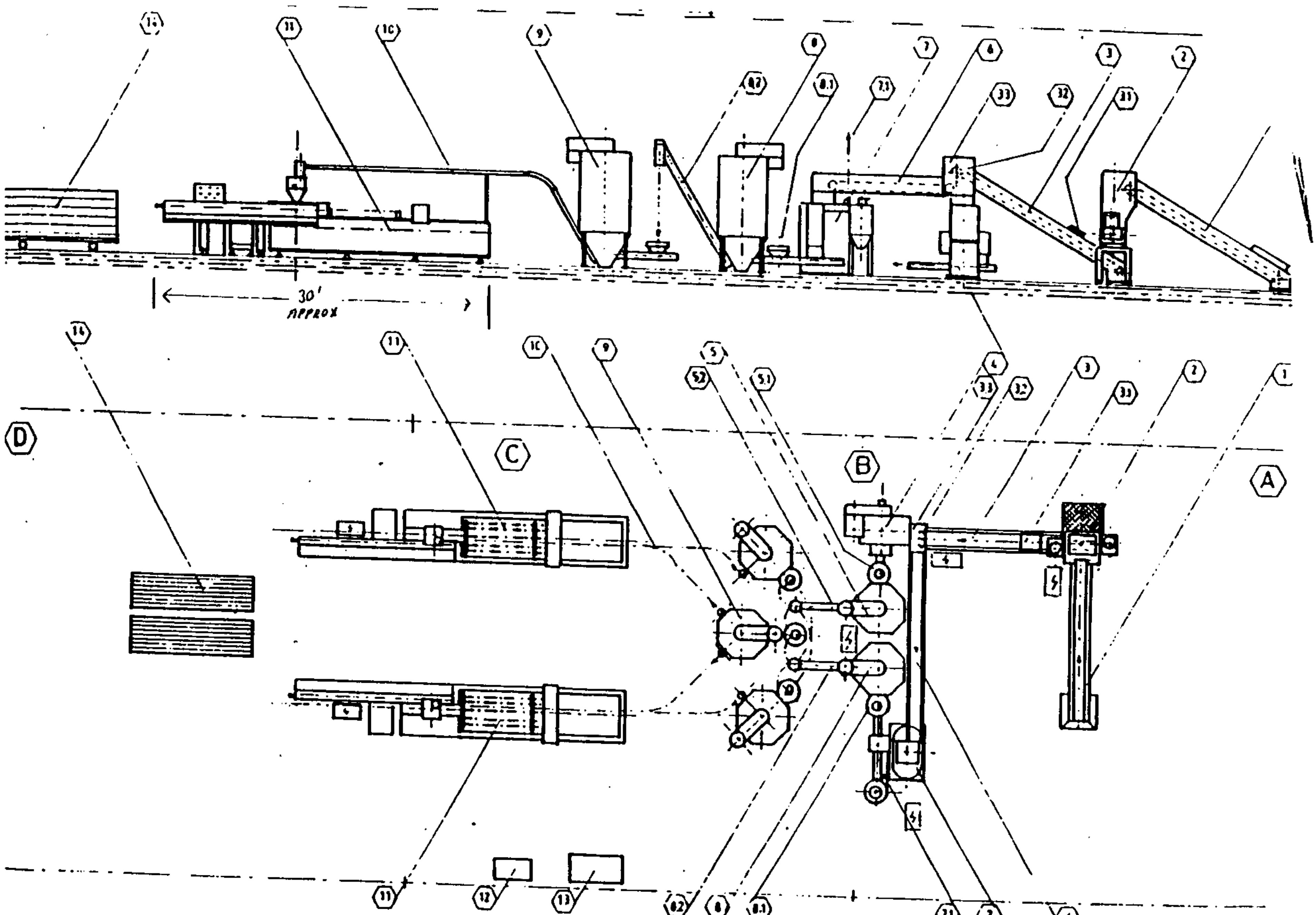
10. Flexible feeding screw

11. Recycling machines ET/1/6400

12. Air-compressor

13. Cooler unit

14. Stocking trolley



Layout _ Two Moulding Machines ET1/8400	1/100
Advanced Recycling Technolo...	

THE MACHINE AND THE PRODUCT

The ET/1 machine makes linear SYNTAL shapes such as posts, poles, stakes, planks, slats and other products where the length is great in relation to the cross-section, and where the cross-section is either constant, or tapered in one direction only. The length which can be produced on the standard ET, is from 3' to 12'. The cross-sections vary from a 1" diameter rod, to a 6" x 6" post. [The smaller diameter cross-sections cannot be molded at the full 12' capacity of the machine. The length of the profile is determined by cooling which is governed by the surface to volume ratio and mixed plastic formulation.]

The shapes produced may be square, round, rectangular, oval, triangular, "T" shaped or irregular depending on the applications for the finished product.

Twelve different shaped molds, all of the same length, may be used at once. Refitting the turret with another set of molds, of a different length, is a relatively easy and rapid operation. These features, which are unique in the plastics industry, are of great value in end use market development and sampling programs.

The raw material for these products may be either unsorted mixed contaminated post consumer plastic wastes, industrial plastic scrap, mixed co-extruded or layered industrial plastic wastes, or various combinations and blends of these materials. The possible combinations are infinite, including the use of additives, modifiers, compatilizers, and pigments yielding molded products with a large range of properties and appearances. The raw material, like the process, is normally inexpensive. In many cases, usable mixed or contaminated plastics can be obtained at negligible cost, or you may even be paid a "tipping fee", saving your supplier the higher landfill disposal costs.

SYNTAL

Unlike wood, Syntal products are resistant to attacks by animals, insects, fungi and bacteria. It is, in short, completely rot and weather proof. Permanent maintenance-free installations can be made in humid conditions, in marshlands or in contact with seawater, many chemicals and solvents, animal urine, etc.... where wood - even treated wood - would have a relatively short life.

SYNTAL also is not subject to splintering or splitting. It has machining properties typical of thermoplastic articles, and very similar to hard wood products. SYNTAL can be nailed, screwed, drilled, welded, milled, sawed, planed and cut with conventional machine shop and wood working tools. Its uses are as wide ranging as your imagination.

USES FOR SYNTAL

Syntal products are an ideal replacement for wood, metal and concrete in the following applications;

1. In applications where wood is attacked by living organisms, including bacteria, fungi, insects, marine borers, etc... such as piling and staging in wet lands, harbor works, boat docks, fence posts, vine stakes, and underground anchors.

2. In animal husbandry applications where hygienic considerations require the possibility of sterilization as a precaution against infection, e.g. pig sty floor boards and horse stalls.

3. In fencing applications where wooden fencing is chewed by animals, or installed in moist areas e.g. horse ranch fencing, parks, nurseries and golf courses.

4. In applications where a high degree of abrasion resistance is required, e.g. harbor fenders. loading docks, ware plates, pallets, work stations, truck beds, decks and walk ways.

5. In applications where an elastic and splinter-proof product is required, e.g. road markers, road sign supports, highway reflector posts, miscellaneous highway markers, guard rails, dock bumper rails, etc.

6. In applications where electrical resistivity is required, e.g. posts and rails for electrical fences, and supports for electrical power wiring.

7. In children's outdoor furniture and playground equipment where wood and metal require frequent refinishing or replacement to take care of rusted parts, deterioration, weather-worn and splinted items, e.g. sand box frames, climbing sets, park benches, picnic tables, barricades and stairs in forest trails.

8. Landscape timbers for soil retainers, tree and flower planters, borders, decorative fencing. Elimination of treated wood with its growing chemical leaching for concerns.

ART has extensive experience with markets and products made on the ET. Markets are now being developed in the United States as plastics recycling becomes a part of our daily routine. The following list includes some successful applications which can be used as a basis of end-use market development in the US.

THE E.T.1. PROCESS

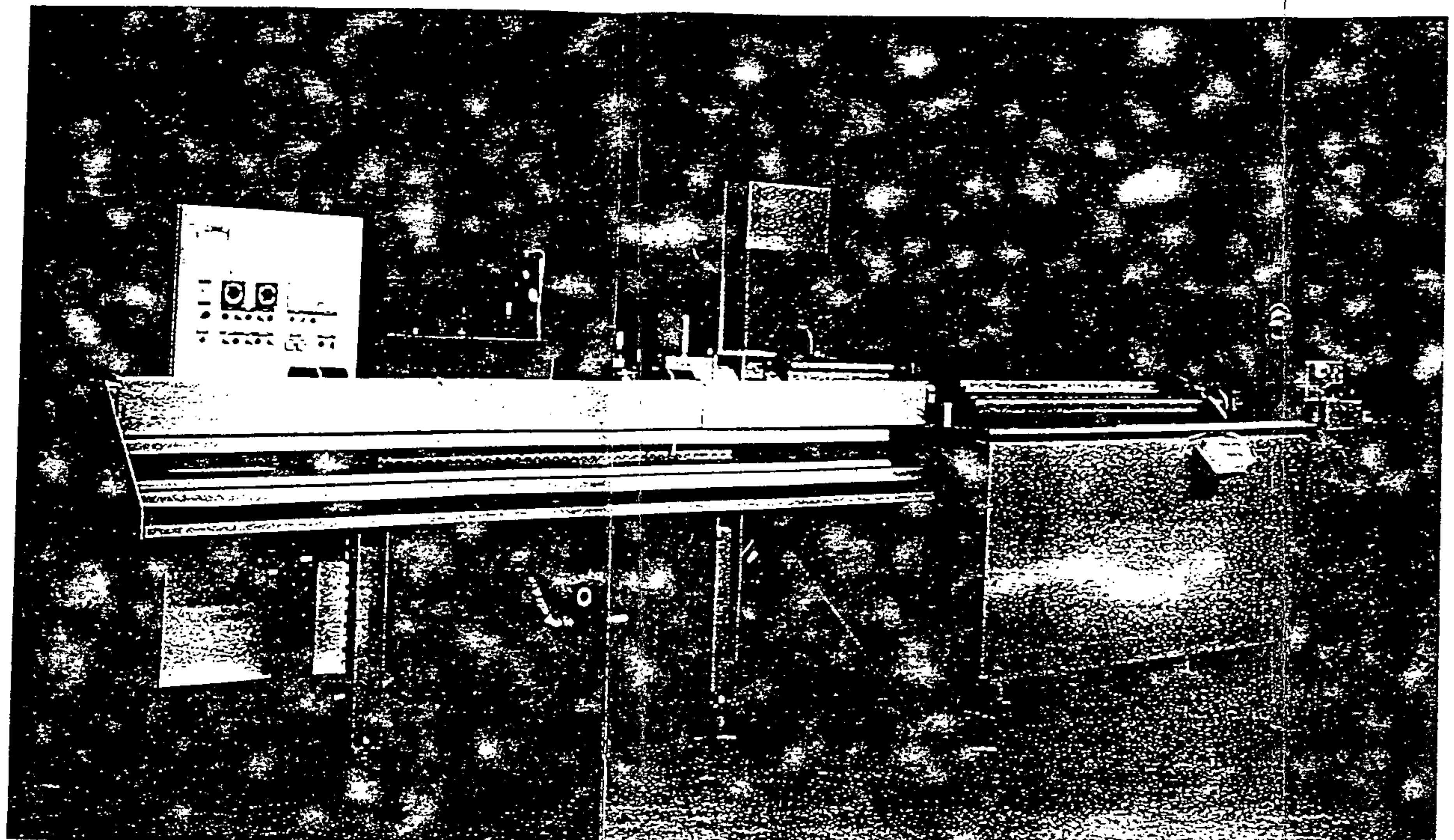
A NEW PROCESS!

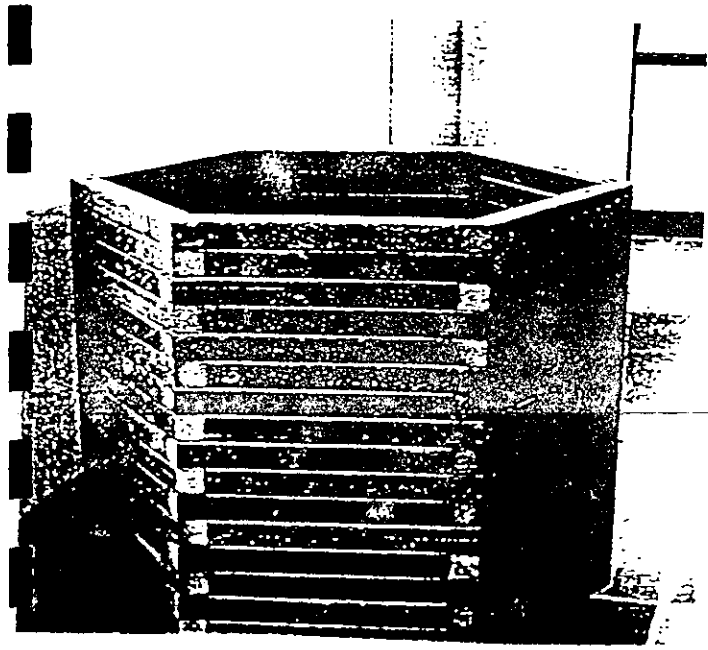
The *E.T.1.* recycling process is a patented process of extrusion moulding, which permits the transformation of mixed, contaminated plastic wastes, directly and automatically, into solid sections of many forms and dimensions.

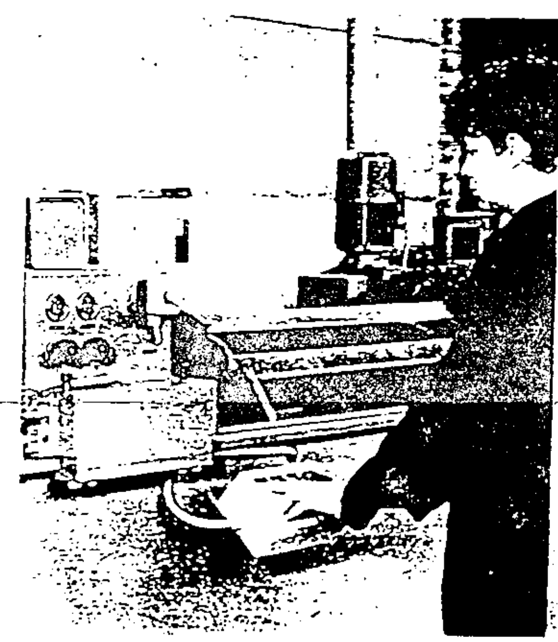
After years of research and experimentation, and the development of several prototypes, A.R.T. is today able to produce a simple, reliable and automatic recycling process, that allows the direct recycling of all thermoplastic wastes, mixed and contaminated, directly into finished products, without prior separation or intensive washing.

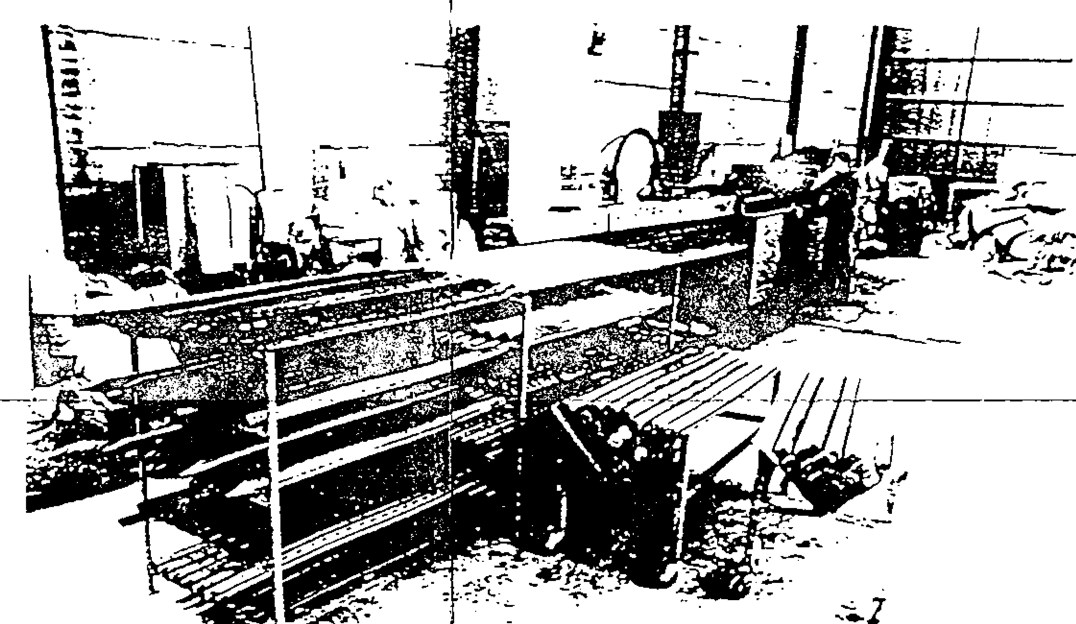
After grinding, screening and densification, the different components are first dried and homogenized in a vertical screw mixer. The mix is transported through a magnetic separator to the hopper of the extruder in which it is transformed by mechanical friction, without any degradation, into a homogeneous plasticized mass, which is then forced into a number of moulds, which are generally made of standard hollow steel sections. This set of moulds is mounted on a turret which rotates on a horizontal axis presenting the moulds successively to the extruder for filling. They are externally cooled by circulating chilled water.

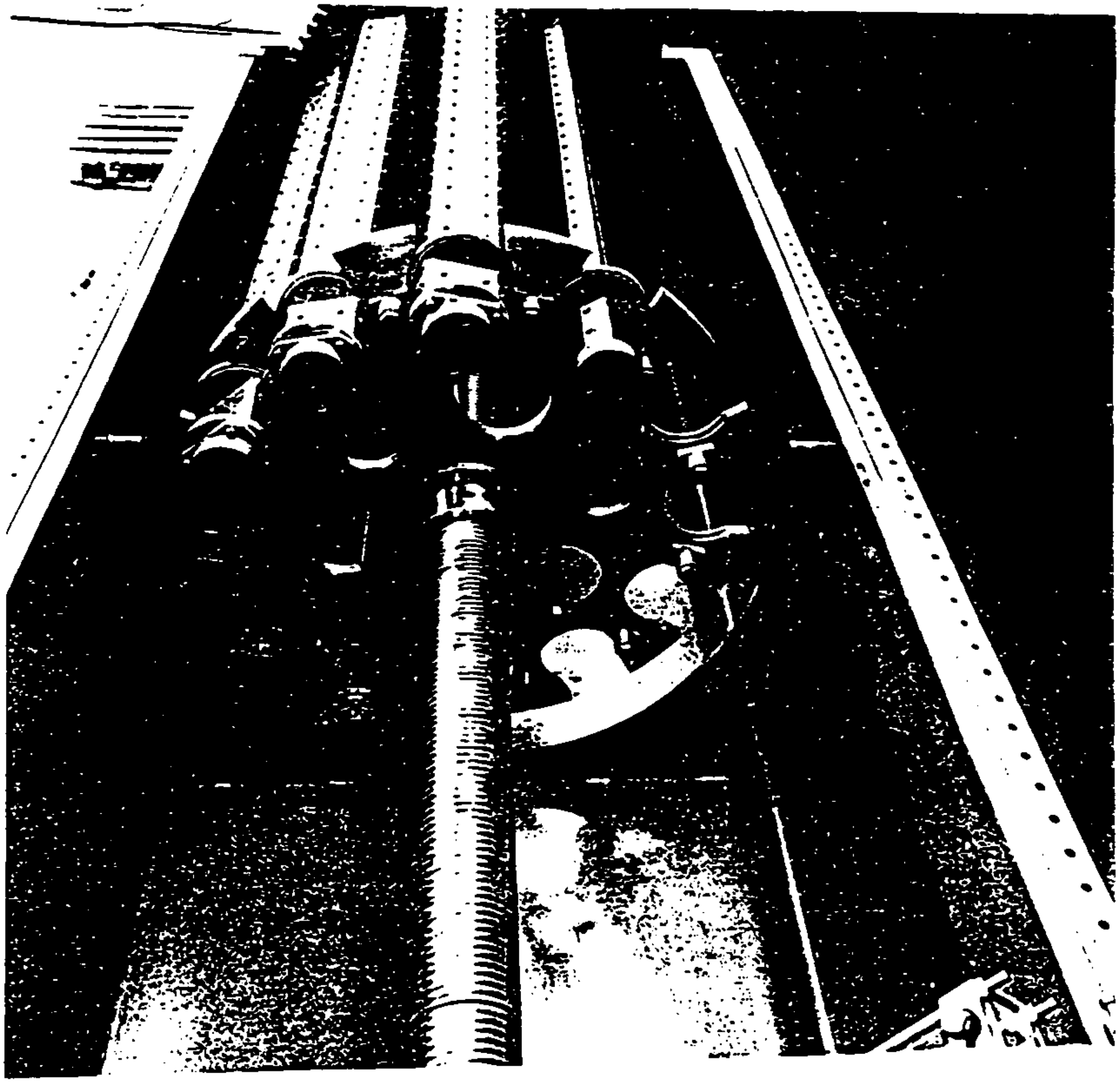
The process *E.T.1.* is simple, automatic and reliable, and without any risk of pollution of the environment.
The total process is automatic, including the ejection of the finished product. The process *E.T.1* is simple, automatic, reliable, economical and requires very little labour and space.
Clean and silent, it can be installed everywhere without emission of noxious vapors or environmental pollution.





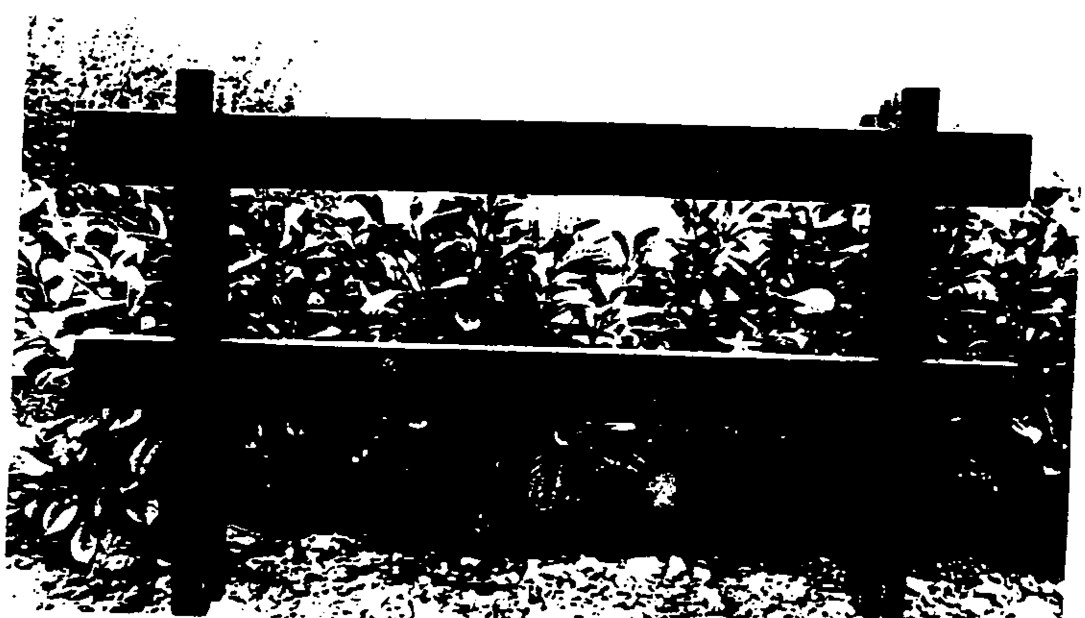






RECYCLE MIXED PLASTIC WASTE...

INTO HIGH QUALITY FINISHED PRODUCTS



THE RECYCLING PROCESS E.T.1.

The recycling process *E.T.1.* simple, economic and profitable is developed, manufactured and marketed by

ADVANCED RECYCLING TECHNOLOGY SA

RECYCLE MIXED PLASTIC WASTE...

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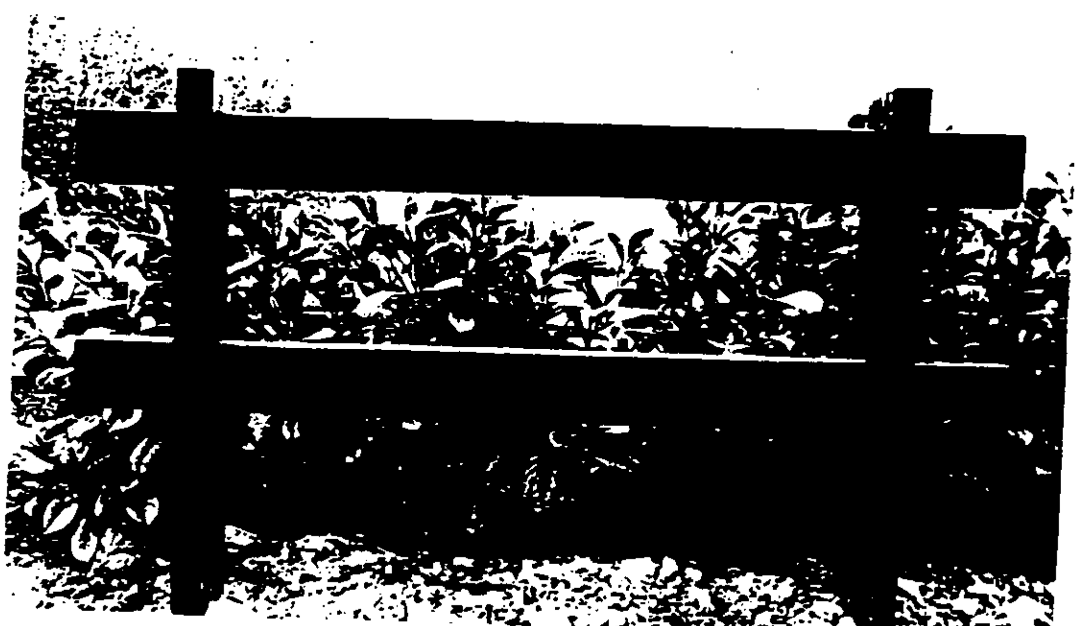


THE RECYCLING PROCESS E.T.1.

The recycling process *E.T.1* simple, economic and profitable is developed, manufactured and marketed by

ADVANCED RECYCLING TECHNOLOGY SA

THE ACTUAL PROBLEM

TREATMENT OF GROWING QUANTITIES OF PLASTIC WASTE.

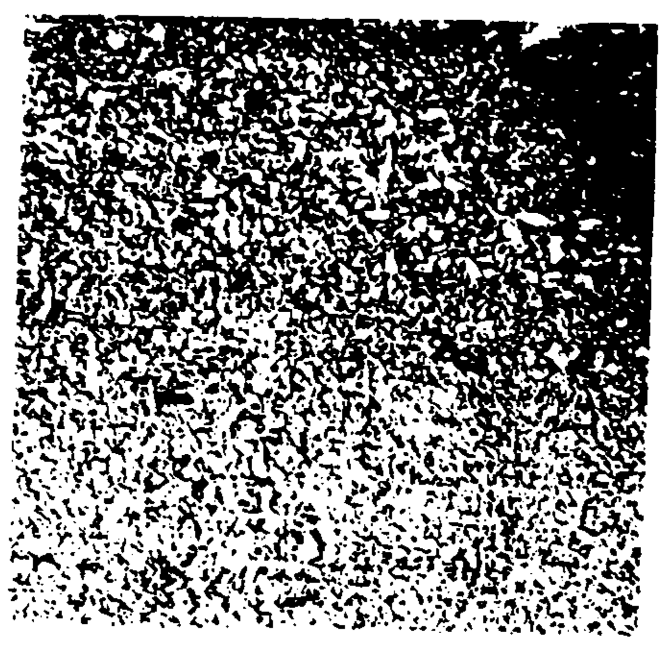
Plastic scrap is found everywhere : in industrial, commercial and domestic wastes. The physical and chemical characteristics of the plastics can differ widely and may even be incompatible

The contaminants are numerous: paper, aluminium, brass, wood, textile and organic substances; they can reach a high proportion of the total weight, up to 50% in some cases.

The possible sources of these wastes are various:

The packaging industry (e.g. laminated or co. extruded films) – the automobile industry and its components (e.g. chromed parts, etc...), the electrical cable industry, the medical and surgical industry, agriculture, without forgetting the main source in the future:

the plastic fraction separated from the domestic wastes.



How possible, pratical, economical and first of all profitable can be the recycling of these wastes?

Washing, separation, incineration, pyrolysis, these disposal processes are generally very expensive, sometimes dangerous and often impracticable.

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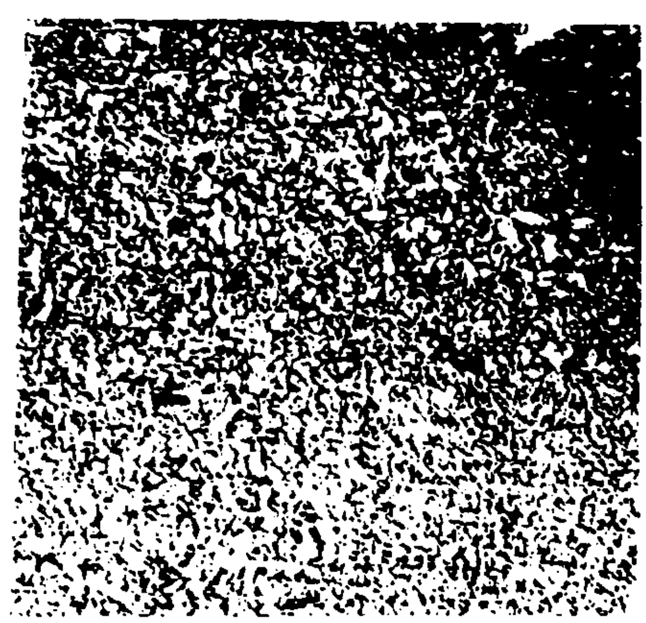

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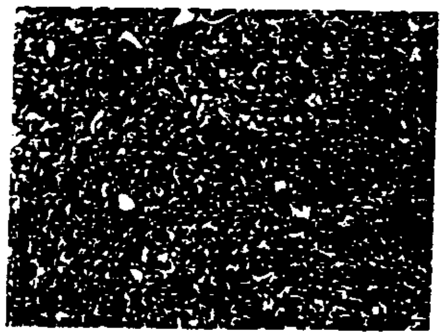
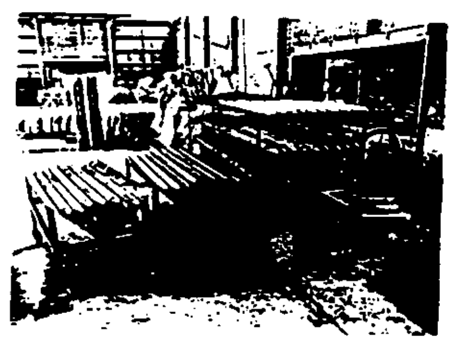
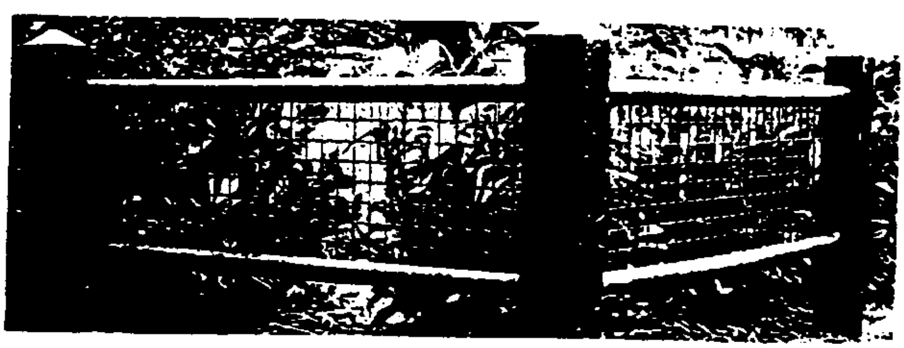
A.R.T. AROUND THE WORLD

The recycling of wastes, an economic and ecological necessity, is becoming increasingly needed in the whole world.

The members of the A.R.T. GROUP are all pioneers in this field: their expertise allowed the development of new technologies based on long practical and specialized experience. This is why the professionals of solid wastes recycling, the national and regional authorities, the research centers, the industrialists and financiers are interested in the *E.T.1.* process and the opportunities this new industry presents.







The recycling process *E.T.1.* is today the only one to be produced in growing quantities and used industrially in all continents: Western Europe, Eastern Europe, America, Australia and other parts of the world.

In spite of this success, A.R.T. continues its efforts and research - to understand better all aspects of waste problems in order to

THE FINISHED PRODUCTS

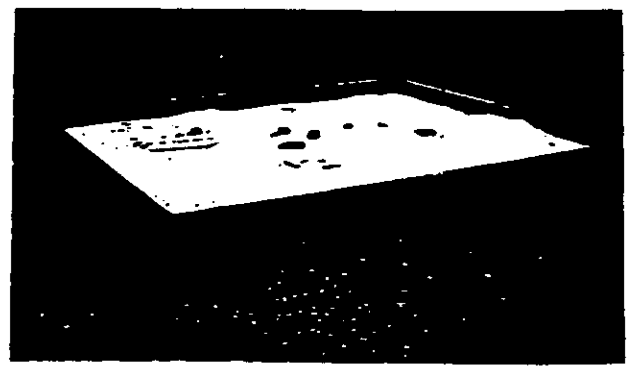
AND THEIR APPLICATIONS!

The *E.T.1.* process permits the manufacture of a very large variety of solid sections of many forms and dimensions that can be substituted advantageously for metal, concrete and wood.

These polyvalent products have generally the same appearance as wood but they also have the qualities of their synthetic components.

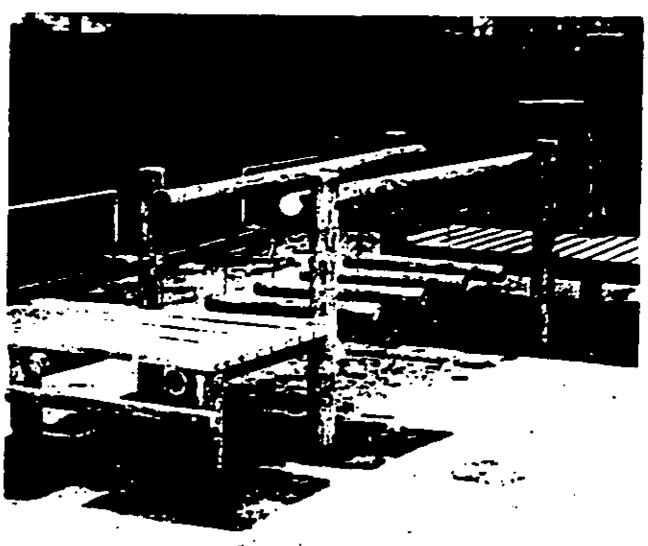
WE CALL THIS SYNTHETIC ALTERNATIVE: SYNTAL

The SYNTAL products are incredibly resistant against impact, water, chemical products, bacteria as well as attack provoked by the most severe weather conditions.
They are not affected even by direct contact with sea water or animal urine.



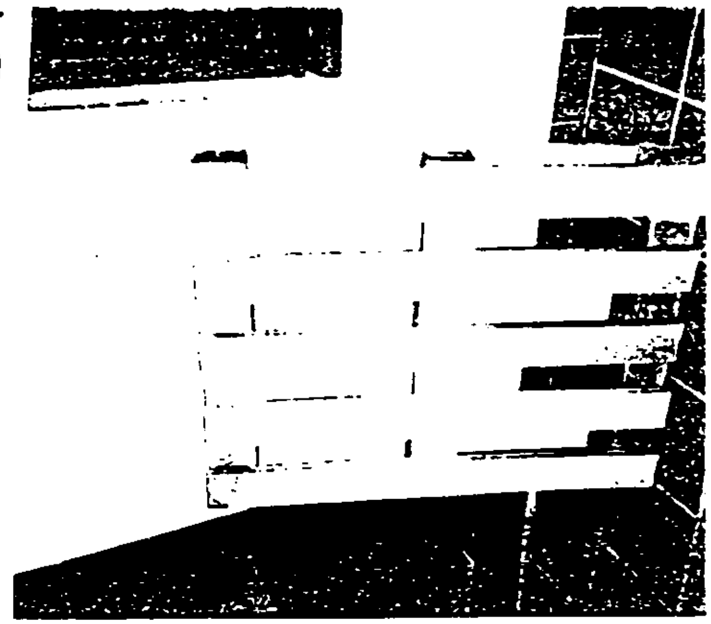
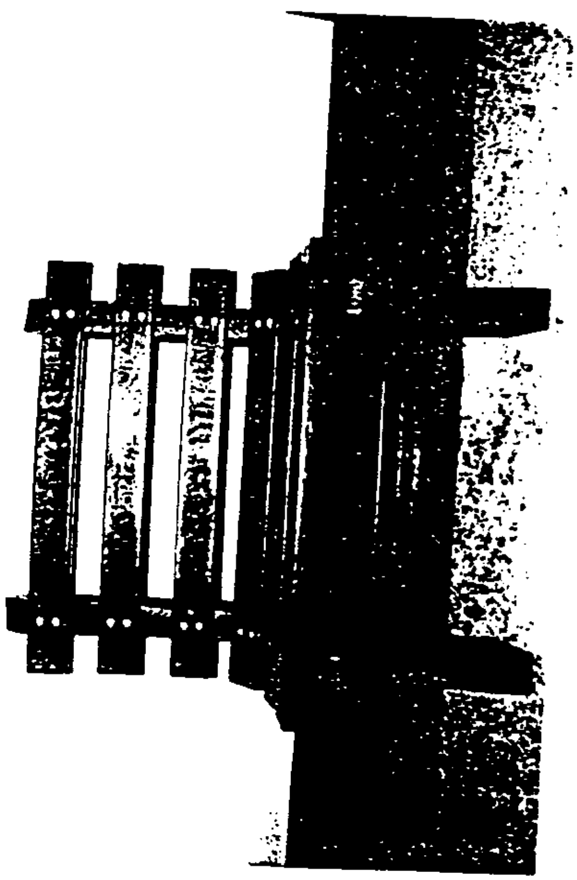
EASY TO FIX

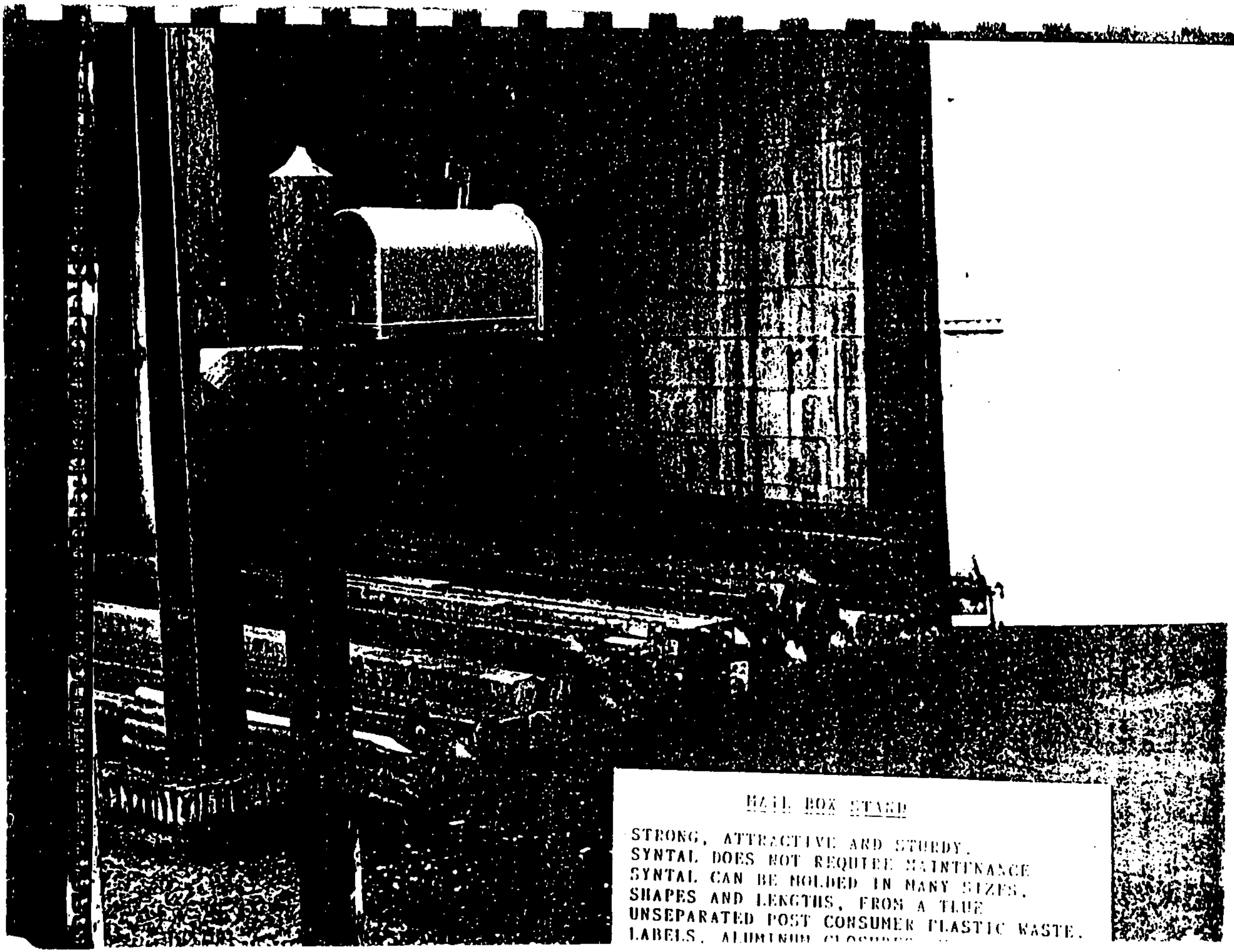
The SYNTAL products can be nailed, screwed, sawed, drilled, planed with simple traditional woodworking machines.
They can also be painted or mass-pigmented.



SOME TYPICAL APPLICATIONS

Stakes, boards for all use (agricultural or marine in particular)
Electrical cattle fences, cattle sheds, paddock fences, coast erosion protection, boatdocking, road signs, urban signs, games and sports fields, vinyards
The versatility and the simplicity of the E.T.1 process give wide scope to the imagination for the creation of new end products

MAIL BOX STAND

STRONG, ATTRACTIVE AND STURDY.
SYNTAL DOES NOT REQUIRE MAINTENANCE
SYNTAL CAN BE MOLDED IN MANY SIZES,
SHAPES AND LENGTHS, FROM A TRUE
UNSEPARATED POST CONSUMER PLASTIC WASTE.
LABELS, ALUMINUM

BARRICADES

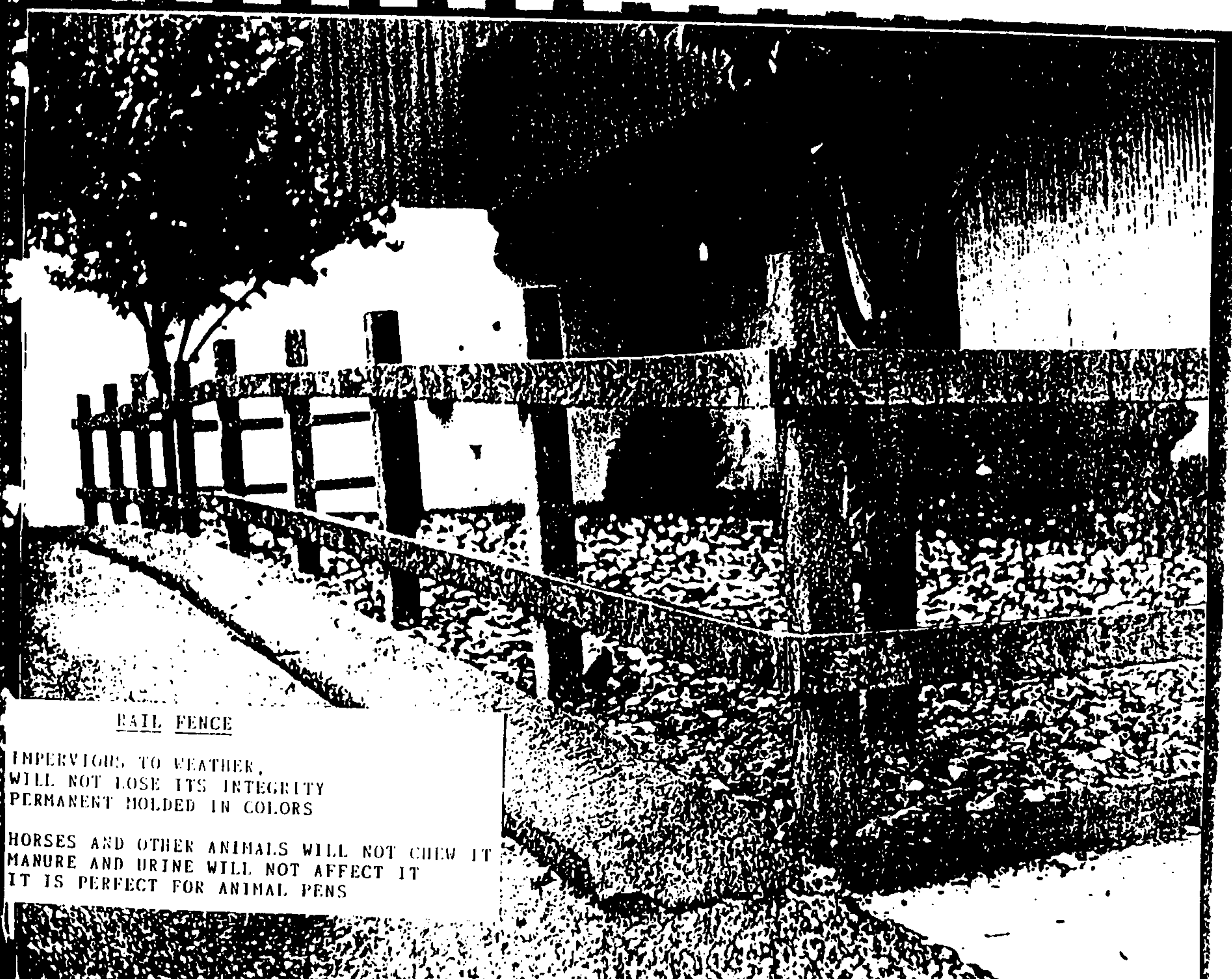
SYRTAL CAN BE USED FOR PORTABLE BARRICADES, ROADSIDE SOUND DEFLECTORS, SIGN POSTS, TRAFFIC DIRECTORS, REFLECTOR POSTS, GUARD POSTS AND RAILS

ITS APPLICATION FOR LANDSCAPE DESIGN, BULKHEADS AND SOIL RETAINERS ELIMINATES COSTLY REPLACEMENT OF ROTTED OR INSECT INFESTED WOOD.

STYLED FENCING

STRONG, DURABLE
ELIMINATES GROUND POST DETERIORATION

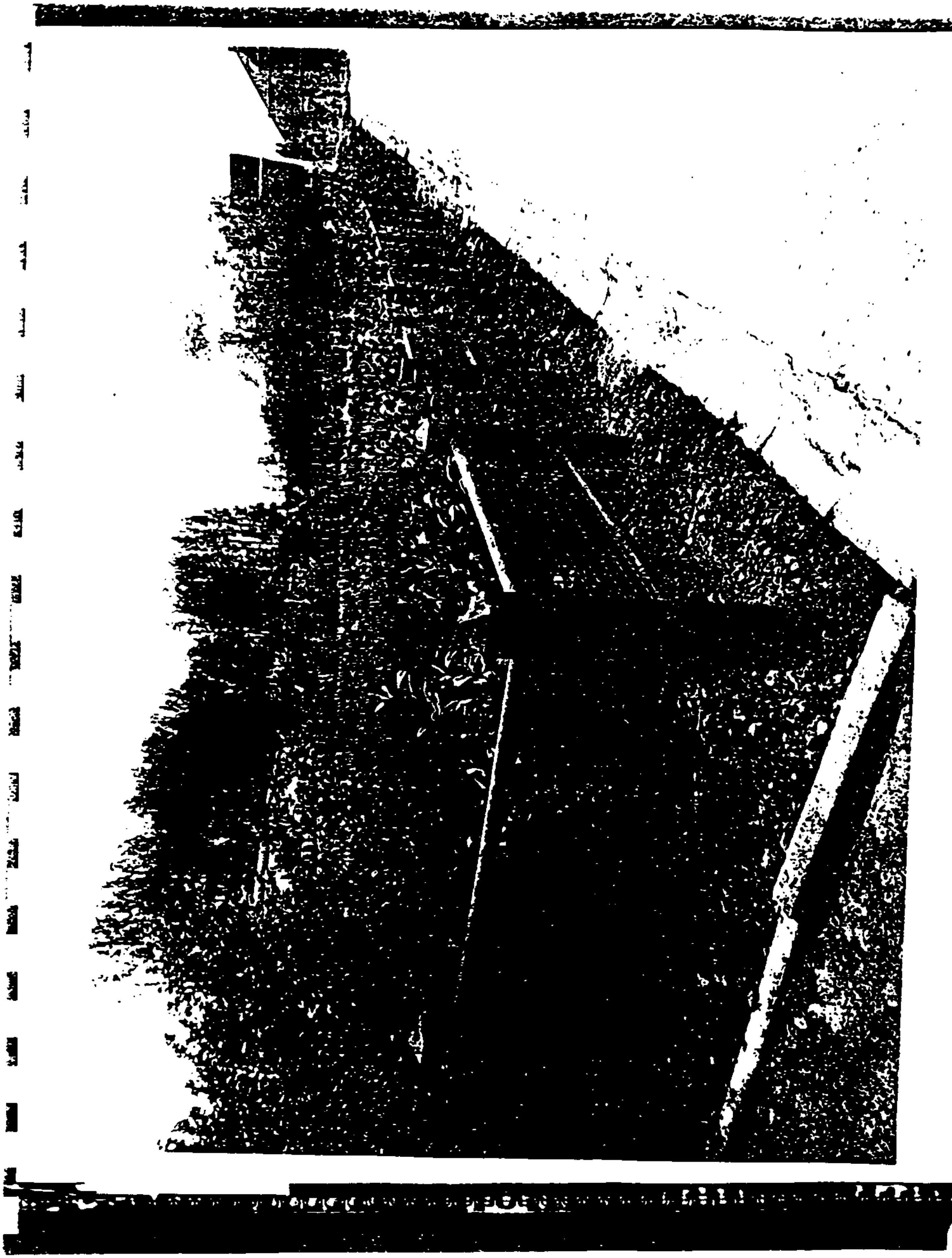
SYNTAL CAN BE FABRICATED JUST LIKE WOOD

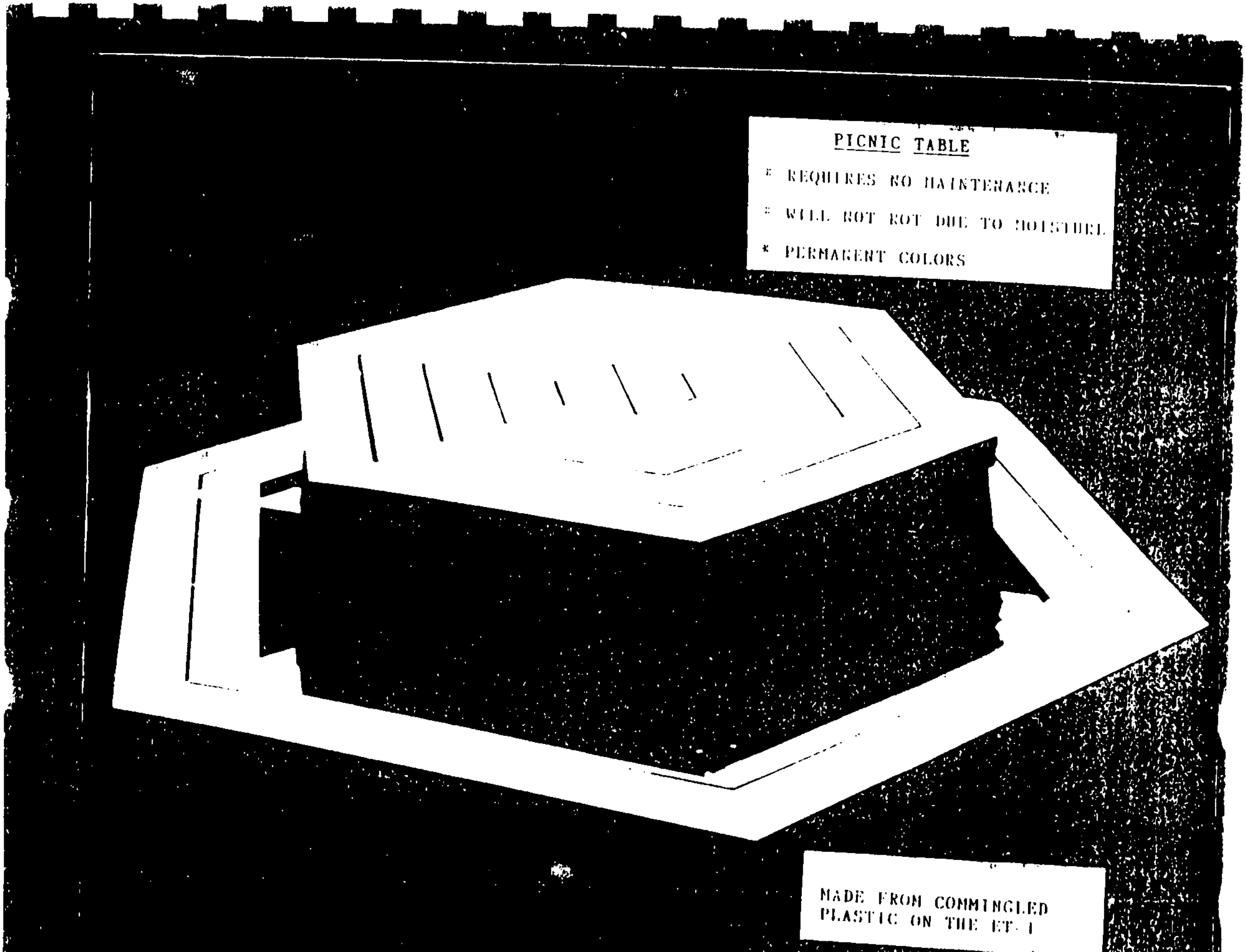


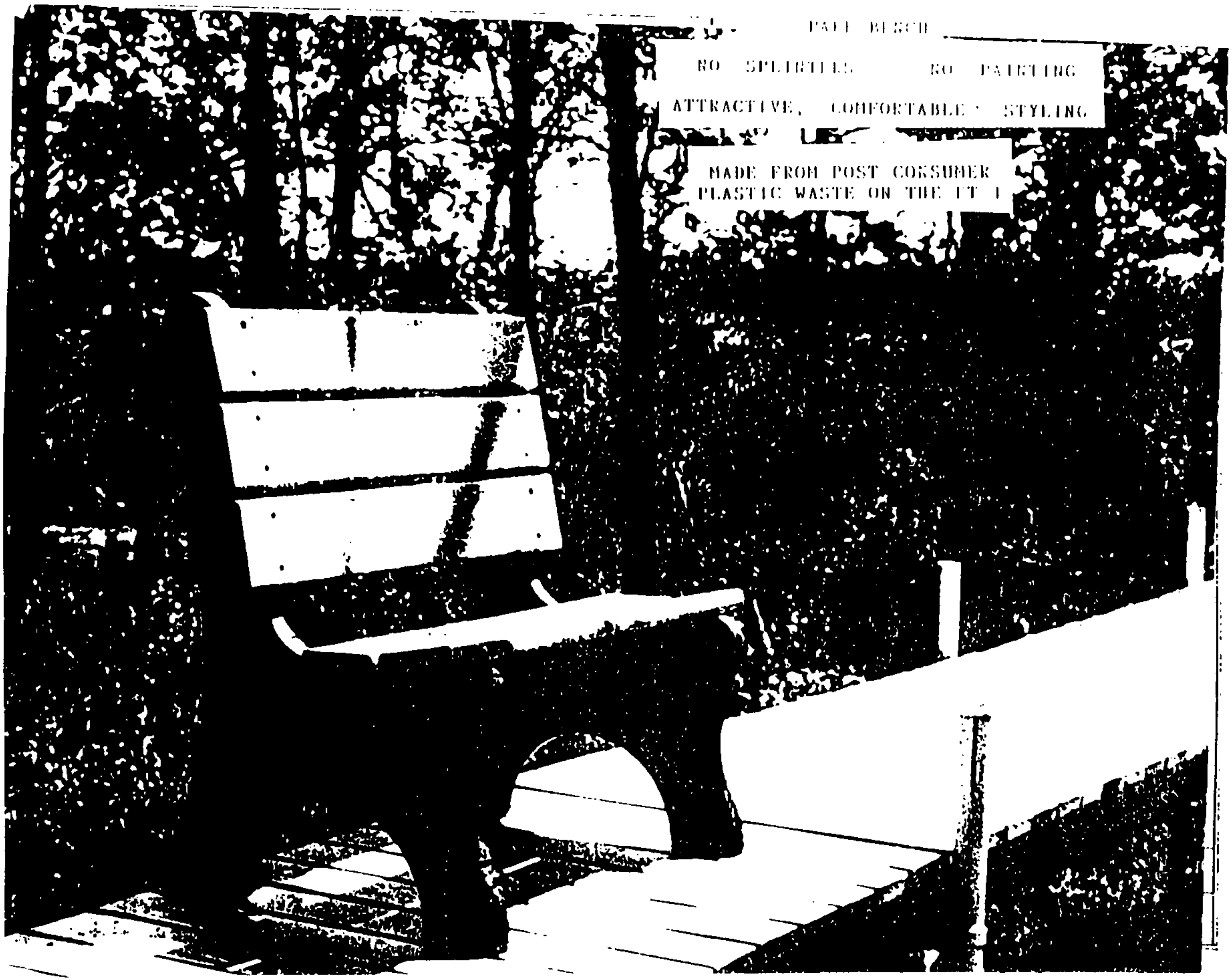
RAIL FENCE

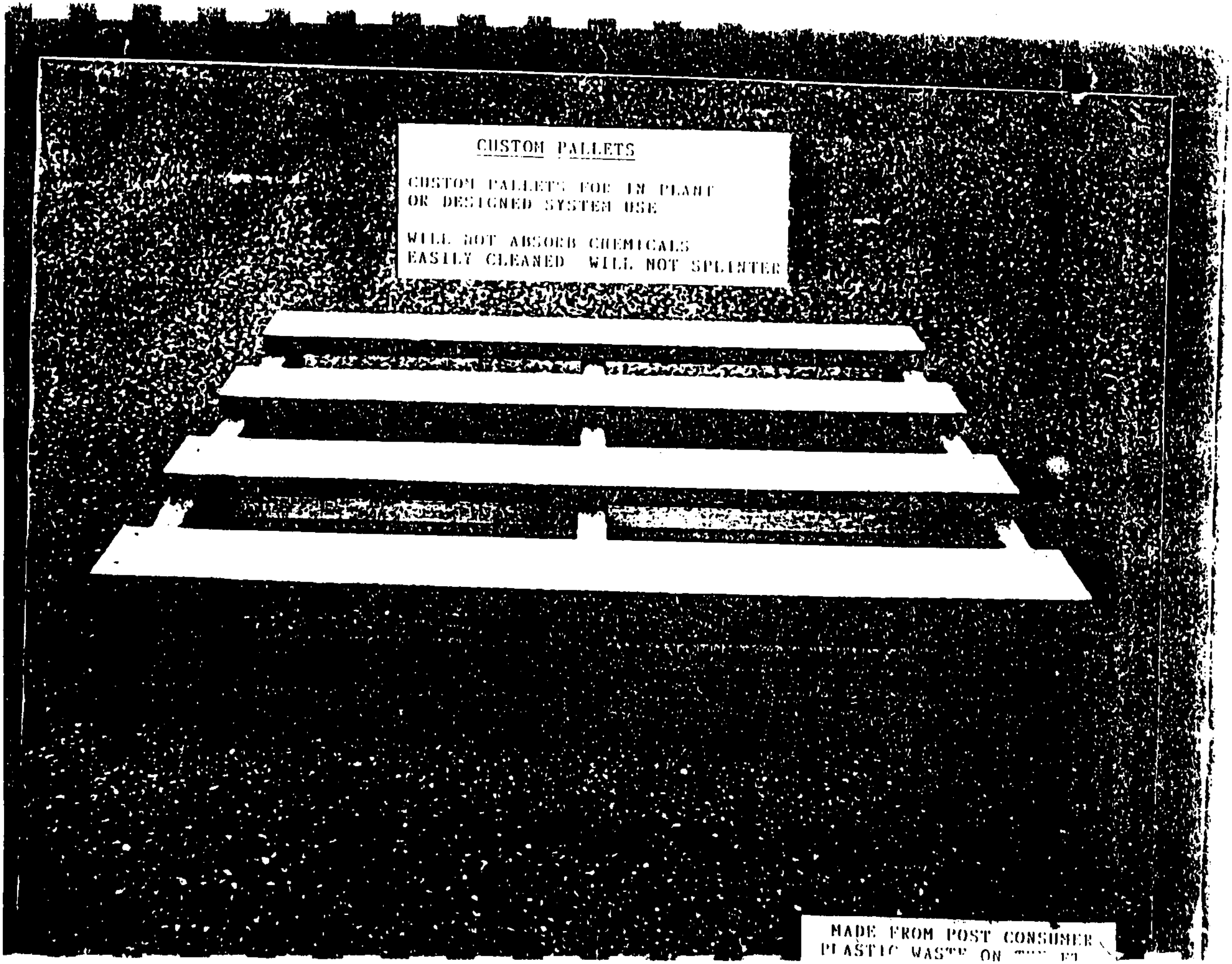
IMPERVIOUS TO WEATHER,
WILL NOT LOSE ITS INTEGRITY
PERMANENT MOLDED IN COLORS

HORSES AND OTHER ANIMALS WILL NOT CHEW IT
MANURE AND URINE WILL NOT AFFECT IT
IT IS PERFECT FOR ANIMAL PENS




PICNIC TABLE
* REQUIRES NO MAINTENANCE
* WILL NOT ROT DUE TO MOISTURE
* PERMANENT COLORS
MADE FROM COMMINGLED PLASTIC ON THE ET-1


NO PAINTING
ATTRACTIVE, COMFORTABLE STYLING
MADE FROM POST CONSUMER
PLASTIC WASTE ON THE


CUSTOM PALLETS
CUSTOM PALLETS FOR IN PLANT
OR DESIGNED SYSTEM USE
WILL NOT ABSORB CHEMICALS
EASILY CLEANED WILL NOT SPLINTER
MADE FROM POST CONSUMER
PLASTIC WASTE ON

A.4 Selected Patents Associated with Plastic Recycling

United States Patent [19]

Brown

[11] 3,852,046

[45] Dec. 3, 1974

[54] METHOD FOR RECYCLING WASTE PLASTICS AND PRODUCTS THEREOF

[76] Inventor: Henry J. Brown, 421 Margo Ave., Long Beach, Calif. 90814

[22] Filed: Jan. 3, 1973

[21] Appl. No.: 320,694

Related U.S. Application Data

[62] Division of Ser. No. 191,901, Oct. 22, 1971, abandoned.

[52] U.S. Cl. .... 44/1 R, 44/1 D, 44/10 R, 44/25

[51] Int. Cl. C10l 5/14, C10l 5/00, C10l 5/40

[58] Field of Search .... 44/10 R, 1 R, 1 D, 17, 44/25; 260/2.3

[56] **References Cited**

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3,637,355	1/1972	Brockbank	44/1 R
3,726,652	4/1973	Schick	44/17 X

Primary Examiner—C. Dees

Attorney, Agent, or Firm—Jerry R. Seiler

[57] ABSTRACT

Waste plastics comprising a mixture of two or more thermoplastic materials are treated by grinding the products to form a particulate thermoplastic mixture, washing the particulate mixture to remove non-plastic materials, placing the thermoplastic mixture in a mold or shaped vessel, and heating the mixture to a temperature above the softening point of the lower melting thermoplastics and below the temperature of the softening point of the highest melting thermo-plastic of the mixture. In another embodiment, particulate thermo-plastic is used as a filler for asphalt compositions. In a further embodiment, waste thermoplastics are mixed with combustible cellulosic materials and formed into logs and the like which thermoplastic mixture has been treated to remove halogen containing thermoplastic such as polyvinyl chloride.

2 Claims, No Drawings

METHOD FOR RECYCLING WASTE PLASTICS AND PRODUCTS THEREOF

This is a division of application Ser. No. 191,901, filed Oct. 22, 1971, now abandoned.

BACKGROUND OF THE INVENTION

With the advent of plastics, many container products are now being made of these relatively low cost, strong and impact resistant materials. For example, many containers which had previously been made from glass or cardboard or other cellulosic materials which are easily reduced in bulk and in the latter case burned or otherwise destroyed are now replaced with plastic. Plastics normally used for packaging and as containers include polyethylene, both high and low density, polystyrene, polyvinyl chloride, and polypropylene. Further, high impact resistant plastics such as acrylonitrile-butadiene-styrene terpolymers are extensively used in preparing household appliances, toys and the like. A great variety of other plastics, too numerous to mention here are also used for producing many other items once prepared from metal or wood production, all of which present a special problem in waste disposal.

Of special interest are the plastics used for containers, which are generated at an alarming rate, because of the difficulty in disposing of these materials due to their high-bulk and resistence to compression, oxidation, etc. It has been estimated that of the annual 400 million tons of collected solid waste as refuse from municipal and industrial sources, plastics constitute approximately 8 million tons. Although the plastics often burn easily, some are ignited or burned only with difficulty, while others such as the halogen containing plastics like PVC are considered dangerous because upon degradation, halogens or hydrogen halides such as hydrochloric acid fumes are given off. Separation of plastics from other refuse is difficult at best unless initiated at the consumer or household refuse collection level while separation of types of plastics from one another is even more difficult or is considered impractical.

Recycling of separated plastics has been considered whereby, for example, scrap or used polyethylene materials are ground up and molded to prepare new products. However, such processes for reclaiming require separation of plastics by kind since the use of plastic mixtures recovered from refuse have not previously been considered feasible to produce generally useful products.

SUMMARY OF THE INVENTION

The present invention is directed to methods of treating waste plastics comprising mixtures of various types of these materials and to methods and compositions for utilizing or disposing of such plasic mixtures in useful and practical ways. According to the invention, mixtures of plastic products are ground to produce particulate plastic mixtures, the plastic is washed or otherwise treated to remove undesirable non-plastic materials and the resulting composition is thereafter treated thermally to produce various products in which single plastic homogeneity is not critical. Alternatively, the particulate plastic may be used as filler for bitumenous or asphalt compositions for roads or similar surfaces. Particulate plastic mixtures may be further treated by liquid floatation means to separate certain plastics having undesirable burning characteristics such as acrylonitriles, etc., after which the recovered plastic may be combined with cellulosic compositions to produce combustible materials such as fireplace logs and the like. These as well as other advantages of the invention will be evident from the following detailed description.

DETAILED DESCRIPTION OF THE INVENTION

The initial step in the recycling process according to the invention comprises placing the plastic products in a grinding, cutting or granulating apparatus to reduce the scrap product to particles or shreds. Any one or combination of a number of devices may be used for fragmenting or particulating the plastic including mill cutters, granulators and the like. The mill cutters may be selected from any desired size depending on the size of the bottle, container or other product which is to be ground by the cutting tool. Further, the spacing and number of teeth on the cutting head or bit may also be varied depending on the size or size range of the particles desired to be obtained. For example, where relatively narrow plastic bottles of the type commonly used for liquid detergents, shampoo and the like are to be ground, the mill cutter surface may be between about 1 and about 2 inches long and any suitable diameter. The spacing, number and depth of the cutting teeth may be varied as well as the speed at which the cutter is turned depending on the rate of cutting or grinding desired and particle size.

The grinding phase may be also carried out in one or more steps as desired. Thus, the first phase may utilize a rough grinding mill cutter which yields rather course particles, ribbons or granules of the plastic which particles may thereafter be further directed to a fine grinding step to yield finer particles. In addition, a granulator apparatus may be used in a single step, which apparatus is known to include rotor knives in combination with a sieve whereby the courser particles which do not pass through the sieve openings or apertures are further ground or cut until the desired small particle size is achieved. Again, such apparatus is well known to those skilled in the art and need not be described in further detail. Obviously, depending on the type of grinding equipment used, be it rough or fine, particle sizes will vary. However, particles capable of passing through 5–25 mesh screens will be suitable for most uses.

The second step involves washing of the particles to remove non-plastic materials such as paper, labels, container residue, metal particles and the like which will be unsuitable if the particles are to be later recycled for molding, forming or casting. However, if the particles are to be used for asphalt fillers or in preparing a combustible fire place logs or similar combustible products as will be more fully explained hereinafter, it is usually not necessary that the residual non-plastic materials be removed. In addition, if extensive non-thermoplastic materials are present such as bottle caps and the like, these may be removed prior to the initial grinding step. For example, the bottles or containers may be passed through pinch rollers and over-sized grates whereby the smaller cracked bottle caps, etc. will be separated by falling through the grate.

The washing step is accomplished by any desirable means such as soaking the plastic particles in a liquid, usually aqueous, with suitable agitation. The liquid should be of a specific gravity so that the plastic particles may be floated away from the non-plastic materials ther fine grinding step is then desired, depending on the appartus chosen, it may then be carried out on the recovered plastic particles.

During the grinding or granulating phase, it may also be desirable to use an antistatic agent especially where the particles are subjected to a fine grinding operation. It has been found that where relatively small particles are produced, the static electrical charges may cause difficulty in handling or recovering the particles from the cutter. Accordingly, when the wash solution contains antistatic agents such as high molecular weight fatty alcohols or other known polymeric anti-static agents, the static electrical problems will be obviated.

Depending on the various types of plastics present in the particular mixture, the plastic composition can be reused for molding, casting or otherwise forming various products. In preparing new molded or cast products from the mixed plastic particle compositions, it is desirable to utilize relatively small particles which are shaped as nearly spherical as possible. Accordingly, where the recovered plastic particles are to be thermally molded or cast, they are preferably further subjected to a mulling phase. The term mulling as used herein is understood to mean any operation which physically transforms irregular particles to a more spherical shape. A number of devices are commercially available for this purpose. The mulling step yields particles which will be more readily compacted than irregular shaped particle mixtures. Such a feature is important in achieving a higher density molded or cast product since initial spacing or separation between particles is minimized, thereby minimizing the amount of flow required. This feature further avoids entrapment of air which would otherwise not only decrease product density but would increase polymer oxidation and degradation due to the presence of entrapped oxygen. Again, however, where the particles are not to be used for molding or casting the mulling step may be omitted. For example, where the particles are to be used as filler for bitumen or asphalt materials or for combustible products, shreds, ribbons or other highly irregular particles may be directly processed without the additional particle shaping step or steps.

RECYCLING FOR CAST OR MOLDED PRODUCTS

By way of example, several used plastic bottles were cleaned to remove paper, labels and other undesirable non-plastic impurities, dried and subjected to a grinding operation. The grinding apparatus comprised a Severance Tool Cutter having 31 helical teeth per inch which cutter was driven at 3450 RPM. The plastic bottles comprised clear polyethylene and orange PVC and which were held against the revolving cutter surface. Small plateletts (about 0.03 × 0.03 × 0.005 inch) were obtained and boiled in salt water to remove static electricity. The particles were then subjected to a mulling operation between sheets of 4/0 sand paper. Mulling was accomplished by pressing the particles between an oscillating metal block and the sand paper sheets. The resulting particles appeared to be substantially spherical and packed to a high bulk density. The particles were then placed in a casting dish and heated in an oven or on a hot plate set at about 500°F. Heat transfer to the particles was slow and overheating is initially [illegible] moved after about 12 minutes, at which time fusion of the polyethylene was essentially complete but degradation was minimal. It was observed that the polyethylene softened and melted thereby surrounding and adhering to the PVC particles. The product achieved was a good quality cast bar having substantially no visible porosity. The product was not brittle and had good impact and strength properties.

In another example, various plastic products were subjected to the same grinding and mulling procedure as above described to achieve a particle mixture of approximately 44% low density polyethylene, 19% high density polyethylene, 31% styrene and 6% PVC, by weight. The mixture was selected to generally reflect mixture of scrap bottles, containers, etc. which might be found in municipal refuse. The particle mixture was placed in the casting vessel and heated by a hot plate for a period of 12 minutes. It was found that the mixture fused to a relatively dense bar having substantially the same impact and strength properties as noted above although some porosity was noted.

A mold or cast of any desirable shape or an extension device may be used in treating the plastic mixtures to achieve a great variety of useful plastic products. Again, the important feature in heating the mixtures in the mold or cast is to use a temperature sufficient to melt the lower melting plastics, but lower than the melting or degradation temperature of the highest melting plastic present. Accordingly, the temperature reached above was controlled by heating time to avoid degradation of PVC which is known to occur at about 250°F. However, if the sample is to be heated for a longer period of time, the heat of the mixture may be controlled by simply heating at the temperature which will avoid melting or degradation of the highest melting plastic of the mixture. Otherwise it may be necessary to monitor the sample temperature.

COURSE GROUND SCRAP FOR BITUMEN OR ASPHALT FILLER

A mixture of course ground clear polyethylene and orange PVC ribbons was prepared by grinding plastic bottles in a mill cutter 1¾ inch diameter × 1 inch long having 10 teeth around the cutter periphery. The cutter was turned 3500 RPM and ribbons having dimensions of about 0.005–0.02 inch thick by 0.02–0.06 inch wide by 0.06–1.0 inches long were recovered. The ribbons were mixed in a commercial cut back, i.e. solvent thinned, asphalt composition in a weight ratio of 30% plastic:70% asphalt. The plastic was readily wet by the asphalt and mixing was accomplished without difficulty and quickly stabilized the asphalt from further flowing. The plastic stabilized asphalt was compared to a similar asphalt in which sand was substituted for the plastic particles. Once the asphalt solvent had evaporated from both samples, it was noted that the plastic filled asphalt composition had significantly higher strength to hand pulling.

A further plastic filled asphalt composition was prepared with fine ground material as described hereinabove. The properties of the asphalt bar were found to be substantially similar to the plastic filled asphalt utilizing the larger ribbons but entrapped air and voids were more easily worked out of the bar. The sample prepared was found to have substantially greater hand pull strength as compared to the sample which was

Plastic filled asphalt is also observed to have substantially improved water and moisture resistance than sand filled asphalt. Such a feature will be appreciated since sand is somewhat incompatible with bitumen or asphalt and is readily wetted with water because of its hydrophilic nature. Thus, asphalt or bitumen does not readily wet or adhere to sand because of the hydrophobic nature of those hydrocarbon based materials. On the other hand, plastics are hydrophobic as compared to sand and are readily wetted by the asphaltic materials thereby resulting in a product having improved resistance to moisture and water as well as the improved strength characteristics noted above. Accordingly, it is believed that the use of scrap plastic particles for filling asphalt or bitumen either along or combined with same will yield an improved product as compared to presently used asphalt compositions incorporating only aggregate and/or sand fillers. The shape is preferably a ribbon, since the filler is added only to prevent cold flow under pressure. Thus, the ribbons act as fiber-like materials in maintaining asphalt integrity. Large ribbons will not pack well, even though steam rolled, so a size compatible with the final asphalt surfacing thickness is dictated. The course ribbon described herein is not too large for most applications, though "fines" would be needed for seal coats. The presence of various types of plastic do not appear to be critical for use in asphalt materials nor do the plastics need necessarily be of different types.

COMBUSTIBLE PLASTIC FILLED PRODUCTS

The use of scrap plastic particles as fillers or bulk material in preparing combustible products such as fireplace logs and the like, although desirable to acquire an effective means for disposing of the scrap plastics presents a special problem because of halogen containing plastics which are common in scrap plastic mixtures. Polyvinyl chloride (PVC) is a commonly used plastic for many containers because of its relatively low cost and flexibility especially in making squeeze-type bottles. It is well understood that upon combustion or degradation of halogen containing plastics, the halogens will be freed as vapors and usually in the form of hydrogen halides such as hydrogen chloride. Accordingly, attempts to burn PVC are obviously undesirable. However, where halogen containing plastic materials or acrylonitrile polymers are to be removed from the plastic mixture, they may be separated by a floatation technique. Such a technique comprises floating the mixed plastic particles including the undesirable plastic materials, in a liquid having a density greater than the desired plastics to be recovered but less than that of the halogen containing plastic. For example, in separating PVC from polyethylene-styrene-PVC mixtures, the use of a liquid having a density of about 1.09–1.10 gm/cc will separate PVC which has a density of about 1.16–1.45. Acrylonitriles such as ABS (acrylonitrile-butadiene-styrene) plastics can similarly be separated since the latter has a density of about 1.1–1.2 whereas polyethylene has a density of about 0.91–0.97 gm/cc.

By way of example, a solution of 1.27 pounds potassium nitrate per gallon of water was prepared having a density of approximately 1.09 g/cc. The particle mixture of 44% low density polyethylene, 19% high density polyethylene, 31% styrene and 6% PVC prepared as described above, was placed in the aqueous solution in the form of the course plastic ribbons. The PVC sank to the bottom of the vessel containing the solution and the remaining floating plastic material was separated, it being found that over 94% of the desired non-halogen containing plastics was recovered. The plastic ribbons were then mixed with a slurry of shredded used newspaper in a weight ratio of between 10%–75% plastic paper. The materials were recovered from the slurry on a fine screen and compressed to remove most of the water and allowed to dry. In another sample, only the paper was used without plastic filler and compressed to approximately the same density and allowed to dry. These materials were shaped in the form of elongated pieces of approximately 1 foot in length and between about 3 and about 6 inches wide at their widest part and ½–1 inch thick. The paper sample alone was ignited and found to glow and smoke only along the edges but was not satisfactorily combustible. On the other hand, samples containing about 25%, 50% and 75% plastic ribbons ignited readily and burned well thereafter in a manner similar to soft wood such as pine logs or pieces of similar size. Accordingly, it is evident that the addition of the scrap plastic materials enhanced combustion properties. Such products serve as a practical means of disposing of the scrap materials thereby being desirable not only from a waste disposal standpoint but also evidencing commercial advantages and uses. It will be appreciated that the density of such combustible products may be varied depending on the desired burning rate as well as other variations including the preparation of desired slurries and use of other combustible cellulosic-type materials as will be appreciated by those skilled in the art. It should also be noted that olefinic materials and especially low cost or waste olefins or aliphatic compounds such as paraffins or natural resins such as pine tar, pitch and the like which burn easily may be substituted for a portion of the plastic particles. The substitution of these materials will be desirable when sufficient waste plastics of the desired types are not readily available.

Odors from the burning samples are not especially strong but might be considered objectionable in certain circumstances. These odors can be masked or typical odors of burning wood may be created by adding agents such as those used in various fragrances. Those familiar with the art of odor control will appreciate the aesthetic value of adding artificial odors.

I claim:

1. A method of disposing of mixed waste thermoplastic materials comprising halogen containing plastics and non-halogen containing plastics comprising the steps:

a. grinding the materials to form a particulate thermoplastic mixture;
b. separating low and high density plastics by floating the mixture through a liquid holding chamber containing a liquid having a density of less than the density of halogen containing plastics;
c. recovering the floating particles;
d. mixing the recovered particles with a slurry of cellulosic material; and
e. compressing the mixture of step (d) to form a combustible product.

2. The method of claim 1 wherein the mixture comprises polyethylene and polyvinyl chloride plastics.

* * * * *

United States Patent [19]

Ooba et al.

[11] 3,857,799

[45] Dec. 31, 1974

[54] PROCESS FOR THE REGENERATION OF PLASTICS

[75] Inventors: Seiichi Ooba, Asaka; Shinichi Hirayama, Fukuyama, both of Japan

[73] Assignee: Fuji Photo Film Co., Ltd., Kanagawa, Japan

[22] Filed: Feb. 25, 1972

[21] Appl. No.: 229,501

[30] Foreign Application Priority Data

Feb. 25, 1971 Japan 46-9483

[52] U.S. Cl. .... 260/2.3, 260/16, 260/17 R, 260/40 R, 260/873, 260/897 R, 260/901

[51] Int. Cl. .. C08f 47/24, C08g 53/22, C08b 29/40

[58] Field of Search .... 260/2.3, 2.5 N, 873

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Primary Examiner—Wilbert J. Briggs, Sr.
Attorney, Agent, or Firm—Sughrue, Rothwell, Mion, Zinn & Macpeak

[57] ABSTRACT

The process for regenerating waste plastics by mixing the waste plastics with an ether-type polyester and at least one member selected from the group consisting of a homopolymer of vinyl acetate, an ethylenevinyl acetate copolymer or a tacky polyolefin; and if necessary a foaming agent, and then molding the mixture into a desired shape.

15 Claims, No Drawings

PROCESS FOR THE REGENERATION OF PLASTICS

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a process for regenerating waste plastics. More specifically, the invention relates to an improved process for regenerating and utilizing waste plastics.

2. Description of the Prior Art

Recently plastics, for instance, a thermoplastic resin such as a polyolefin type resin or a polystyrene type resin and a thermo-setting resin such as a urea type resin, a melamine type resin, or a phenol type resin have been utilized in various fields as moldings such as vessels, fibers, films, sponges, etc., and the production amounts required have increased remarkably.

These moldings are wasted after use but the disposal of the waste plastics is a great trouble in every field. That is to say, as the most common disposal method, the waste plastics are burned, but in this case injurious gases are formed and also heat and smoke are generated as well as the fact such a disposal requires an expensive burning furnace.

A disposal of waste plastics without the necessity of burning has been proposed. That is to say, the recovery and regeneration have been attempted for a polyvinyl chloride film or a polyethylene film used as a substantially single article and for a single use, e.g., used as an agricultural house, but in many cases the polyvinyl chloride is mutually intermingled with polyethylene and thus it is quite difficult to separate them owing to the immiscibility of them. Therefore, the economical regeneration of them has not succeeded. Also, in the field of polyvinyl chloride leather, a method is known in which such a leather with a backing cloth is treated with concentrated sulfuric acid under heating to dissolve away the cloth and after washing with water, the remaining polyvinyl chloride is recovered. However, since such a process is difficult from an economic point of view and further since such a process is accompanied with a problem of water pollution from the sulfuric acid-containing waste solution such a process has not been practically employed.

Another important problem encountered in the regeneration and utilization processes without the necessity of a burning operation is that such plastics contain small amounts of organic and inorganic materials and even if each plastic can be separated, such foreign matters are intermingled inevitably in the plastic recovered.

An object of this invention is, therefore, to provide a process for chemically treating waste plastics and economically regenerating the plastics without causing the problem of water pollution.

The above object of this invention is attained by crushing the waste plastics without separating them from each other, blending the crushed plastics with adhesives, and after blending further, if necessary, a foaming agent therewith, molding the mixture according to the desired purposes.

The important feature of this invention is in the point of using the two kinds of compounds (a) and (b) shown below.

That is to say: (a) an ether-type polyester prepared by heating a mixture of polyethylene terephthalate and at least one kind of glycol other than ethylene glycol to substitute the ethylene glycol units in the polyethylene terephthalate with the glycol, and (b) at least one member selected from the group consisting of a vinyl acetate homopolymer, an ethylene vinyl acetate copolymer, and tacky polyolefins.

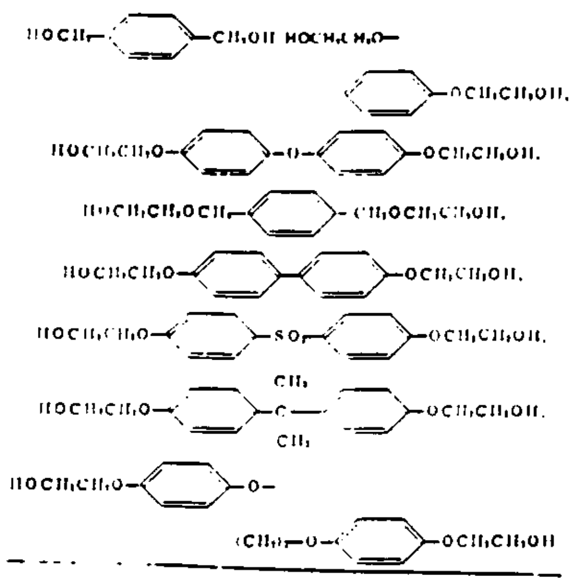
The above ether-type polyesters (a) can be prepared by gradually adding the polyethylene terephthalate to one or more of the glycols and gradually heating the mixture in a flowing dry nitrogen atmosphere. The polymer is gradually dissolved in the glycol or glycols or is dispersed therein after the temperature of the mixture has reached the melting point of the polymer. The reaction temperature is normally the boiling point of the glycol or glycols or in the vicinity thereof, and is preferably about 200°-260°C. A catalyst may be used although it is not necessary, the catalyst being those catalysts which are generally used in the synthesis of polyethylene terephthalate such as an alkali metal, an alkaline earth metal or derivatives thereof. In effect, an ester interchange reaction takes place between the glycol and the polyethylene terephthalate wherein the ethylene glycol components in the polyethylene terephthalate molecule are substituted by the other glycol. Thereafter, the substituted ethylene glycol may be distilled out from the mixture and removed therefrom. The reaction is carried out for about 2-20 hours and the properties of the resulting product vary depending upon the time of reaction. Generally, the reaction period preferably is 6-10 hours. At the end of the reaction, when it is complete, the system is kept under a vacuum at the final reaction temperature in order to remove the excess glycol and the formed ethylene glycol. The adhesive property of the resulting product depends upon the content of the raw materials used and the amount of the glycol which is substituted for the ethylene glycol units of the polyethylene terephalate. Generally, from about 30 to 100 percent of the ethylene glycol components of the polyethylene terephthalate are substituted by the other glycol.

Such ether-type polyesters have sufficient adhesive properties not only for various inorganic materials but also for polyolefins and specific synthetic rubbers that have hitherto been believed to show poor adhesive properties to polyesters. The component (b) used together with the ether-type polyester also has an adhesive property and by using the component together with the ether-type polyester, the adhesive effect thereof can be further increased. The practical examples of the components (b) are an emulsion of a vinyl acetate homopolymer, an emulsion or a solution of an ethylene-vinyl acetate copolymer, and a tacky polyolefin such as a polyolefin having a low polymerization degree or atactic polypropylene.

Besides the component (b) mentioned above, cross-linkable adhesives such as urea type resins or melamine type resins may be used if necessary.

When a foaming agent is used in this invention, every foaming agent conventionally known may be used without any restriction.

Glycols other than ethylene glycol are used in this invention, e.g., polymethylene glycols $\{HO(CH_2)_nOH$, $n=3-20\}$, such as trimethylene glycol, tetramethylene glycol, pentamethylene glycol, hexamethylene glycol, and the like; polyethylene glycols $\{HO(CH_2CH_2O)_nOH$, $n=2-100\}$, such as diethylene glycol, triethylene glycol, and the like; alkylene glycols, such as propylene glycol, butylene glycol, neopentyl glycol, hexylene glycol, octylene glycol, cyclohexane-1, 4-dimethanol, and the like, or compounds having aromatic groups between two hydroxyl groups, such as compounds of the following formulas, and the like, can be used.



By utilizing the adhesive property, the component (a) and the component (b) are sufficiently dispersed in crushed plastic waste which may contain inorganic matters to some extent by a solvent method, a powder mixing method, etc., according to the apparent mixing ratio, the mixture is dried, and after being aggregated by melting them to some extent if necessary, molded into a solid article, a foamed article, a sheet, a board, or a laminate by means of heat molding, rolling, lamination, etc. Of course, in this case a thermo-foaming agent such as sodium carbonate may be incorporated in the mixture to provide a hard material or a heat insulating material.

The plastic wastes used in this invention include shaped articles such as vessels which are crushed in the practice of this invention and also fine wastes such as waste fibers which can be used without the necessity of a crushing operation.

According to the process of this invention waste plastics are all recovered and further they are regenerated for reuse and accordingly not only are the troubles caused by such wastes removed but also plastic articles are produced from such wastes with a low cost. Moreover, because a burning operation is not employed in this invention, the practice of the process of this invention does not suffer from the formation of noxious gases or smoke. Thus, the process of this invention is quite a significant industrial process.

Hereinafter, the invention will be more specifically described by referring to the following examples.

EXAMPLE 1

A plastic waste mixture of polyethylene hollow bottles, polystyrene vessels, polystyrene foams, polyvinyl chloride films, and polyvinyl chloride leathers containing further almost the same amounts of waste woods and papers was crushed into rice-grain forms by means of a crusher and to 100 parts by weight of the grains were added successively a 20 percent solution of 10 parts by weight of the ether-type polyester, an emulsion of 10 parts by weight of polyvinyl acetate, and a 60 percent aqueous solution of 5 parts by weight of an urea resin. The mixture was sufficiently blended and dried at 50°-70°C. By press molding the dried mixture at a temperature of higher than 180°C, sheet-shaped soft solid articles or soft solid boards having various curved surfaces were obtained.

EXAMPLE 2

Waste plastics of polyolefin, polystyrene, polymethacrylate, and reinforced plastics containing some amounts of inorganic matters were crushed into particles smaller than rice grains and after adding to 100 parts by weight of the crushed waste a 50 percent solution of 20 parts by weight of the ether-type polyester, an emulsion of 15 parts by weight of polyvinyl acetate, a solution of 5 parts by weight of a low molecular weight polyolefin, and 15 parts by weight of sodium bicarbonate followed by blending well, the mixture was dried at 50°C to remove water and other solvents completely and molded under a pressure of lower than 20 kg/cm² at a temperature of higher than 180°C to provide a foamed board.

EXAMPLE 3

A plastic waste mixture containing more than 50 percent polyolefin, other thermoplastic resins, celluloses, and small proportions of clay, wood powder and fibers was crushed into rice-grain form and after adding to 100 parts by weight of the crushed waste mixture a 50 percent solution of 30 parts by weight of an ether-type polyester, an emulsion of 20 parts by weight of an ethylene-vinyl acetate copolymer containing 15 percent vinyl acetate, and a 60 percent solution of 10 parts by weight of urea resin and drying at about 60°C, the mixture was further mixed with 20 parts by weight of sodium bicarbonate powder and molded in a metallic mold at a temperature of lower than 180°C under a low pressure to provide a semi-soft foamed board.

EXAMPLE 4

A plastic waste mainly consisting of polyolefin and containing other transparent thermoplastic resins was formed into fine pieces by means of a cracker roll and after adding to 100 parts by weight of the fine pieces a 5 percent solution of 20 parts by weight of the ether-type polyester and an emulsion of 10 parts by weight of polyvinyl acetate and blending the mixture sufficiently, the mixture was dried continuously at a temperature of higher than 60°C on a conveyor belt and then rolled by means of a heating roll to provide a transparent or translucent plastic sheet.

EXAMPLE 5

A plastic waste containing 70 percent of a thermoplastic transparent resin and 20 percent of a thermosetting resin was crushed into particles of a size less than rice grains and after adding successively to 100 parts by weight of the crushed plastic waste a 30 percent solution of 10 parts by weight of the ether-type polyester, an emulsion of 30 percent by weight of polyvinyl acetate, a solution of 10 percent by weight of a urea resin, and 30 parts by weight of sodium bicarbonate, blending sufficiently, and drying the mixture at a temperature of lower than 50°C, the mixture was press-molded between metallic plates coated with the ether-type polyester followed by drying to provide a sandwich-type board.

EXAMPLE 6

A mixture of 100 parts by weight of a plastic waste mainly consisting of thermoplastic resins, 20 parts by weight of atactic polypropylene and 20 parts by weight of the ether-type polyester was melted by heating applied to a surface lubricant paper by means of a roll coater and after further coating the plastic-coated surface of the paper with the ether-type polyester, the coated paper was stuck to a carpet by means of a laminator and thereafter the lubricant paper was stripped off to provide a plastic-coated carpet.

What is claimed is:

1. A process for regenerating waste plastic material comprising,

A. mixing said waste plastic material with (1) a modified polyester prepared by heating polyethylene terephthalate in the presence of a glycol to substitute said glycol for 30 to 100 percent of the repeating ethylene glycol units of said polyethylene terephthalate, said glycol being selected from the group consisting of polymethylene glycols, polyethylene glycols, alkylene glycols and glycols represented by the formula $HOCH_2-X-CH_2OH$ wherein X is an organic group having at least one aromatic ring, with the proviso that said glycol is not ethylene glycol, and (2) at least one member selected from the group consisting of a vinyl acetate homopolymer, an ethylene-vinyl acetate copolymer and a tacky polyolefin selected from the group consisting of a polyolefin having a low polymerization degree and atactic polypropylene, the amount of components (1) and (2), in combination, being effective to adhere said waste plastic material in a moldable form; and

B. molding the resulting mixture into the desired shape; said plastic being selected from the group consisting of thermoplastic and thermosetting resins.

2. The process of claim 1 wherein said waste plastic material is crushed before said mixing step.

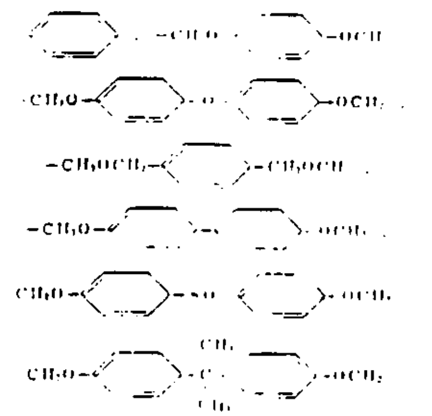
3. The process of claim 1 wherein said plastic is selected from the group consisting of polyethylene, polyvinyl chloride, polystyrene, polymethacrylates, urea resins, melamine resins, phenol resins and cellulose resins.

4. The process of claim 1 wherein said glycol is a polymethylene glycol represented by the formula $HO(CH_2)_nOH$ wherein n varies from 3 to 20.

5. The process of claim 1 wherein said glycol is a polyethylene glycol represented by the formula $HO(CH_2CH_2O)_nOH$ wherein n varies from 2 to 100.

6. The process of claim 1 wherein said glycol is an alkylene glycol selected from the group consisting of propylene glycol, butylene glycol, neopentyl glycol, hexylene glycol, octylene glycol and cyclohexane-1,4-dimethanol.

7. The process of claim 1 wherein X is selected from the group consisting of



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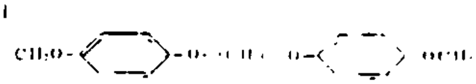

8. The process of claim 1 wherein said waste plastic material is mixed with a foaming agent in addition to said ether-type polyester (1) and said member (2) prior to said molding step.

9. The process of claim 8 wherein said waste plastic material is crushed prior to said mixing step.

10. The process of claim 8 wherein said plastic is selected from the group consisting of polyethylene, polyvinyl chloride, polystyrene, polymethacrylates, urea resins, melamine resins, phenol resins and cellulose resins.

11. The process of claim 1 wherein said plastic is a thermoplastic resin.

12. The process of claim 1 wherein said plastic is a thermosetting resin.

13. The process of claim 2 wherein said crushing is to render said waste plastic material into particulate form.

14. The process of claim 1 wherein the ratio of component to component (2), on a parts by weight basis, is 1:1/3 to 3.

15. The process of claim 1 wherein the ratio of component to component (2) expressed as the result of component (1)/component on a parts by weight basis is from 1/3 to 1.5.

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United States Patent [19]

Hart et al.

[11] 4,249,875

[45] Feb. 10, 1981

[54] CO-EXTRUSION APPARATUS AND METHOD FOR PRODUCING MULTIPLE-LAYERED THERMOPLASTIC PIPE

[75] Inventors: Edward Hart; Raleigh N. Rutledge, both of Big Spring, Tex.

[73] Assignee: Cosden Technology, Inc., Dallas, Tex.

[21] Appl. No.: 942,792

[22] Filed: Sep. 15, 1978

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 812,041, Jul. 1, 1977, abandoned.

[51] Int. Cl.[3] B29D 23/04; B29D 9/00

[52] U.S. Cl. 425/133.1; 425/380; 425/462

[58] Field of Search 264/173, 45.9; 425/133.1, 462, 380, 97, 467

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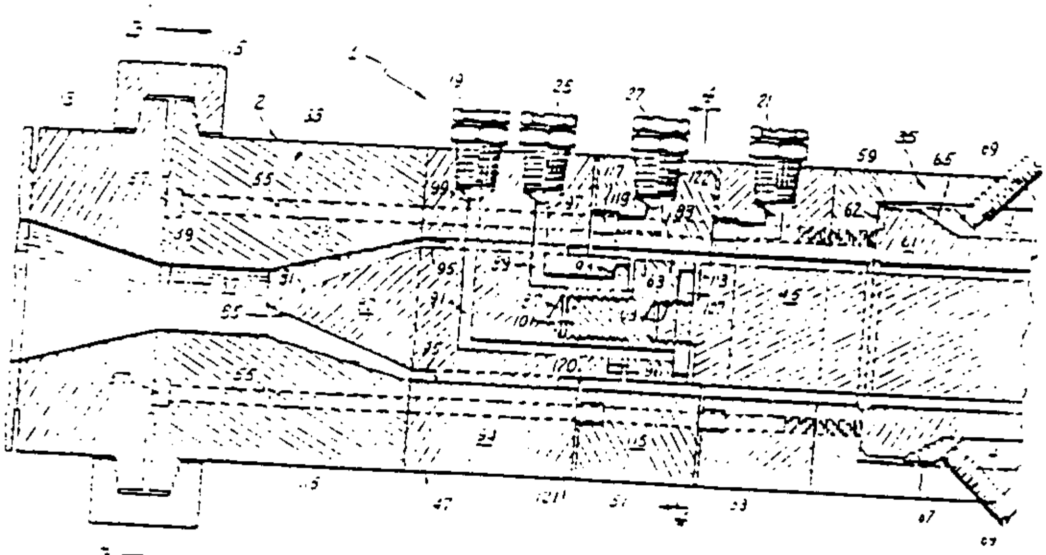
Primary Examiner—James B. Lowe

Attorney, Agent, or Firm—Schwartz, Jeffery, Schwaab, Mack, Blumenthal & Koch

[57] **ABSTRACT**

A melt extrusion process and apparatus for producing a multiple-layered pipe (preferably of two or more thermoplastic resins) are disclosed. The process comprises extruding a cylindrical stream of thermoplastic material, converting the cylindrical stream to an annular stream, applying at least one inner annular layer of thermoplastic to the inner surface of the annular stream, applying at least one outer annular layer of thermoplastic material to the annular stream, and extruding the resultant multiple-layered annular stream. Apparatus for producing this pipe includes a modular pipe die having inside and outside laydown means, flow equalizing means within each of the inner and outer laydown means to obviate layer imperfections, and adjustable means to control the concentricity of the outer layers. The invention finds particular application in the production of a thermoplastic pipe having an intermediate expanded core.

17 Claims, 10 Drawing Figures



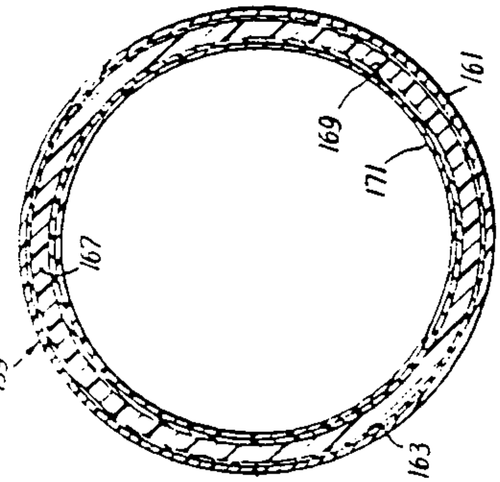


Fig. 7.

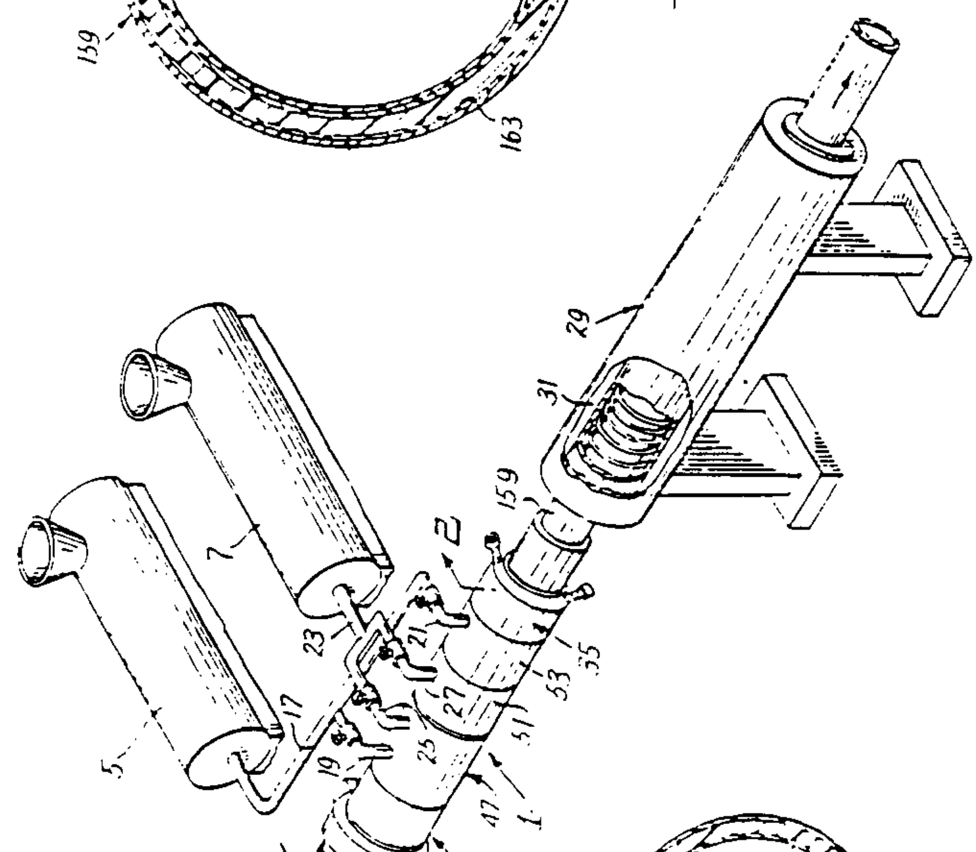


Fig. 1.

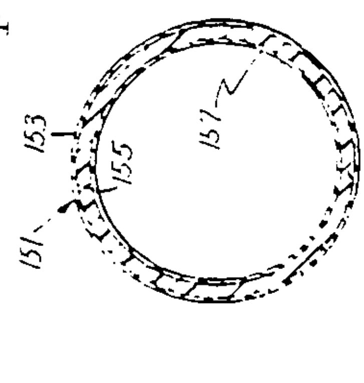


Fig. 6.

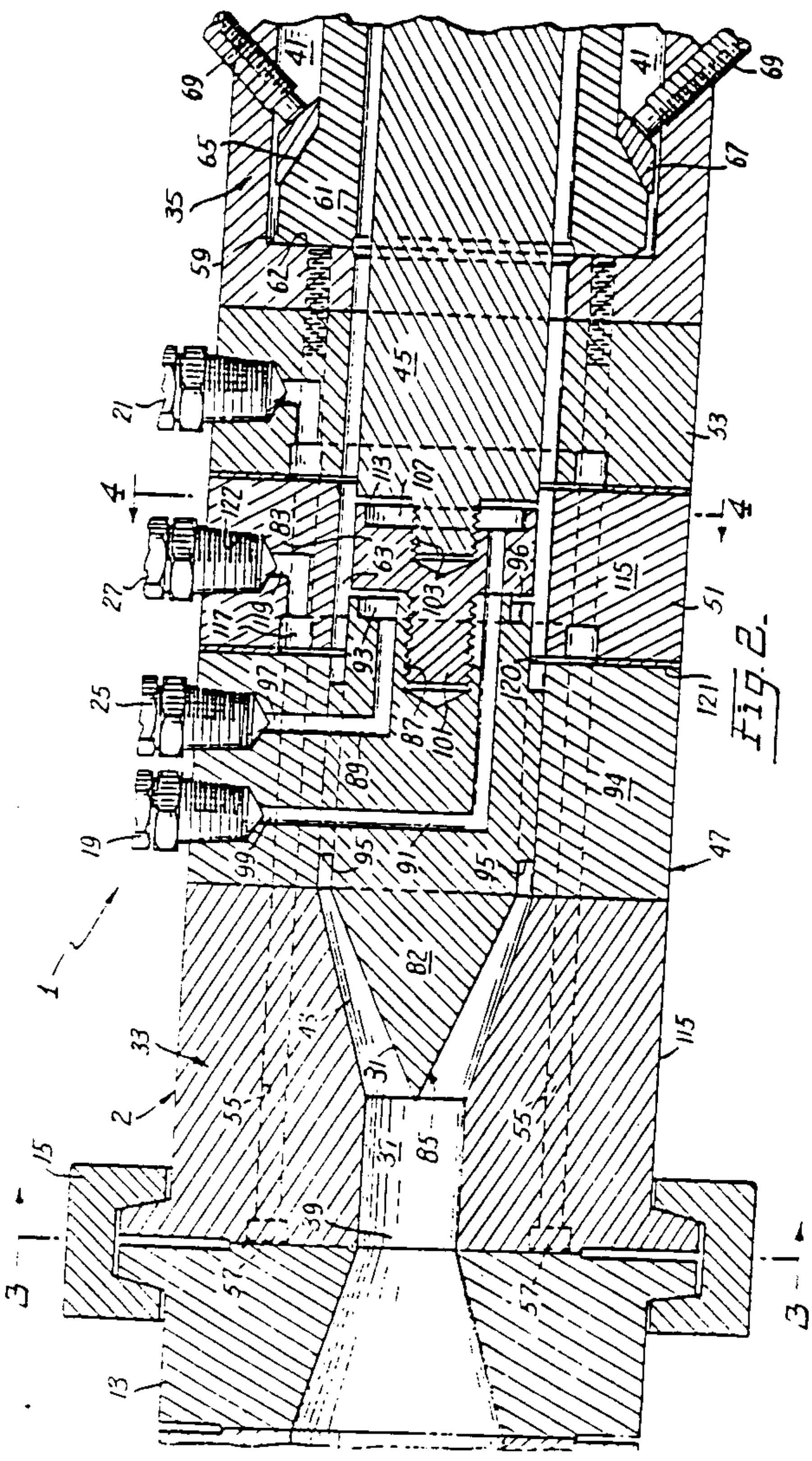

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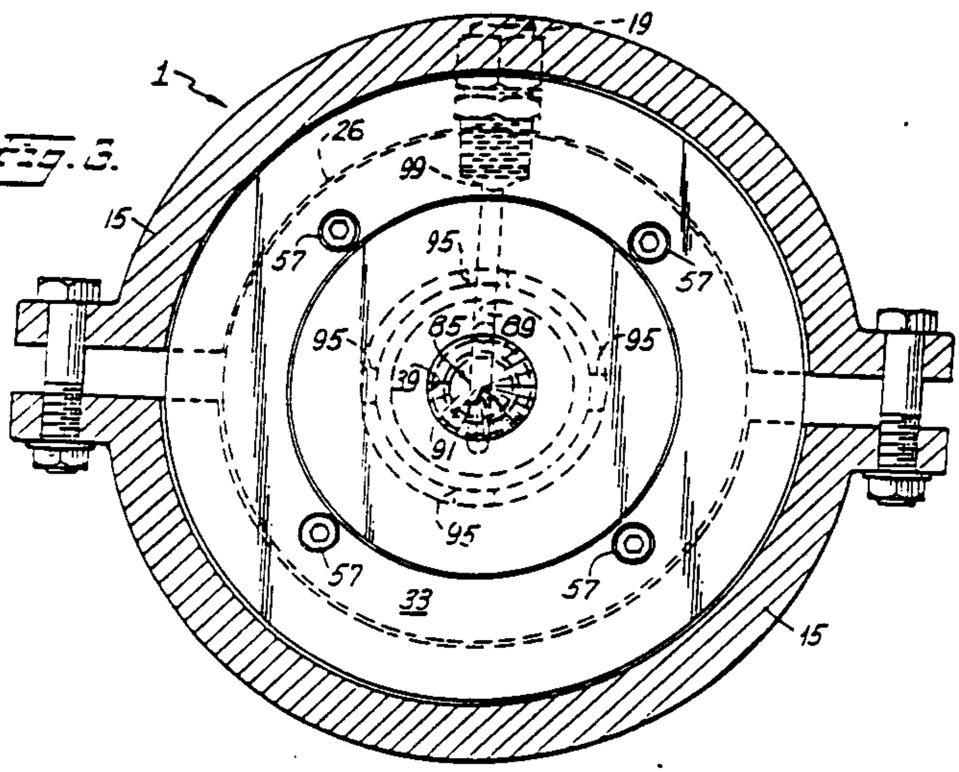
Fig. 2.

FIG. 3.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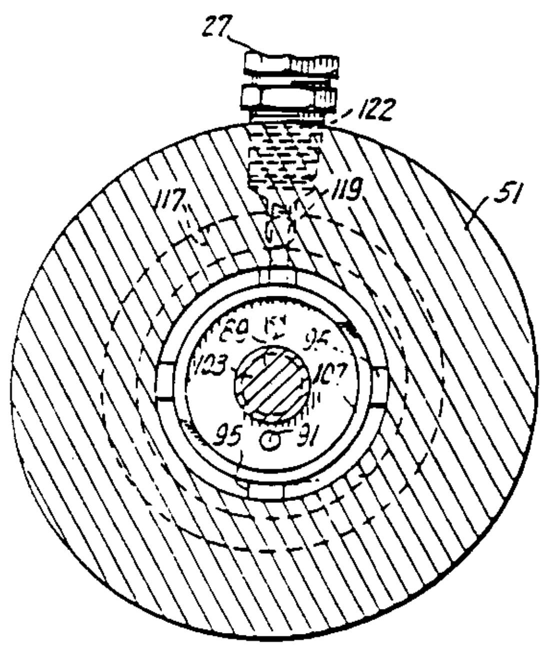
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122
117
119
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103
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91

FIG. 4.

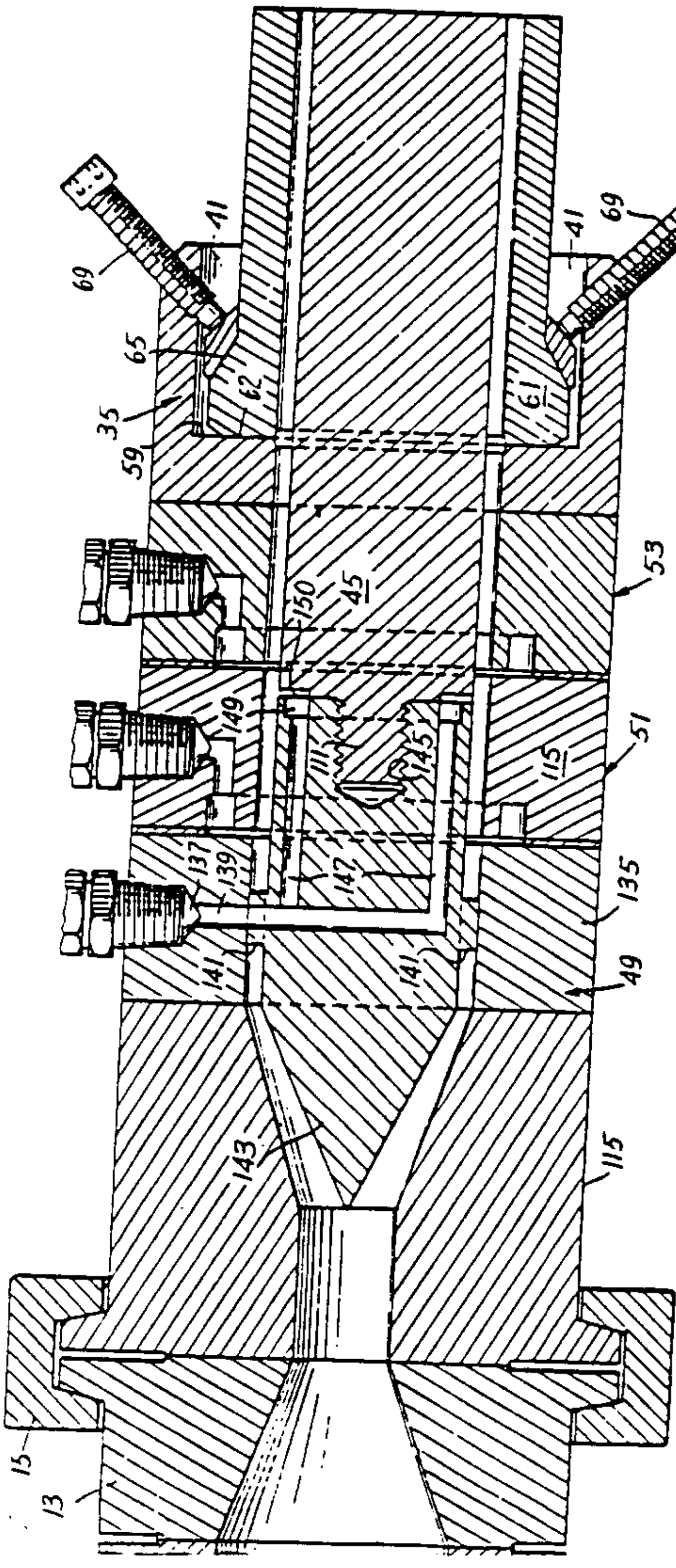
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Fig. 5.

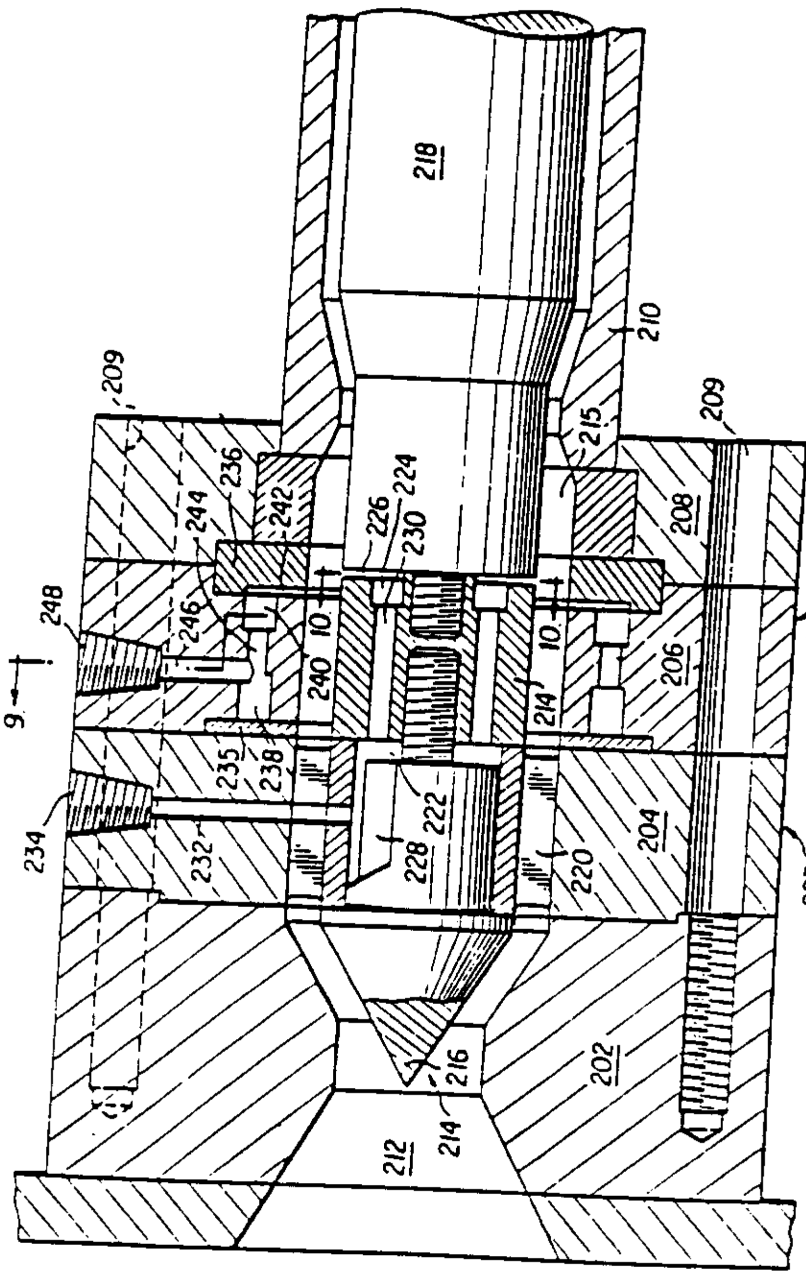
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FIG. 8

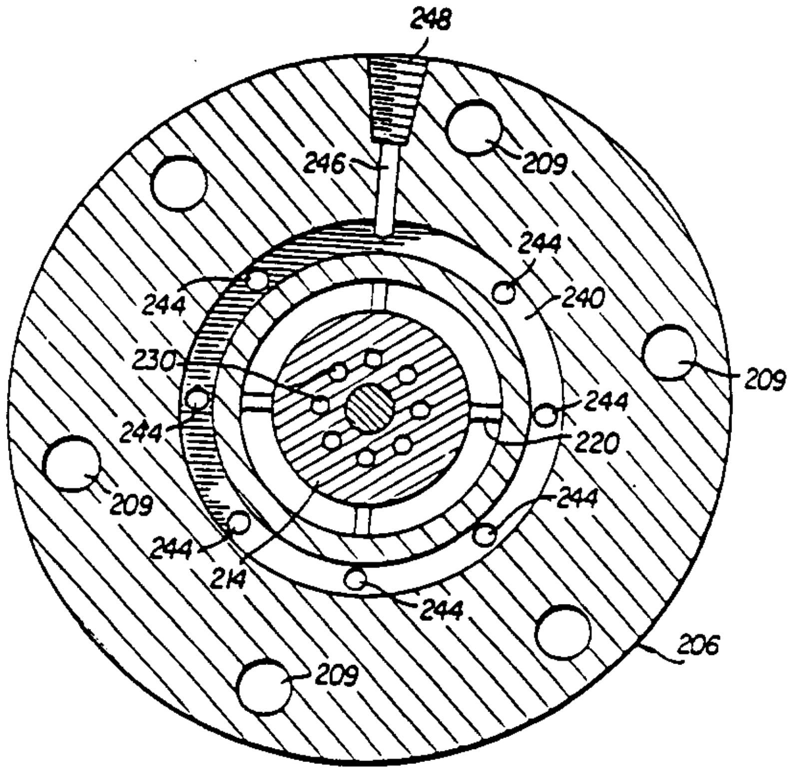
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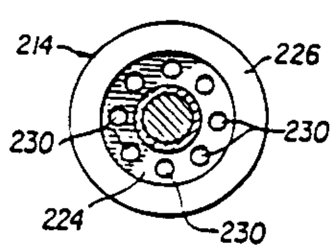
FIG. 9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230
224
230

FIG. 10

CO-EXTRUSION APPARATUS AND METHOD FOR PRODUCING MULTIPLE-LAYERED THERMOPLASTIC PIPE

CROSS-REFERENCE TO RELATED APPLICATIONS

The instant application is a divisional continuation-in-part application of co-pending application, Ser. No. 812,041, filed July 1, 1977 now abandoned.

BACKGROUND OF THE INVENTION

The present invention relates to multiple-layered pipe, preferably of two or more thermoplastic resins, and preferably having three layers comprising at least one outer layer, an intermediate core, and at least one inner layer, and a process and apparatus for the manufacture of such pipe. The present invention is particularly useful for producing pipe having an intermediate core of expanded thermoplastic resin.

Many attempts have been made to produce a multiple layered pipe in order to combine the desirable characteristics of different thermoplastic resins. These attempts have usually involved extruding several streams of thermoplastic resins through a series of concentric tubes which are fixed relative to one another in a radial manner, such as by spiders, to define annular passages therebetween, and then subsequently joining the resultant annular layers to produce a multiple-layered pipe. Pipes prepared by such processes and apparatus, however, have had spider marks thereon due to the flow interruptions caused by the many spiders necessitated in such apparatus. Moreover, such apparatus contain adjusting screws which protrude into the individual die passages for adjusting the thickness of the annular layers. These screws also interfere with the flow of the molten resin as it is being extruded, whereby additional marks have been developed upon the pipe.

Furthermore, it is undesirable to provide an extrusion die for each layer of the desired pipe. Since high internal pressure is required for the extrusion of the highly viscous heat plastified thermoplastic material, such apparatus are subject to distortions in the die which cause undesirable nonuniformity in the thickness of each layer, unless the extrusion pressures of each layer are balanced. However, in practice, it is frequently difficult to maintain extrusion pressures constant in their proper relationship. Those types of apparatus employing a separate die for each layer thus inherently involve difficulty in controlling the thickness of each layer in the desired pipe.

Another disadvantage associated with prior art apparatus for the production of co-extruded plastic pipe is the inability of the prior art apparatus to equalize the flow of thermoplastic within the die so that the heat plastified thermoplastic is applied as a continuous layer of constant thickness. This problem is particularly prevalent in those apparatus in which layers of thermoplastic are extruded through radial orifices. In order to form a layer of constant thickness, it is absolutely essential in such apparatus that the flow of thermoplastic through the orifice is constant along its entire circumference.

In the extrusion of multiple-layered pipe having an intermediate core of expanded thermoplastic material, this inability to form uniform layers of thermoplastic becomes even more objectionable. In order to produce a thermoplastic pipe with an expanded core which possesses high mechanical strength, it is absolutely necessary that each layer has a constant thickness. Failure to achieve very precise uniformity of thickness of each layer in expanded pipe, results in a product which has inferior physical properties.

In U.S. Pat. No. 3,223,761 is disclosed a process and apparatus for producing multiple-layered plastic tubing without a separate die for each layer of tubing. Several streams of the desired thermoplastic are fed to a multiported laydown which produces a composite multiple-layered cylindrical stream. This stream is then transported to an annular die having a mandrel which forms the cylindrical stream into an annular stream. However, in order to maintain layer uniformity of thickness, it is necessary that the extrusion process occur under objectionally high pressure conditions and with a velocity below the threshold of turbulent flow to preserve laminar flow conditions. Such apparatus and process are limited, however, to the extrusion of a three-layered pipe of only two different materials. For the extrusion of pipe containing more than two thermoplastic resins, a plurality of extruders having tapered nozzles are selectively positioned within the cylindrical stream to form a core of a new thermoplastic material. These extruders interfere with the melt flow, yielding a pipe with manufacturing imperfections. To maintain uniformity of layer thickness in this prior art apparatus, it is furthermore essential that the very precise process conditions described above be maintained, a difficult fact to accomplish in practice.

U.S. Pat. Nos. 3,447,204, 3,819,792, and 4,061,461 disclose die apparatus for producing a multiple-layered tube without employing the die-within-the-die concept. Such apparatus is limited, however, to the production of only two layered structures. Moreover, with such apparatus the flow of thermoplastic through the extrusion passageways is not balanced, precluding thereby the formation of layers of uniform thickness.

As has been stated above, the disadvantages associated with the above processes and apparatus are particularly acute in the production of multiple-layered thermoplastic pipe with an intermediate core of expanded thermoplastic material. The smaller amount of expensive thermoplastic resin in the core region, and the decrease in weight associated therewith, has made expanded pipe very attractive. Accordingly, it was proposed in U.S. Pat. No. 3,782,870 to produce a thermoplastic multiple-layered pipe with an intermediate core of expanded material. Such prior art expanded pipe has been marked, however, by prohibitatively low mechanical strength, low resistance to shock, high brittleness, and generally to be of inferior quality to non-expanded thermoplastic pipe. Moreover, such pipe has been manufactured from only a single thermoplastic resin and thus possesses inferior characteristics when compared to non-expanded pipe combining the desirable properties of several thermoplastic resins.

One attempt to produce a multiple-layered pipe having an intermediate expanded core without a separate die for each layer is disclosed in U.S. Pat. No. 3,299,192 in which a multiple-layered tube is formed by extruding a stream of thermoplastic containing a blowing agent, converting the stream into an annular stream, and then forming inner and outer skins thereon by quench chilling the annular stream. Necessarily, such a method is limited to the manufacture of pipe from only a single thermoplastic resin. Pipe produced by this method, therefore, exhibits the inferior physical characteristics associated with expanded pipe manufactured from only a single thermoplastic material.

The above-noted physical defects associated with prior art expanded pipe can be attributed to a failure in the prior art to develop a process and apparatus which can effectively control to very precise tolerances the uniformity of thickness of each layer. The inability of the prior art to control precisely layer thickness can be further attributed to the inability to produce plastic flow equalization throughout the narrow flow passages within a die. The inability of the prior art to produce a practicable expanded pipe is indicative, more generally, of the inability of the prior art to produce multiple-layered pipe of at least two thermoplastic resins with a uniform and desired thickness for each layer.

It would be desirable, therefore, if an apparatus and process for the production of multiple-layered pipe were available which could attain very precise control of layer thickness and flow equalization of the thermoplastic throughout the narrow extrusion passages of the die.

SUMMARY OF THE INVENTION

It is an object of the present invention, therefore, to produce a die apparatus for the production of multiple-layered pipe, preferably of at least two thermoplastic resins, which does not employ a separate die passage for each layer of resin.

It is a further object of the present invention to provide a process for the production of high quality multiple-layered pipe, preferably of at least two thermoplastic resins.

Still another object of the instant invention is to provide a modular pipe die capable of producing extruded thermoplastic pipe having from two to five layers.

It is another object of the present invention to provide a balanced flow die apparatus wherein the flow of thermoplastic is maintained at a constant value over the entire area of an extrusion passage.

It is yet another object of the present invention to provide a die apparatus which can control the thickness of each layer uniformly with a low percentage deviation.

It is still another object of the present invention to provide a die apparatus which enables various types of thermoplastic resins to be used for extruding a multilayer pipe therefrom.

A further object of the present invention is to provide a multiple-layered pipe having an intermediate core of expanded thermoplastic resin.

Yet another object of the present invention is to provide such expanded pipe combining the desirable characteristics of several thermoplastic resins.

An additional object of the present invention is to provide expanded multiple-layered pipe having a high mechanical strength, high shock resistance, low weight, and large savings of thermoplastic resin.

It is a further object of the present invention to provide a process for the production of non-expanded pipe having high mechanical strength, high shock resistance, low weight, and large savings of thermoplastic resin.

A specific object of the present invention is the provision of a balanced flow die apparatus in which layers of thermoplastic can be applied in a uniform manner.

The foregoing objectives are achieved according to the instant invention through the provision of a modular die apparatus and a process which enable multiple-layered pipe, having from two to five layers and combining the desirable characteristics of several thermoplastic resins, to be produced, and concomitantly which enable the production of pipe which has uniform layer thickness, which is not marked by manufacturing imperfections, and which has high mechanical strength. It has been found that pipe with the aforementioned desirable characteristics may be produced, according to the instant invention, through the use of a modular die apparatus which eliminates the separate die for each layer concept. Since apparatus employing this concept is subject to die distortions which produce non-uniformity of layer thickness, high uniformity of layer thickness can be achieved by utilizing an apparatus which employs only a single die passage. Moreover, it has been found that by providing flow equalizing means in each of the laydown means, flow of thermoplastic through the laydown orifices can be equalized, resulting in greater uniformity of layer thickness.

The modular die apparatus of the instant invention comprises a balanced-flow die apparatus having a main extrusion passageway with an annular cross-section for transporting a first annular stream of thermoplastic. At least one inner laydown means circumscribed by the main extrusion passageway is provided for applying a layer of thermoplastic to the inner surface of the first annular stream of thermoplastic. At least one outer laydown means circumferentially surrounding said main extrusion passageway is also provided for applying a layer of thermoplastic to the outer surface of the first annular stream of thermoplastic. Each of the inner and outer laydown means comprise an annular radial orifice which communicates with the main extrusion passageway, and an annular feed ring which supplies thermoplastic to the orifice. In a further, preferred embodiment of the instant invention, each of the inner and outer laydowns further comprises means for equalizing the flow of thermoplastic to a uniform value over the entire circumference of the orifices.

As has been stated above, the present invention is particularly applicable to the manufacture of a multiple-layered thermoplastic pipe having an intermediate expanded core. Accordingly, the present invention also contemplates a process for the preparation of such pipe which comprises forming in an extrusion apparatus a first cylindrical solid stream of a thermoplastic resinous material containing a blowing agent; converting the cylindrical stream into n annular stream by axially piercing and radially distributing the cylindrical stream; applying at least one inner annular layer to the annular stream from a second stream of thermoplastic resinous material; applying at least one outer annular layer to the annular stream from a third stream of thermoplastic material, thereby producing a multiple-layered annular stream; and extruding the multiple-layered annular stream through an annular die orifice to from a pipe. As a further embodimet, the die is heated during the extrusion step to produce pipe with a high gloss. Additionally, the thus formed pipe may be vacuum sized to produce the final pipe product.

A two-layered expanded pipe may also be produced in a variation of the above process. In this process, a cylindrical solid first stream of a heat plastified thermoplastic resinous material, containing a blowing agent, is formed in an extrusion apparatus, and subsequently converted into an annular stream by axially piercing and radially distributing the stream. At least one annular layer of a second stream of heat plastified thermoplastic resinous material is then applied along the outer circumference of the annular stream, thereby producing a multiple-layered annular stream having an inner expanded layer. The multiple-layered annular stream is then extruded through an annular die orifice to form a pipe. Optionally, the die may also be heated during the extrusion step to produce a pipe with a high gloss thereon, and/or it may also be vacuum sized to form a final pipe product.

It is also contemplated by the present invention to provide a multiple-layered pipe having an expanded core which combines the desirable characteristics of at least two different thermoplastic materials. This pipe comprises at least one outer layer of a first thermoplastic resinous material, an intermediate core of expanded thermoplastic resinous material, and at least one inner layer of a second thermoplastic resinous material. In a preferred embodiment, the first thermoplastic is selected for external appearance and weatherability properties, one example being ABS. As used herein, the term "ABS" refers to the many copolymers of styrene, butadiene, and acrylonitrile well known to those skilled in the art. The expanded core my be of any suitable thermoplastic compatible with the thermoplastics of the inner and outer layers. Preferably, however, it is an inexpensive or even a scrap polymer. The second thermoplastic resin is preferably chemically resistant, such as for examples ABS.

The instant invention is also advantageous for the production of a five-layered expanded thermoplastic pipe. In this embodiment, the pipe comprises a core of expanded thermoplastic, two outer layers of thermoplastic material, and two inner layers of a different thermoplastic material. The expanded core may be of any suitable thermoplastic, but preferably is made from an inexpensive or scrap polymer. The first outer layer may again be of a suitable thermoplastic, or it may be a thermoplastic adhesive. The second outer layer is formed by a thermoplastic selected for external appearance properties and weatherability, such as ABS. The first inner layer may be any suitable thermoplastic, or it may also be an adhesive. The second inner layer is preferably formed of a chemically resistant thermoplastic, such as ABS.

While the instant apparatus and process has been described as being particularly applicable to the production of expanded multiple-layered pipe, it is equally applicable to the production of non-expanded pipe, due to its ability to produce a pipe having high uniformity of layer thickness without spider marks or other imperfections. In the preparation of this type of pipe, the same apparatus and processes may be utilized; however blowing agent is deleted from the streams of thermoplastic material to be extruded.

Various other objects, features, and attendant advantages of this invention will be more fully appreciated from the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an isometric diagrammatic representation of the various stages of the coextrusion process of the present invention, showing the attachment of the extruders and vacuum sizer in relation to a coextrusion die according to the instant invention adapted for the formation of a five-layer pipe;

FIG. 2 is an enlarged longitudinal section through the die body, the spider assembly, and the outer laydown plate of the pipe die shown in FIG. 1;

FIG. 3 is a transverse vertical sectional view through the clamping ring along the left end face of the die body first section taken on the line 3—3 of FIG. 2;

FIG. 4 is a fragmentary transverse vertical sectional view, taken on the line 4—4 of FIG. 2;

FIG. 5 is an enlarged longitudinal sectional view through an alternative embodiment of the die apparatus of the instant invention, shown employing a one-layer applying spider assembly;

FIG. 6 is a sectional view of the thermoplastic pipe produced according to the present invention;

FIG. 7 is an enlarged sectional view similar to FIG. 6 of a modified form of the thermoplastic pipe.

FIG. 8 is a longitudinal section of a pipe die in accordance with a further embodiment of the instant invention wherein flow equalizing means are disposed in each of the inner and outer laydown means;

FIG. 9 is a fragmentary transverse vertical sectional view, taken along the line 9—9 of FIG. 8; and

FIG. 10 is a fragmentary transverse vertical sectional view, taken along the line 10—10 of FIG. 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In its preferred embodiment, the apparatus of the instant invention comprises a modular pipe die with inner and outer laydown means. With the installation of additional laydowns, pipe structures having from two to five layers can be produced. Broadly, the die comprises a multiple piece die body having a first section containing a die mouth and an end section containing a die inlet, and having a central longitudinal passage therethrough defining a main extrusion passage through the die. The inner laydown means comprises a set of interchangeable spider assemblies each having the capacity for applying a different number of inner layers. In one embodiment, the instant invention provides a spider assembly having means for applying one inner layer to a stream of thermoplastic. In another embodiment, a spider assembly capable of applying two inner layers is employed in order to form a five-layered pipe product. Each of the spider assemblies are manufactured to be interposed between the die body first and end sections, and has a body portion with a central longitudinal passage therethrough, and a cylindrical mandrel portion disposed within the spider body passage in spaced relation therewith to define the main extrusion passage. The mandrel is provided with a tapered head for converting a cylindrical solid stream of thermoplastic into an annular stream. The inner layer applying means are also disposed within the mandrel. This means comprises at least one annular feed ring terminating in a radial orifice for applying at least one layer of thermoplastic resinous material to the inner surface of an annular stream flowing over the mandrel. A plurality of radial passages serve to position the mandrel within the spider body, and also contain feed conduits therethrough for feeding a stream of thermplastic resin under pressure to the annular feed ring.

To produce a pipe having more than one inner layer, a two-layer spider assembly is chosen which has two annular feed rings, each terminating in an annular radial orifice for applying a layer of thermoplastic material to the inner surface of an annular stream flowing over the mandrel. Each of these feed rings is supplied by its own feed conduit with thermoplastic material through the spider radial passages.

A longitudinal spindle is disposed within the die body flow passage in spaced relation therewith and is secured to said mandrel in an end-to-end relationship to define a continuous extrusion passage. Interposed between the die body first and end sections, downstream of the spider, and circumscribing the die mandrel is the means for applying the outer layers. This means comprises at least one laydown plate which has a central longitudinal passage aligned with the die body flow passage, and an annular feed ring which circumscribes the central passage of the laydown plate. A port supplies thermoplastic under pressure to the feed ring. An annular radial orifice communicates with the feed ring to feed an annular layer of thermoplastic to the extrusion passage defined by the mandrel and the laydown plate body. For the extrusion of more than one outer layer, a plurality of laydown plates are secured in an end-to-end relationship in interposition between the die body first and end sections, each laydown plate forming one outer layer of the resulting pipe.

In the preferred embodiment, each of the inner and outer laydown means preferably further comprises means for equalizing the flow of thermoplastic such that thermoplastic flows through each orifice in a uniform manner over its entire circumference. This means preferably comprises a pressure balanced annular reservoir chamber which is connected to the annular feed rings of each of the laydowns. In the preferred embodiment the pressure balanced annular reservoir chamber comprises an annular chamber which is connected to the annular feed rings by a plurality of selectively spaced feed ports.

Disposed within the die mouth in an end-to-end relationship is a spindle sleeve which has a smooth face which abuts a similar smooth face in the die mouth. The spindle sleeve surrounds the spindle in a spaced relation, defining a portion of the annular extrusion passage. The mandrel sleeve is movably secured within the die mouth and is adapted to undergo eccentric movement around said mandrel, for adjusting the concentricity of the pipe.

Referring now to the drawings, FIG. 1 illustrates an embodiment of the instant invention adapted for the manufacture of five-layered thermoplastic pipe. The die apparatus, generally indicated at 1, comprises a two-piece die body, a first die body section 33 and an end die body section 35. Interposed between the die body sections 33 and 35, is a spider assembly 47 for applying two inner layers to a stream of thermoplastic. Downstream from the spider assembly, is the outer layer applying means, laydown plates 51 and 53. The thermoplastic resin which subsequently forms the core layer of the finished pipe is separately kneaded by the extruder 3, and is extruded through feed pipe 9 and control valve 11 into the die 1. Extruder 5 provides the thermoplastic resin for forming one outer layer and one inner layer of the finished pipe, feed pipe 17 feeding a supply of the resin through the feed conduit 19 to the spider assembly 47, and through the feed conduit 21 to the laydown plate 53. Extruder 7 provides the thermoplastic resin forming he inner and outer layers adjacent the core layer through feedline 23 and feed conduits 25 and 27 to the spider assembly 47 and first laydown plate 51. Valve 11 on feed line 9, and the control valves on feed conduits 19, 25, 27, and 21 provide an independent adjustment to obtain pressure equalization between each of the feed lines. Adjustment of the thickness of the various layers is achieved without the use of interfering screws, by varying the relative extrusion velocities of each of the extruders 3, 5, and 7. The instant apparatus therefore permits independent layer thickness adjustment without the use of interfering adjustment screws.

Also shown in FIG. 1 is a vacuum sizer 29 which preferably is utilized in conjunction with the die apparatus of the instant invention. The vacuum sizer 29 is constructed to contain in approximately the first half of its length, a sizing die 31 in which the extruded pipe passes immediately after its exit from the extrusion die 1. The sizing die 31 functions to adjust the extruded pipe to its finished size. For an expanded pipe product, the finished product size will generally be approximately equal to that of the extruded product. However, for a solid pipe, the sizing die 31 reduces the pipe size slightly to its finished dimension.

The latter half of the vacuum sizer 29 is constituted by a cooling chamber, not shown, also maintained under vacuum. In this chamber, the final extruded and now sized pipe is cooled as nearly as possible to ambient temperature in order to further solidify the thermoplastic materials of each of the layers of the pipe. Cooling is suitably achieved by contacting the extruded article with a fine spray of cooling water. Alternatively, cooling may be achieved by immersing the pipe in a water bath.

FIG. 2 illustrates one embodiment of the die apparatus of the instant invention, adapted for the manufacture of a five-layer pipe. The die body 2, as has been aforementioned, is a multiple piece structure, comprising first die body section 33 and end die body section 35. Each of these sections has a central longitudinal passage 37 extending therethrough which defines the plastic flow space through the die. Passage 37 includes an inlet 39 on the first die body section 33, and terminates in a die mouth 41 on the end die body section 35. In the preferred embodiment, the passage 37 diverges downstream of the inlet 39 to form a passage of larger radius 43.

Interposed between the two die body sections 33 and 35 is the inner laydown means. This means comprises a set of interchangeable spider assemblies, each of which has the capacity for applying a different number of inner layers to a stream of thermoplastic. FIG. 2 illustrates the use of a spider assembly having the capacity for applying two inner layers, generally indicated at 47 and hereinafter referred to as a two-layer spider assembly. The two-layer spider assembly 47, shown in FIG. 2, comprises a body portion 94 having a mandrel supported therein, generally indicated at 85. The body portion 94 has a set of longitudinal bores 55 extending therethrough for securing the spider assembly in an end-to-end relationship with the first die body section 33 by means of screws 57. The body portion 94 also contains a central longitudinal passage which form a continuation of the die body central passage 37. The mandrel is equidistantly positioned within this passage by means of radial members 95, defining with the body portion 94 a pipe-forming or extrusion passage 63.

The mandrel 85 performs two functions. Firstly, it includes a tapered head 81 for converting a cylindrical stream of thermoplastic into an annular stream by axially piercing and radially separating a solid cylindrical stream of thermoplastic flowing through the die body central passage 37. This tapered head 81 extends into the diverging portion 43 of the central passage 37 to facilitate the formation of the annular stream. The annular stream of thermoplastic formed therein subsequently will become the core layer of the finished thermoplastic pipe product.

A second function which the spider mandrel 85 performs is the application of at least one inner layer of thermoplastic to the cylindrical stream flowing over the mandrel 85 through the extrusion passage 63. To this end, the mandrel 85 has disposed therein at least one means for applying at least one annular layer of thermoplastic to the inner circumference of the annular thermoplastic stream flowing thereover. This means comprises at least one annular feed ring disposed within the mandrel 85 which acts as a reservoir for a stream of thermoplastic which is to be subsequently applied as an inner layer to an annular stream of thermoplastic flowing over the mandrel, and an annular radial orifice connecting the feed ring with the extrusion passage 63. FIG. 2 illustrates an embodiment of the instant invention wherein a spider assembly having the capacity for the formation of two inner layers is employed. Accordingly, the mandrel 85 has disposed therein a first feed ring 93 and a second feed ring 107. The feed ring 93 terminates in an orifice 96 which communicates with the extrusion passage 63. Similarly, feed ring 107 terminates in orifice 113, also communicating with extrusion passage 63. The first feed ring 93 applies a first inner layer of thermoplastic to an annular stream of thermoplastic flowing over the mandrel 85. The second feed ring 107 applies a second inner layer of thermoplastic and is located downstream from the first feed ring 93.

FIGS. 2, 3, and 4 illustrate the means for supplying each of the feed rings with a stream of molten thermoplastic under pressure. The body portion 94 (see FIG. 2) of the spider assembly 47 contains ports 97 and 99 which communicate with feed lines from the extruders. The port 97 communicates with the feed ring 93 by means of feed passage 89 extending through the body portion 94, the radial member 95, and the mandrel 85. Similarly, port 99 communicates with feed ring 107 by means of feed passage 91.

The two feed rings 93 and 107 may be formed within the mandrel 85 by any suitable means. However, it is convenient to form the mandrel 85 in two sections to facilitate the formation of the feed rings 93 and 107 therein. Accordingly, the mandrel 85 comprises a first section 82 containing the tapered head 81 and a second section 83. The first section 82 includes a threaded socket 87 which receives a threaded head 101 on the second section 83. Along the end face of the first section 82, the first annular feed ring 93 and its attendant orifice 96 may be conveniently milled. The left end face of the second section 83 of the mandrel 85 is then employed to define the final wall of the feed ring 93. The second mandrel section 83 also includes a threaded socket 103 for receiving the threaded head of the spindle 45. The second feed ring 107 may then be conveniently milled along the right end face of the second mandrel section 83. The left end face of the spindle 45 completes the feed ring 107 and orifice 113.

FIG. 5 illustrates an embodiment of the die apparatus according to the instant invention in which a one layer spider assembly 49 is interchanged with the two layer spider assembly 47. The one layer spider assembly 49 includes a body portion 135 and a single mandrel section 143. The spider mandrel section 143 has a tapered head thereon for converting a solid cylindrical stream of thermoplastic into an annular stream. A plurality of radial members 141 also serve to equidistantly space the spider mandrel 143 within the central longitudinal passage of the body portion 135. The mandrel 143 also contains a threaded socket 145 which receives the threaded head 111 of spindle 45. A single annular feed ring 149 is formed along the right end face of the mandrel section 143 by milling. The single feed ring 149 communicates with orifice 150, defined by the point of intersection of the mandrel 143 and the spindle 45. A stream of molten thermoplastic is suitably conveyed to the feed ring 149 hrough port 137, radial feed passage 139, and longitudinal feed passages 147.

The present invention thus provides a set of interchangeable spider assemblies which enable a thermoplastic pipe to be produced having one or two inner layers. It should be obvious to those skilled in the art, however, that by modifying the concepts of the instant invention, spider assemblies having the capacity of forming more than two inner layers can be provided. Similarly, by employing a spider assembly which does not contain a feed ring and attendant orifice within the mandrel a thermoplastic pipe without an inner layer may be formed. This latter situation can also be suitably achieved by merely closing the control valve on the feed lines from the extruders.

Applicants have found that the use of spiders does not interfere with the plastic flow around the mandrel, thereby producing objectionable spider marks on the resultant pipe, when the thermoplastic stream is extruded under pressure for a sufficient length to allow the thermoplastic to recombine into a single continuous layer before issuance through the die orifice. Accordingly, by positioning the spider at a point early in the extrusion process before a multiple-layered annular stream is formed, and by providing a length of uninterrupted extrusion passage, objectionable spider marks can be obviated. Moreover, it has been discovered that greater uniformity of layer thickness can be achieved by a die apparatus and process which does not employ a separate die for each layer of pipe, such apparatus being inherently subject to distortions. Furthermore, by extruding thermoplastic in indentifiable annular layers, rather than extruding the thermoplastic as cylindrical streams which are subsequently converted to an annular stream, greater uniformity of layer thickness can be produced.

In a conventional apparatus, in which a mandrel converts a multiple-layered cylindrical stream into an annular stream, the process of radially distributing the thermoplastic material produces irregularity in layer thickness, particularly in the inner layers of a multiple-layered pipe. It is advantageous therefore to extrude the thermoplastic of the inner layer of layers as an annular stream rather than as a cylindrical stream. Accordingly, in the instant invention, the spider assemblies are positioned next to the first die body section 33, thereby eliminating any interruptions in the multiple-layered annular stream. Moreover, the spindle 45 is employed to provide a suitable length of extrusion passage, wherein the layers of bonded thermoplastic are allowed to stabilize before exiting the die. As has been aforementioned, the spindle 45 includes a threaded head 111 which is received in a threaded socket on either of the spider assemblies 47 or 49. The spider assemblies 47 and 49 thus serve another function, spacing the spindle 45 within the die body central passage 37. The spindle 45 and the end die body section 35 cooperate to define an extrusion passage which is a continuation of the spider die passage 63 which permits stabilization of the thermoplastic layers.

FIGS. 2 and 5 illustrate the means for applying outer layers to a stream of thermoplastic according to the present invention. This means comprises at least one outer laydown plate. FIGS. 2 and 5 illustrate the die apparatus of the instant invention with the use of two outer laydown plates 51 and 53. It should be obvious, of course, to those skilled in the art that a single laydown plate may be employed where only a single outer layer is desired, or a plurality of laydown plates may be employed where more than two outer layers are desired. Alternatively, the laydown plates may be entirely deleted from the die apparatus where no outer layers are desired. In still another embodiment, where no outer layers are desired, flow of thermoplastic to the outer laydowns may simply be stopped by closing off the appropriate feed ports. Each of the laydown plates are identical and interchangeable. Accordingly, the laydown plates will be described with reference to the first laydown plate 51 shown in FIGS. 2 and 5. The laydown plate 51 is interposed between the die body sections 33 and 35 downstream of the spider assembly 47 or 49. The laydown plate 51 comprises a body portion 115 which has a plurality of longitudinal bores 55 which receive bolts 57 for securing the laydown plate within the die apparatus in an end-to-end relationship. The laydown body 115 contains a longitudinal central passage which is a continuation of the die body central passage 37 and which, when laydown plate 51 is interposed between die body sections 33 and 35, is aligned therewith. The laydown body 115 circumscribes the mandrel sections 85 or 143, and spindle 45, and defines therewith a portion of the extrusion passage 63. Circumscribed about the extrusion passage 63 and disposed within the body of the laydown plate 51 is an annular feed ring 117. A port 122 is drilled in laydown plate 51 and terminates in feed passage 119 which supplies feed ring 117 with a stream of thermoplastic resin. Feed ring 117 terminates in an annular radial orifice 120 which discharges into extrusion passage 63. One wall of feed ring 117 and orifice 120 is defined by the abutting face of spider assembly 47 or 49 when laydown plate 51 is secured thereto. Interposed between laydown plate 51 and the spider assembly 47 or 49 is an annular gasket 121 which functions to ensure a positive seal between spider assembly 47 and laydown plate 51.

The present invention also contemplates that a multiple-layered pipe with more than one outer layer may be formed by employing a plurality of outer laydown plates 51 secured serially together, as shown in FIGS. 2 and 5. Each laydown plate will form an annulus of thermoplastic around an annular stream of thermoplastic flowing through the die passage 63, resulting in a pipe with a plurality of outer layers.

The thickness of each of the layers of the thermoplastic pipe produced according to the instant invention is controlled by varying the extrusion velocities on the extruders 3, 5 and 7. This feature eliminates the need for adjustment screws within the die passages, thereby obviating any interruptions in the thermoplastic material flow. Additionally, a second adjustment feature may also be provided by the use of spacers. The thickness of the outer layers may be adjusted by employing annular gaskets 121 of different thickness, thereby varying the width of the orifice 120. Similarly, a spacer ring may be seated on the threaded head of mandrel section 83 and spindle 45 to adjust the width of the orifices 96 and 113. However, in the preferred embodiments, the thickness of each layer is adjusted by variation in the extrusion velocities.

The die apparatus of the present invention also contains means for controlling the concentricity of a multiple-layered pipe produced therefrom. Disposed in the die mouth 41 of FIGS. 2 and 5 in an end-to-end relationship is a spindle sleeve 61 which has a smooth face 62 which abutts a similarly smooth face 59 in die mouth 41. Spindle sleeve 61 surrounds spindle 45 in a spaced relationship, defining a continuous uninterrupted annular extension of extrusion passage 63 of variable concentricity, and which is of sufficient length to stabilize the layers of bonded thermoplastic. Spindle sleeve 61 is adapted to undergo eccentric movement around spindle 45, thereby controlling the overall concentricity of a multiple-layered pipe produced from the present die apparatus. A collar 67 is seated on head 65 of spindle sleeve 61. Adjustment screws 69, extending through the die body section 35, act on collar 67, thereby adjustably securing spindle sleeve 61 in die mouth 41.

FIGS. 8–10 illustrate a preferred embodiment of the die apparatus of the instant invention, adapted for the production of the three-layered pipe, in which means are disposed within each of the inner and outer laydown means for equalizing the flow of thermoplastic over the entire circumference of the radial orifices used therein. Similar to the die apparatus of FIGS. 2 and 5, the apparatus of FIG. 8 comprises a multiple-piece die body, comprising first body section 202, containing a die inlet, and end body section 208. Interposed between the die body sections 202 and 208 are an inner laydown plate, generally indicated at 203, and an outer laydown plate, generaly indicated at 205. Each of the members 202, 203, 205 and 208 contain bores 209 therein, in which suitable screws may be inserted for securing the die together. The die body, comprised of the members 202, 203, 205, and 208 has a central longitudinal passage 212 therein which forms the central plastic flow space for the die.

The inner laydown plate or means 203 comprises a body portion 204 having radial protrusions 220 which extend into the passage 212 for supporting therein, in spaced relation therewith, the die mandrel, generally indicated at 214. The die body and mandrel 214 thus form therebetween the main extrusion passageway 215 of the die. Mandrel 214 is formed with a tapered head 216 to facilitate the radial separation of the main stream of thermoplastic flowing through passage 212 into a cylindrical stream of thermoplastic. To ease this process, passage 212 converges at the tapered tip 216 of mandrel 214. Secured to the mandrel 214 in end-to-end relationship is the spindle 218, which together with the eccentrically adjustable spindle sleeve 210 form an extension of the extrusion passage 215 of sufficient length to enable the bonded layers of thermoplastic to stabilize before exiting the die.

In order to apply an inner layer of thermoplastic to the annular stream flowing over the mandrel 214, the mandrel has an annular feed ring 224 disposed therein, which terminates in an annular radial orifice 226 communicating with the main extrusion passage 215. For supplying thermoplastic to the feed ring 224, the inner laydown body portion 204 is provided with a port 234 and radial passage 232 therein, passing through protrusion 220, which communicates with longitudinal feed passage 228 disposed in mandrel 214. In accordance with the inventive concepts of the instant invention, means are interposed between the longitudinal feed passage 228 and feed ring 224 for providing an equal

United States Patent [19]

Hahn et al.

[11] **Patent Number:** 4,483,669

[45] **Date of Patent:** Nov. 20, 1984

[54] MULTIPLE-LAYERED SHEETING APPARATUS

[75] Inventors: Granville J. Hahn; Raleigh N. Rutledge; Jackie D. Murley, all of Big Spring, Tex.

[73] Assignee: Cosden Technology, Inc., Dallas, Tex.

[21] Appl. No.: 485,141

[22] Filed: Apr. 15, 1983

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 408,105, Aug. 16, 1982, Pat. No. 4,443,397.

[51] Int. Cl.[3] B29F 3/04

[52] U.S. Cl. .... 425/131.1; 264/171; 425/133.5; 425/146; 425/376 A; 425/462; 425/466

[58] Field of Search .... 264/171, 173; 425/131.1, 133.1, 133.5, 376 A, 146, 462, 466, 465

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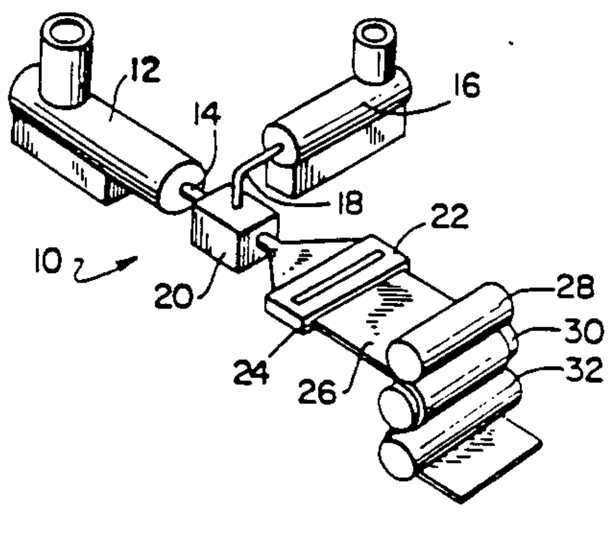
Primary Examiner—Jeffery Thurlow

Attorney, Agent, or Firm—Schwartz, Jeffery, Schwaab, Mack, Blumenthal & Koch

[57] **ABSTRACT**

Disclosed is a process and apparatus for extrusion of multiple-layer sheeting comprising an improved co-extrusion feedblock and valve plate for laying down co-extruded resin streams onto a main extruded polymeric resin. The new design provides advantageous external control of the layer number as well as a more refined control of layer thicknesses.

11 Claims, 7 Drawing Figures



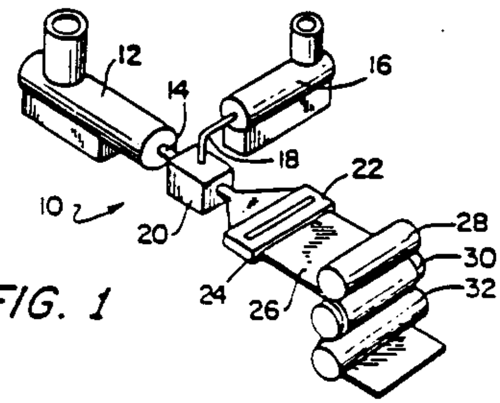

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FIG. 1

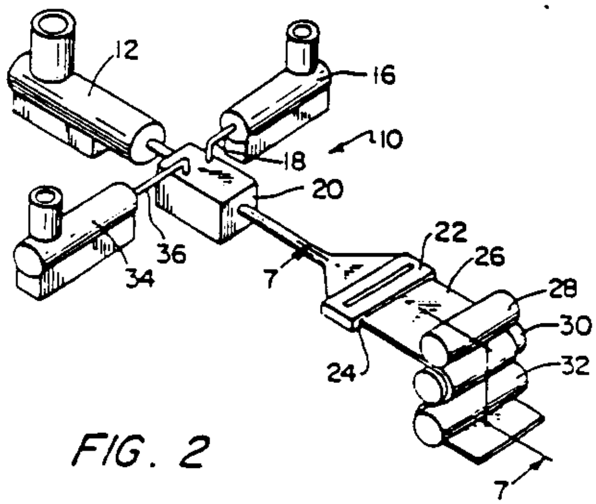
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FIG. 2

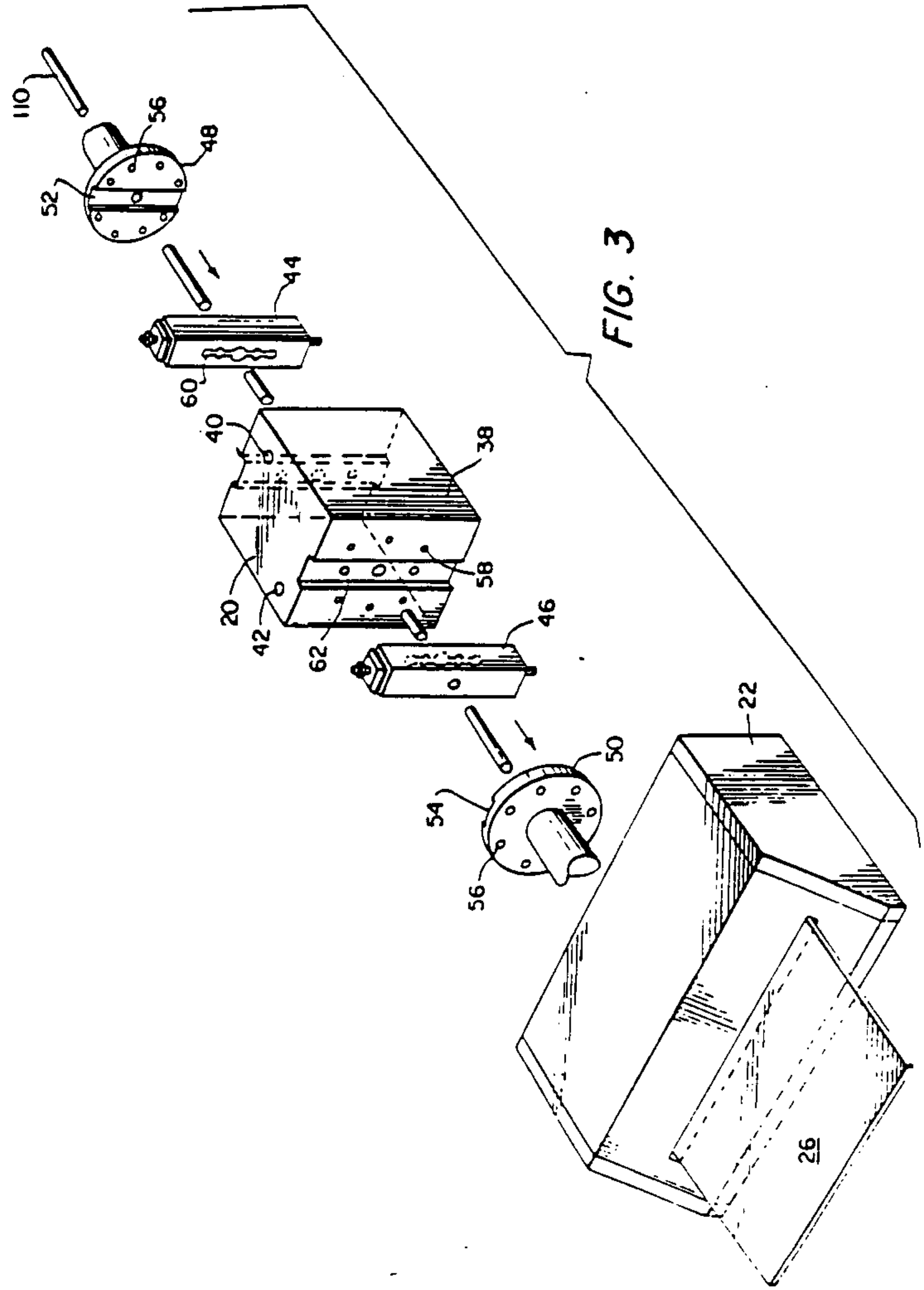

FIG. 3

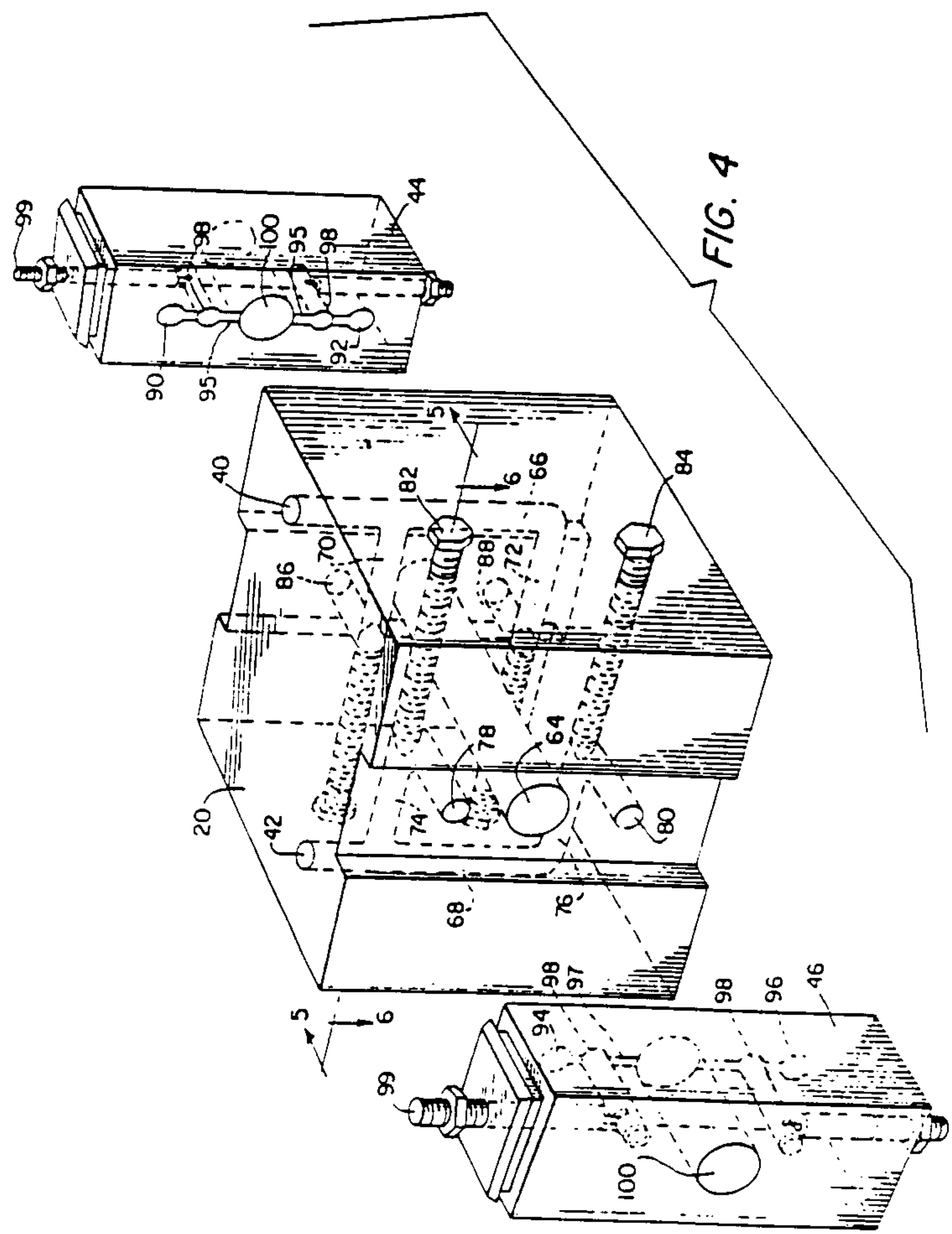
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FIG. 4

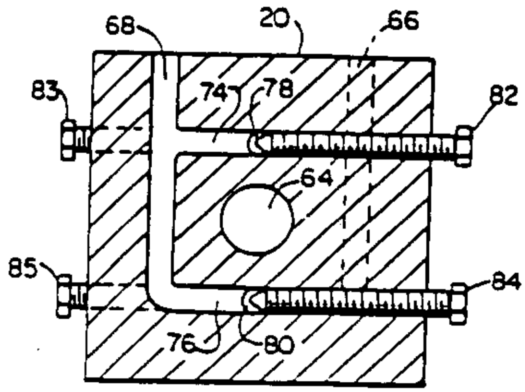

FIG. 5

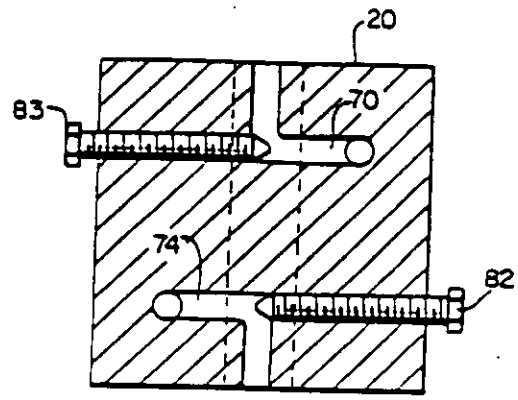

FIG. 6

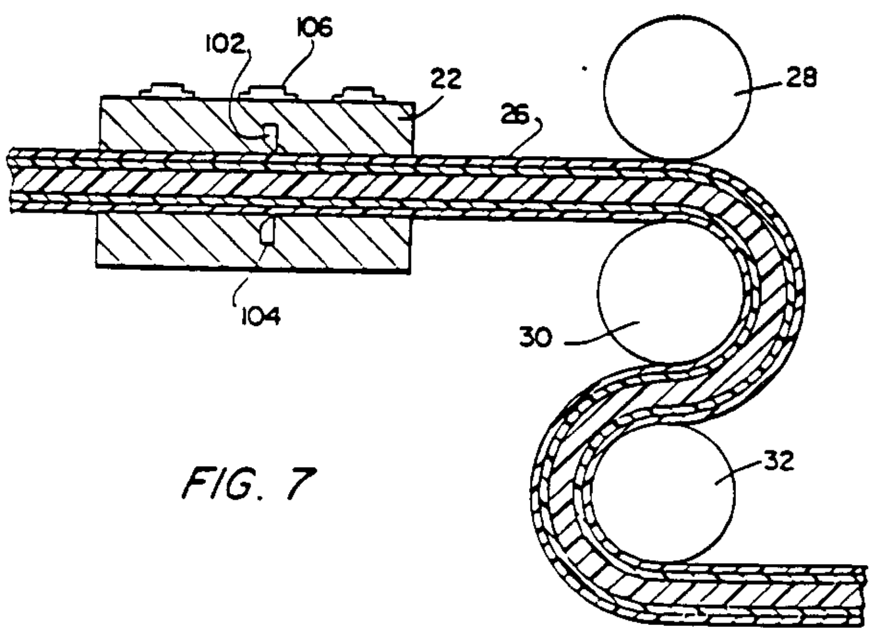

FIG. 7

MULTIPLE-LAYERED SHEETING APPARATUS

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of our copending application, Ser. No. 408,105, filed Aug. 16, 1982, now U.S. Pat. No. 4,443,397 issued Apr. 17, 1984.

BACKGROUND OF THE INVENTION

The present invention relates to the production of multiple-layer film or sheeting, and more especially, to an improved process and apparatus for extrusion of multiple-layer sheeting having a layer or layers of polymeric material having desirable surface characteristics. More especially, the present invention comprises the co-extrusion of multiple-layered sheeting, with each layer exhibiting uniform layer thickness across the width thereof, by an apparatus which has an improved laydown means and which is easily adjustable to produce sheeting products having from two to five layers.

Co-extrusion processes for the production of multilayered sheeting are, of course, well known in the art. However, prior processes do not guarantee, and and often do not produce, co-extruded layers of uniform thickness on the main extruded material. This problem is especially acute when the co-extruded layer comprises a polymeric material having a comparatively low viscosity. Such a material tends to migrate from areas of higher extruder die pressure, to areas of lower extruder die pressure. This results in a sheeting product having varying layer thicknesses across the width of the sheet.

Furthermore, in known processes and apparatus, it was not readily possible to adjust the relative thickness of the various layers, in response to different processing characteristics and/or different requirements for the final products. Furthermore, it was not easy to vary the number of layers to be included in a particular product or to distribute the various layers to give a uniform multiple layer sheet. In these processes, it is often necessary to shut down operation while adjustments and/or modifications are made in the process. A shutdown of this type is extremely time-consuming and expensive due to the cost of labor, materials and lost output.

Thus, the present invention is concerned with an improved laydown means and process for use in the production of multiple-layered sheeting of materials, particularly those which have different processing characteristics, resulting in a uniformity of layer thickness across the entire width of the extruded sheeting.

The present invention is also directed to an improved laydown means for the application of multiple-layers of polymeric material to an initial polymeric base layer, the different polymeric materials in most cases exhibiting different processing characteristics. The laydown device permits easy adjustment of overall layer thickness as well as adjustment of the number of layers.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a co-extrusion apparatus for producing multiple-layer sheeting having an improved laydown means for applying a layer or layers of uniform thickness(es) across its width.

Another object of the present invention is to provide a co-extrusion apparatus for producing multiple-layer sheeting having a laydown means for applying a layer or layers of polymeric materials to a base polymer layer, the polymeric materials exhibiting different processing characteristics, resulting in sheeting comprising a layer or layers of uniform thickness(es) across their width.

Still another object of the present invention is the provision of an apparatus for producing multiple-layer sheeting having simple means for controlling the thickness of individual layers at any point across the entire width of the sheeting and for controlling the number of the layers of the sheeting.

Yet another object of the present invention is to provide an apparatus for producing multiple-layer sheeting which can be completely externally controlled to vary layer thickness and layer number.

Still yet another object of the present invention is to provide an apparatus and a process for providing online variations of the layer thickness and layer number.

A further object of the present invention is to provide a process for producing in a single extrusion step multiple-layer sheeting having uniform layer thickness across the width of the sheeting.

Still another object of the present invention is to provide a process for producing in a single extrusion step multiple-layer sheeting wherein the number and thickness of layers can be simply controlled.

Yet another object of the present invention is the provision of a process for producing a multiple-layered sheeting applicable to a wide variety of polymeric materials for use as both the extruded base layer and the co-extruded laydown resin.

Thus, in accomplishing the foregoing and other objectives, there is provided in accordance with one aspect of the present invention a co-extrusion apparatus for the production of multi-layer products of thermoplastic synthetic resins having selected numbers of layers, comprising a main extruder for producing a main heat-plasticized resin stream, at least one co-extruder for producing a source of heat plastified resin stream, a co-extrusion feedblock positioned downstream of the extruder and the co-extruder for receiving the main resin stream and the side resin stream and for producing a combined resin stream, the co-extrusion feedblock comprising at least one slotted valve plate having a central orifice which provides for the passage of the main resin stream, slotted portions on either side of the central orifice for laying down layers of the side resin stream onto the main resin stream and valve means for controlling the side resin stream, conduit means within the co-extrusion block for splitting the side resin stream and supplying sub-streams thereof to the slotted portions, adjustment means for varying the volume of flow in each of the sub-streams, and a sheeting die downstream of the co-extrusion block for receiving the combined stream and for forming the multi-layered product into a multi-layered sheet.

In a preferred embodiment of the present invention, the co-extruder feedblock is positioned between the main extruder and the sheeting die along the base layer flowpath, and comprises a central orifice aligned with the central orifice of the slotted die providing for the passage of the base layer therethrough.

In another aspect of the present invention, there is provided a co-extrusion feedblock used in the production of multiple-layer products of thermoplastic synthetic resins having selected numbers of layers, comprising first conduit means within the feedblock for receiving and transporting a main heat-plasticized resin stream through the feedblock, and second conduit means within the feedblock for receiving at least one side stream of co-extruded heat plasticized resin, for splitting said co-extruded resin stream into sub-streams, and for transporting the sub-streams for application to the main resin stream.

In a preferred embodiment, the feedblock further comprises externally adjustable screws for engaging the second conduit means and for controlling the flow of the resin sub-streams.

In another aspect of the present invention, there is provided a process for producing a multi-layer sheeting, comprising the steps of extruding a base layer stream of a heat-plastified material, co-extruding at least one side stream of a heat-plastified material, passing the base layer stream through a co-extrusion feedblock, passing the side stream into the feedblock, splitting the side stream in the feedblock into two sub-streams, selectively passing the sub-streams to a selected valve plate member attached to the feedblock, the valve plate member having a slot for each sub-stream and valve means for controlling the resin flow therethrough, laying down at least one layer of the sub-stream upon the base layer stream at the plate member to produce a multi-layered stream, and passing the multi-layered stream through an extrusion die to form the multi-layered sheeting.

Other objects, features and advantages of the present invention will become apparent from the detailed description of preferred embodiments which follows, when considered in view of the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view of an apparatus for the preparation of a multiple-layer sheet or film according to the present invention;

FIG. 2 is similar to FIG. 1, and represents an apparatus having two co-extruders for the preparation of a multiple-layer sheet or film;

FIG. 3 is an exploded schematic view of the feedblock and extrusion die according to the present invention;

FIG. 4 is a detailed schematic representation of the feedblock;

FIG. 5 is a cross-sectional end view of the feedblock taken along the line 5—5 of FIG. 4;

FIG. 6 is a cross-sectional top view of the feedblock taken along line 6—6 of FIG. 4; and

FIG. 7 is a cross-sectional view of the layer thickness adjusting apparatus taken along line 7—7 of FIG. 2.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

In accordance with the present invention, there have been provided an improved process and apparatus for producing a multiple-layered sheet or film having layers of uniform thickness across the entire sheeting or film. More particularly, the sheet or film may be produced from two or more polymeric materials exhibiting different processing characteristics, particularly melt viscosity. Specifically, the sheeting or film can comprise from one to four or more layers of co-extruded resinous material applied to a polymeric base layer. In each case, each of the individual co-extruded layers exhibits uniform thickness across its width. Thus, by the combination of these different layers, a product is obtained having improved characteristics, especially improved surface characteristics. Because of the uniform thickness, such a product will exhibit a consistency in the improved characteristic not previously possible. An example of a product which the present invention can provide is a plastic cup of the type presently used by the airlines. Such a cup would comprise a base layer of polystyrene and a co-extruded polyethylene terephthalate (PET) surface layer. This is only one example of many products within the scope of the present invention.

Referring now to the drawings, in FIG. 1 there is schematically illustrated an apparatus, generally designated by the reference numeral 10, particularly adapted for the process of the invention. The apparatus 10 comprises in cooperative combination a main extruder 12 for the extrusion of a first synthetic resinous material, and connected thereto, a discharge conduit 14. A first co-extruder 16 having a discharge conduit 18 is adapted for providing a stream of heat plastified synthetic resin. Conduit 18 terminates at co-extrusion block 20 at a point upstream of the sheeting die 22 which is in operative communication with co-extrusion block 20 and receives the flow therefrom. Sheet 26 is formed at the die lips 24 and thereafter progresses from the die to polished cooling rollers 28, 30 and 32.

In FIG. 2 there is schematically illustrated an apparatus similar to that of FIG. 1, except that in FIG. 2 there are shown two co-extruders as compared to the one co-extruder of FIG. 1. Therefore, in addition to the apparatus described in FIG. 1, the apparatus 10 further comprises a second co-extruder 34 having a discharge conduit 36 connected thereto. The discharge conduit 36 terminates in approximately the same area of the co-extrusion block 20 as discharge conduit 18.

In FIG. 3 there is illustrated an internal, exploded perspective view of co-extrusion block 20. The block 20 comprises a main co-extrusion body 38. The block further comprises conduit inlets 40 and 42 for receiving the co-extruded synthetic resin streams from co-extruders 16 and 34 of FIGS. 1 and 2. Slotted valve plates 44 and 46 are positioned upstream and downstream of the main co-extrusion body, respectively. These plates are held in place by the slotted housing members 48 and 50, respectively. Each housing member comprises a slot 52, 54 for receiving the slotted valve plates, and a series of bolt holes 56 corresponding to similar holes 58 on the main co-extrusion body. The slotted valve plates 44 and 46 have slotted orifices, generally indicated at 60, which align with outlet orifices, generally indicated at 62, of the feedblock for providing passage for the co-extruded resin streams passing through feedblock 20.

FIG. 4 is a detailed perspective illustration of the feedblock 20 described above as would be seen looking upstream of the feedblock. The feedblock has a main conduit 64 through which the main stream of synthetic resin passes. The conduit 64 extends completely through the feedblock As previously noted, the feedblock has conduit inlets 40 and 42 for receiving co-extruded heat-plasticized resin side streams. The inlets 40, 42 lead to conduits 66 and 68 which extend vertically downwards therefrom. Each conduit 66, 68 branches into two horizontally extending conduits 70, 72 and 74, 76. The branch conduits are positioned vertically one above the other and extend approximately perpendicularly from the vertically extending shaft. The vertically extending shafts terminate into the lower conduits 72 and 76. This arrangement functions to divide the resin streams entering at inlets 40 and 42 into two sub-streams each.

The branch conduits extend from the vertically extending conduits 66 and 68 which are offset from the central longitudinal axis, toward this central axis to points equal distance above and below the main resin flow stream 64. The branch conduits then are curved in a manner which aligns the flow of the co-extruded polymers with that of the main resin stream.

Extending horizontally into the branch conduits 74 and 76 at this point of curvature are flow controlling screws 82 and 84, also shown in FIGS. 5 and 6. A similar screw arrangement is provided to conduits 70 and 72. By engaging the branch conduits at this point, the screws can easily and precisely control the resin flow through the conduits This control is accomplished by adjusting the screws to the penetration depth necessary. This particular arrangement is very useful in shutting off the flow of one or more of the streams when only a two- or three-layer product is required.

The branch conduits terminate at outlets vertically aligned with the main resin stream. As shown, conduits 74 and 76 terminate at outlets 78 and 80, respectively. Conduits 70 and 72 have similar outlets 86 and 88.

The outlet orifices 78, 80 and 86, 88 are aligned with inlet bores 90, 92 and 94, 96 of the valve plates 44 and 46, respectively, thus providing for the passage of the resin from the feedblock to the valve plates. Slots 95 and 97 connect the inlet bores to the main resin conduit 100 and pass over a further cavity described below.

The valve plates are provided with means by which the flow of polymer that passes to the valve plate can be valved, or controlled, to determine the amount provided to the main resin stream which, of course, determines the final layer thickness. This valving means basically comprises a camsert arrangement positioned within a cavity, generally shown as 98 in FIG. 4. The camsert and valve plate arrangement is described in greater detail in copending application Ser. No. 485,550, Valve Plate and Feedblock Design and Process Therefor, Granville J. Hahn et al. the disclosure of which is hereby incorporated by reference.

As previously mentioned, FIGS. 5 and 6 further illustrate the feedblock and conduit design according to the present invention. FIG. 5 is a sectional end view which shows the branch conduits 74 and 76 extending from vertical conduit 68 toward the center of the feedblock 20 and terminating at outlets 78 and 80 vertically arranged on opposite sides of the main resin conduit 64. Screws 82 and 84 are shown extending to engage the branch conduits 74 and 76 to control the resin flow. This view also more clearly shows screws 83 and 85 which engage branch conduits 70 and 72 (not shown) in a manner similar to that of screws 82 and 84 Vertical conduit 66 is also illustrated.

FIG. 6 is a top cross-sectional view of the feedblock 20 and more clearly shows the conduitscrew relationship. The engagement of the screws 82 and 83 into the conduits 70 and 74 in the vicinity of the conduit bends is clearly shown.

FIG. 7 is a cross-sectional view of the extrusion die and rollers taken along line 7—7 of FIG. 2. There is shown the sheeting die 22 having the extruded product 26 passing therethrough. Restrictor bars 102 and 104 can be adjusted depending upon processing conditions. Instrument 106 measures product thickness and can be adjusted accordingly. Finally, as previously discussed, polished cooling rollers 28, 30 and 32 are provided downstream of the die to cool the multiple-layered sheeting

In the co-extrusion process of the present invention, there is provided by extruder 12 a base layer stream, generally referred to as 110 in FIG. 3. The composition of the base layer stream can be selected from a wide variety of polymers. As a practical matter, a lower grade, less-expensive polymer is used. Such polymers are usually inferior with regard to certain characteristics, for example, appearance. Examples of appropriate materials for use as a base layer include polystyrene, both the homopolymers and copolymers thereof. Included within this latter category are impact polystyrenes which comprise graft copolymers of styrene upon conjugated diene backbone polymers such as polybutadiene, butadiene-styrene copolymers, butadiene-acrylonitrile copolymers, natural rubber, etc. Likewise included in this category are normal copolymers of styrene with other well-known, conventional monomers. This list is by no means limiting.

This base layer stream 110 then passes into the co-extrusion block of FIGS. 3 and 4. Also entering the co-extrusion block are co-extruded resin streams through inlet passages 40 and 42, these co-extruded streams coming from discharge conduits 18 and 36 of co-extruders 16 and 34, respectively.

For the sake of a more complete description, the present invention will be described with reference to the embodiment wherein there are two co-extruded resin streams, and thus, subsequently four layers applied to the base sheeting, two layers to each side.

Specifically referring to FIG. 4, the co-extruded streams enter the feedblock 20 through inlet passages 40 and 42, and pass through the main co-extrusion body via conduits 66 and 68 and are then divided into sub-streams by passing through branch conduits 70, 72 and 74, 76. The sub-streams pass through the branch conduits past the screws 82-85. These screws determine the number and extent of the streams which eventually will be applied to the main resin stream. By engaging and disengaging the screws into the conduit paths, resin flow is controlled. By complete engagement into the path, the entire flow is retarded. Thus the screws provide a simple means for controlling the presence of the layers to the base sheeting.

An advantageous result of the present invention is the control of the layer application by external means. By utilizing the screw arrangement herein described, the operator can monitor the sheeting as it is produced and quickly and easily vary the polymer applied to the main resin layer by simple manual adjustment of the screws. Additionally, should process requirements necessitate an increase or decrease in the number of layers, simple manipulation of the screws will accomplish this requirement. This results in insignificant loss of time and product when such changes are required and can be accomplished online. Previously, such adjustment resulted in loss of time and production due to shutdown and to faulty product produced during initial startup as the process was being refined to meet requirements.

Assuming that all four co-extruded streams will be applied to the main resin stream, the streams exit the feedblock 20 at outlets 78, 80 and 86, 88 which communicate directly with inlet bores 90, 92, 94 and 96 of the value plates 44 and 46. The resin streams pass from these bores through slots 95 and 97 to the main resin orifice 100 where the co-extruded resins are applied to the main polymer resin

As the resins progress from the inlet bores to main orifice 100, they pass over a camsert cavity having a camsert therein. A "camsert" is used here to describe a restrictor means which is cam operated. The camsert is controlled within the cavity so as to move perpendicularly to the resin flow. In advancing the camsert in the cavity, the camsert constricts the resin flow, and thus, would result in a reduction in flow and layer thickness. Likewise, should the layer thickness be too small, the camsert can be withdrawn the necessary distance thus allowing an increase in resin flow to conduit 100. The valving arrangement provides a high degree of layer thickness control and adjustment.

The means for controlling the movement of the camsert are, like the feedblock screw arrangement, housed externally to the value plate and are easily accessible to the operator. The combination of the two external flow control means allows easily accessible and adjustable control of the layers of the sheeting product with reduced time and cost.

The co-extruded resinous materials of the present invention can be selected from a variety of polymeric materials. Synthetic resins within the scope of the invention include PVF (polyvinyl fluoride), ABS (acrylonitrile-butadiene-styrene), PET (polyethylene terephthalate), HIPS (high impact polystyrene), acrylic resins, polyolefins, etc. This list is exemplary and by no means limiting. Any thermoplastic synthetic resins which are customarily extruded are within the scope of the invention.

The following specific example is provided to facilitate a better understanding of the invention, it being understood that the same is intended to be merely illustrative and in no way limitative.

EXAMPLE

A main resin stream of high impact polystyrene (Cosden Oil and Chemical Co. 825D pellets) is extruded from a 3½ inch diameter two stage vented extruder containing a 4:1 compression ratio screw. Two 2½ inch diameter 30:1 single stage side extruders also having a 4:1 compression ratio screw are arranged as illustrated in FIG. 2 and supply a second adhesive layer of DuPont CXA 3101, and a third stream of PETG (polyethylene terephthalate glycol) (Eastman Kodar 6763). The polystyrene is extruded at a temperature of 440° F. and a feed rate of approximately 680 lbs./hr. The adhesive side stream is discharged from the 2½ inch extruder at 330° F. and at a feed rate of approximately 5-10 lbs/hr. The PETG stream is discharged from the 2½ inch extruder at 505° F. and at a feed rate of approximately 30 lbs./hr.

The first side stream is divided into two streams. The flow of one of the two streams is then completely stopped so that only one layer of adhesive is applied to form an intermediate layer on one side of the polystyrene. The second side stream is also divided into two streams, and likewise, the flow of one of these two streams is completely stopped so that only one layer of PETG is applied, the PETG layer being applied to the adhesive layer previously formed. There results a single stratified stream having junction interfaces between the three separate layers. The combined stream is conducted to an extrusion die orifice 52 inches wide with lips set at approximately 100 mils. The die temperature averages about 460° F.

Upon leaving the die lips, the extruded sheet passes a series of three 15-inch polished chrome cooling rolls, the top roll maintained at 160° F., middle roll at 180° F. and bottom roll at 150° F. Roll pressures at top and bottom are maintained at 20 psi, and at a gap setting of 100 mils.

Examination of the final sheeting product evidences essentially uniform layers of the PETG, adhesive and impact polystyrene The thickness of the layer of the impact polystyrene is 88 mils The thickness of the adhesive layer is approximately 2 mils, and the thickness of the PETG is 10 mils. The individual layers are of uniform thickness across the entire width.

Thus, there has been provided according to the invention a process for co-extruding multi-layered sheeting having uniform layer thicknesses.

While the fundamental novel features and advantages of the invention have been pointed out in connection with a few illustrated embodiments thereof, it will be appreciated that various obvious modifications of the co-extrusion process and apparatus will suggest themselves to one of ordinary skill in the art. Therefore, it is intended to be limited only by the scope of the following claims.

What is claimed is:

1. A co-extrusion apparatus for the production of multi-layered products of thermoplastic synthetic resins having selected numbers of layers, comprising:

- a main extruder for producing a main heat-plastified resin stream;
- at least one co-extruder for producing a side heat-plastified resin stream;
- a co-extrusion feedblock, positioned downstream of said extruder and said co-extruder, comprising:
  - a main co-extrusion body having a central orifice providing for the passage therethrough of a base layer of said main resin stream;
  - at least one conduit means within said co-extrusion feedblock for receiving said side heat-plastified resin stream from said co-extruder, for splitting said side resin stream into two sub-streams and for transporting said sub-streams through said feedblock, said conduit means comprising a vertical shaft which divides into two horizontally projecting sub-conduits parallel to one another, said two sub-conduits being engaged by adjustment means which control the level of flow of said sub-streams, said adjustment means being internal to said co-extrusion feedblock and comprising means for external adjustment thereof,
- at least one slotted plate positioned on either side of said main co-extrusion body transverse to the direction of flow of said main resin stream, including:
  - a central orifice aligned with the central orifice of said main co-extrusion body,
  - slotted portions on either side of said central orifice for laying down layers of said side resin stream upon said main resin stream, each of said slotted portions comprising a circular bore area extending partially through the thickness of said slotted plate and positioned opposite each other in regard to said central orifice and having a slot connecting each of said bores to said orifice, wherein each of said bore areas operatively engages said conduit means of said main co-extrusion body to provide for the passage of said sub-streams from said main co-extrusion body into said bore areas and along said slots to be applied to said main resin stream to form a combined stream, and

valve means for internally controlling the flow of each of said sub-streams by means external of said valve plate comprising two circular camsert cavities extending partially through the thickness of said plate, said cavities being positioned opposite each other in regard to said central orifice and opening into said slotted portions extending longitudinally from said central orifice and each cavity housing an adjustable camsert which is movable within said cavity and, upon adjustment, extends into said slotted portion to control the flow of resin flow, and

a sheeting die downstream of said co-extrusion block for receiving said combined stream and for forming the multi-layered product into a multi-layered sheet.

2. A co-extrusion apparatus as claimed in claim 1, wherein said co-extrusion feedblock further comprises:

a main co-extrusion body positioned between said main extruder and said sheeting die, said body comprising a central orifice aligned with said central orifice of said slotted plate providing for the passage of said base layer therethrough.

3. A co-extrusion apparatus as claimed in claim 1, wherein said camsert comprises an elliptically-shaped orifice housing an eccentric, said eccentric upon rotation positions said camsert within said cavity.

4. A co-extrusion apparatus as claimed in claim 3, further comprising an external means for rotating said eccentric.

5. A co-extrusion apparatus as claimed in claim 4, wherein said eccentric rotating means comprise screws.

6. A co-extrusion apparatus as claimed in claim 1, wherein said stream splitting means divides said co-extruded stream into two streams and returns said divided co-extruded streams to said bores of said slotted plate.

7. A co-extrusion apparatus as claimed in claim 1, wherein said flow-varying means are internal to said co-extrusion block and comprise means for external adjustment thereof.

8. A co-extrusion apparatus as claimed in claim 7, wherein said flow-varying means comprises screws.

9. A co-extrusion apparatus as claimed in claim 7, wherein said flow-varying means is capable of completely retarding the flow of said side resin stream through one of said sub-streams.

10. A co-extrusion apparatus as claimed in claim 1, comprising two of said slotted valve plates positioned at opposite sides of said main co-extrusion body in the direction of travel of said base layer, and wherein said co-extrusion block further comprises a second conduit means and a second adjustment means for said second slotted valve plate.

11. A co-extrusion apparatus as claimed in claim 10, comprising a second co-extruder connected upstream of said feedblock for supplying a second side stream of heat-plastified resin to said second slotted plate.

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