SW22C

Rubber Reuse and Solid Waste Management

Part I

SOLID WASTE MANAGEMENT IN THE FABRICATED RUBBER PRODUCTS INDUSTRY, 1968

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Part I of this publication (SW-22c) was written for the Federal solid waste management program by ROBERT J. PETTIGREW and FRANK H. RONINGER Uniroyal Chemical, a division of Uniroyal, Inc. under Contract No. PH 86-68-208

U.S. ENVIRONMENTAL PROTECTION AGENCY
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Preface

This report on solid wastes generated by the operations of the fabricated rubber products industry was prepared by Uniroyal Chemical, a division of Uniroyal, Inc., pursuant to contract PH 86-68-208 with the Federal solid waste management program (now part of the U.S. Environmental Protection Agency). The statements, findings, conclusions, recommendations, and data in this report are not necessarily those of the Agency, nor does mention of commercial products imply endorsement by the U.S. Government.

The principal investigator was Robert J. Pettigrew with the support of the Commercial Development and Research and Development staffs of Uniroyal Chemical and by the Economic Analysis and Long Range Planning staff of Uniroyal, Inc.

Valuable suggestions and review advice were provided by Rodney L. Cummins and Clarence A. Clemons of the Federal solid waste management program.

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Summary

SOLID WASTE MANAGEMENT IN THE FABRICATED RUBBER PRODUCTS INDUSTRY, 1968

The fabricated rubber products industry consists of those manufacturers who combine elastomeric materials, fabrics, metal products, chemicals and mineral fillers purchased from others and by suitable processing produce tens of thousands of different products for the use of consumers and industry. The largest volumes of these products are automotive tires, but they include canvas and rubber footwear, wire and cable covers, hose and belting, foam and sponge, and the great variety of molded consumer and industrial products grouped together as mechanical rubber goods. The common characteristic of the industry is that its products are based on elastomers (rubber) to the exclusion of similar products based on plastics. The industry does not include the manufacture of synthetic elastomers nor the reclaiming of rubber as these are supplying industries and not part of the fabricating industry.

In 1968 the fabricated rubber products industry produced 10.7 billion pounds of products with a shipping value in excess of 7.5 billion dollars and employed about 250,000 people. There were some 1,500 companies operating at 2,000 locations but the great majority were small specialty shops employing 10 people or less. If value of shipments is used as a measure of production, manufacturing facilities in only 10 states account for 75 percent of the output of products. These are the North Atlantic and East North Central States plus Alabama, Texas and California. Figure I-1 shows the concentration of the fabricated rubber products industry in the important states as percent of the total based on the value of shipments.

All of the 10.7 billion pounds of product will be used by consumers or industry and in a fairly limited period will be worn-out and abandoned and enter into the general solid waste mass of the country as will be discussed in Part II of this study, *Waste Rubber and Its Reuse, 1968.*

This part of the study is concerned only with the solid waste problem which (originates from the fabrication of rubber products and which) must be disposed of at the manufacturing site. It is not concerned with ultimate disposal by the consumer of the product or the product package.

In the manufacture of the 10.7 billion pounds of salable rubber products in 1968, it is estimated that 1,058 million pounds of solid wastes originated from the fabricating facilities and had to be disposed of at those locations. These solid wastes had no present value and represented a disposal cost of about $9.5 million for collection, haulage and dumping. This sum does not include the cost to the fabricator of processing these semi-finished goods, but this internal cost is a constant stimulus to the producer to keep wastes to the lowest level possible.

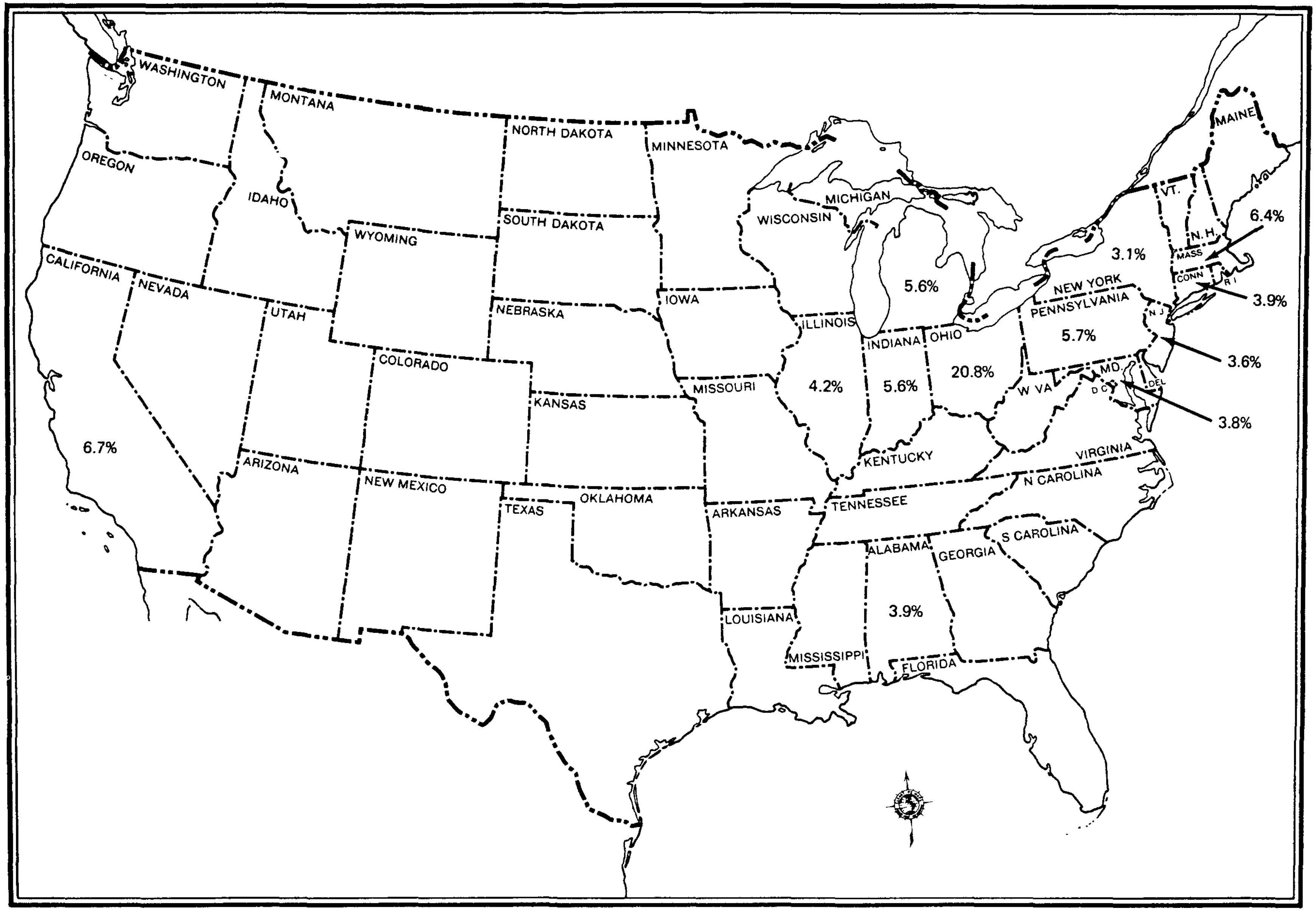

FIGURE I-1 TWELVE MAJOR FABRICATED RUBBER PRODUCTS MANUFACTURING STATES BASED ON VALUE OF GOODS SHIPPED

The kinds and relative quantities of this manufacturer's solid waste will vary according to the product or products made at a particular location. The complexity of the industry has necessitated grouping the products made into six general categories and the types of waste into five categories. Table I-1 gives the estimated breakdown of fabricator's solid wastes for the entire industry in 1968. Details for each of the product categories are given later in the report as the quantity per million pounds of product as a guide to evaluation of the solid waste problem for any specific location knowing the product mix at that location.

In Table I-1, and subsequent tables in this volume, the solid waste categories include materials as follows. Paper, cardboard and wood includes all such inputs to the fabrication plant as raw material bags and wrappers, carton, non-returnable wood boxes, pallets, and shipping dunnage, machinery crates, production cards and stationery waste, and production supplies. It does not include out-bound cartons, wrappings or other packaging. Rubber compound includes in-process wastes consisting of trimmings, molding wastes, damaged stocks, quality control rejects or other combinations of rubber, pigments and chemicals which cannot be reprocessed in any way in the plant or sold to others at some value. Textiles refer to woven, knitted, nonwoven, or cord textile products, usually cotton or synthetic, which are used in fabricated rubber products and may be trimmings, short ends, damaged goods or quality rejects from any stage of processing and are of such a nature that they cannot be reprocessed in some way or sold to others for value. Metals are both ferrous and non-ferrous wires, fittings or other attachments from damaged or rejected products which cannot be recovered or sold for value and the largest part would be ferrous beadwire from pneumatic tires or ferrous inserts from moldings. The other category includes plastic wrapper film or worn-out separators, plastic and glass bottles, metal cans or drums, and miscellaneous unclassified floor sweepings and other earthy materials.

The tire and tire products segment of the industry accounts for about three-quarters of the total weight of finished products but generates only about 40 percent of the total solid waste. Because of the large volume of a single type of product, tires are generally made by semi-automated procedures in modern or modernized factories. This permits the use of bulk raw materials reducing the amount of input paper bags to be disposed of. It permits standardized assembly procedures and better waste cost control and provides the possibility of utilizing process waste in less critical products such as flaps and other tire accessories. An important part of the rubber compound waste is cure-bags which are relatively short-lived accessories to the tire curing operation and which when discarded cannot always be sent to reclaimers.

Table I-1

SOLID WASTE GENERATED BY THE FABRICATED RUBBER PRODUCTS INDUSTRY: 1968
(Millions of pounds)

Type of Waste	**Type of Rubber Product**						
	Tires and Tire Products	**Foot-wear**	**Belts**	**Hose**	**Foam and Sponge**	**Mech. Goods**	**Total**
Paper, cardboard, and wood	100.5	8.5	6.8	11.7	9.6	65.5	202.6
Rubber compound	89.3	45.0	10.2	19.2	54.0	140.7	358.4
Textile materials	44.2	33.0	6.3	6.3	0.1	42.8	132.7
Metals	72.7	00.5	0.6	3.6	---	21.3	98.7
Other Materials	105.2	17 5	7.6	17.2	16.2	102.0	265.7
Total Wastes	411.9	104.5	31.5	58.0	79.9	372.3	1,058.1

For the footwear segment the paper input is small because much of the raw material enters in a pre-processed condition to avoid soil. Because of the domination of hand work on a great variety of small units, the wastage in rubber compound and textile material trimmings is too high to use up entirely in lower quality components such as inner soles and counter stocks. There is a limited market for these wastes to others, but the net disposable waste is high.

For the belting, hose, and mechanical goods segments, which are usually combined in a single plant, the big waste item is rubber compound, usually in the cured state so it cannot be recycled. This segment is made up of a very large number of items largely hand-built to rigid specifications. As a result there is a sizable amount of spoilage and quality rejects which cannot be safely sold as off-grade products but must be scrapped and disposed of as solid waste.

Most foam and sponge product raw materials are received as bulk water suspensions and so the input paper is relatively small. The foam process in itself produces wastage of rubber compound as trimmings and this makes up a large part of the solid waste. Many attempts have been made to reconstitute this foam scrap into useful products but they have met with little success as they lack the special properties of new foam. The waste is not at all attractive to rubber reclaimers because of its bulkiness.

The problem of solid wastes is no novelty to the fabricated rubber products industry forced upon them by the great number of units of an endless variety that they must produce to rigid specification by largely hand assembly methods. Rubber industry management is well aware of the internal cost of producing solid waste. This cost is reflected in high reject rates, wasted raw material, and most of all, wasted labor, a high price commodity. Short of further automation and other capital investment, there is little likelihood that production wastes can be reduced further in the near future.

Most top management is not aware of the actual cost of solid waste disposal which includes in-plant collection and baling, and outside hauling and dump fees or investments. In many cases only lower management levels are aware of the actual disposal costs. Several plants have salvage operations which sell all the waste they can and hope that this revenue will offset part or all of the solid waste disposal costs.

Certainly more careful segregation of waste by kind would make disposal more effective and possibly reduce the total amount by allowing more rework. Powder spillage and trim scrap could be kept out of general waste and returned to process. Reworking of plastic separator sheets was reported by one major company, cutting that particular waste item to one-sixth of what it was. Such investments for reprocessing can reduce the disposal costs and amounts of solid waste to be disposed.

The segregation of solid waste will allow for the incineration of the non-rubber portion which accounts for sixty-percent of the material now being disposed of in land fill sites. Present techniques waste valuable land fill sites by discarding many non-contaminating combustibles in them. Further, incinerator technology should be developed that will enable industry or municipality to burn rubber products without polluting the atmosphere and thus eliminate much of the need for land fill operations in or near our crowded metropolitan areas. Incineration is a short term solution to the problem. Ultimately reuse and recycle are the long term solutions to the total solid waste problem.

Introduction

The Solid Waste Disposal Act (Pl 89-272) enacted by the Congress of the United States in October 1965, authorized the Department of Health, Education, and Welfare to initiate a program of research and development in solid wastes management. The Act also authorized assistance to states, local governments, and interstate agencies as well as to private agencies, groups, and individuals in solving solid waste disposal problems in order to alleviate this serious national problem. In order to efficiently perform responsibilities under this Act, it is necessary that accurate basic information be made available on the kinds, quantities, distribution and potential economic disposal of the solid wastes generated by specific industries.

This study was performed with the generous cooperation of the fabricated rubber products industry in order to evaluate the solid waste problems in the operation of this specific industry. It is intended as a guide for all concerned with solid waste utilization and disposal and it is hoped that it will be of assistance to the industry itself in its continuing efforts to control the problem.

The study was conducted during the period July 1, 1968 to July 1, 1969 and specifically covers the situation for the calendar year 1968 with historical backgrounds and best estimates of the future through 1973. The information was obtained through personal interviews as described in Appendix A, Study Methods, of this report.

Since many of the terms used may be unfamiliar outside of the rubber industry, the less obvious ones are defined in Appendix B, Glossary, of this report.

Acknowledgments

A study such as the present one which encompasses the whole of a large and diversified industry would not have been possible without the generous cooperation of many knowledgeable individuals in that industry. We wish to express our thanks for the assistance of the personnel of the following companies, associations, and institutes.

Acme Hamilton Manufacturing Corp.
Trenton, New Jersey

Acushnet Co.
New Bedford, Mass.

Aldan Rubber Co.
Philadelphia, Pa.

Alliance Rubber Co.
Alliance, Ohio

Amerace Corp.
Butler, New Jersey

Ames Rubber Corp.
Hamburg, New Jersey

Armstrong Rubber Co.
West Haven, Conn.

Ashland Rubber Products Corp.
Ashland, Ohio

A. Baker Manufacturing Co., Inc.
South Bend, Ind.

Barr Rubber Products
Sandusky, Ohio

Brunswick Rubber Co.
New Brunswick, N. J.

Burke Rubber Co.
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Burton Rubber Processing
Burton, Ohio

H. O. Canfield, Inc.
Clifton Forge, Va.

Carlisle Tire & Rubber Division
Carlisle, Pa.

Carol Wire & Cable Corp.
Pawtucket, R. I.

Cat's Paw Rubber Co.
Baltimore, Md.

Centrex Corp.
Findlay, Ohio

Chemical Rubber Products, Inc.
Beacon, N. Y.

Comar Products, Inc.
Butler, N. J.

Bata Shoe Co.
Belcamp, Md.

Beebe Rubber Co.
Nashua, N. H.

Bishop Manufacturing Co.
Cedar Grove, N. J.

Boston Woven Hose & Rubber
Cambridge, Mass.

Cooper Tire & Rubber Co.
Findlay, Ohio

Davol Rubber Co.
Providence, R. I.

De Laval Separator Co.
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Dunlop Tire & Rubber Corp.
Buffalo, N. Y.

Electric Hose & Rubber Co.
Wilmington, Del.

Faultless Rubber Co.
Ashland, Ohio

Firestone Tire & Rubber Co.
Akron, Ohio

Garlock, Inc.
Palmyra, N. Y.

Gates Rubber Co.
Denver, Colo.

Globe Manufacturing
Fall River, Mass.

Goodall Rubber Co.
Trenton, N. J.

B. F. Goodrich Co.
Akron, Ohio

Goodyear Tire & Rubber Co.
Akron, Ohio

Graflo Rubber Co.
Radford, Va.

Griswold Rubber Co.
Moosup, Conn.

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Converse Rubber Corp.
Malden, Mass.

Cooke Color & Chemical Co.
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Lord Manufacturing Co.
Erie, Pa.

Lovell Manufacturing Co.
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Manhattan Rubber
Passaic, N. J.

Mansfield Tire & Rubber Co.
Mansfield, Ohio

Master Processing Corp.
Lynwood, Cal.

Midwest Rubber Reclaiming
East St. Louis, Ill.

Monarch Rubber Co.
Baltimore, Md.

National Hose Co.
Dover, N. J.

Nearpara Rubber Co.
Trenton, N. J.

Oliver Tire & Rubber Co.
Oakland, Cal.

Pawling Rubber
Pawling, N. Y.

Permacel
New Brunswick, N. J.

Perry Rubber Co.
Massillon, Ohio

H. K. Porter Co.
Pittsburgh, Pa.

Republic Rubber
Youngstown, Ohio

Rome Cable
Rome, New York

Schenuit Rubber Co.
Baltimore, Md.

Kirkhill Rubber Co.
Brea, Cal.

A Larkin & Son
Chicago, Ill.

Laurie Rubber Reclaiming
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Los Angeles Standard Rubber
Los Angeles, Cal.

Uniroyal, Inc.
New York, N. Y.

U. S. Rubber Reclaiming
Vicksburg, Miss.

Victor Balata & Textile Belting Co.
Easton, Pa.

Vogt Manufacturing Co.
Rochester, N. Y.

A Schulman, Inc.
Chicago, Ill.

Swan Rubber Co.
Bucyrus, Ohio

Taylor Bros. Co.
Cleveland, Ohio

Thompson Aircraft Tire
San Francisco, Cal.

W. J. Voit Rubber Co.
Santa Ana, Cal.

Vulcanized Rubber & Plastics Co.
Morrisville, Pa.

West American Rubber Co.
Orange, Cal.

Xylos Rubber Co.
Akron, Ohio

Associations

The Asphalt Institute
College Park, Md.

The National Tire Dealers and Retreaders Association, Inc.
Washington, D.C.

Rubber Manufacturers Association
New York, N. Y.

The Rubber Reclaimers Association, Inc.
New York, N. Y.

HISTORY OF THE FABRICATED RUBBER PRODUCTS INDUSTRY

The term "rubber" is one of those unfortunate English language expressions which has taken on many imprecise and only vaguely related meanings. It is said that when the native material first appeared it was first used for "rubbing" (erasing) and so gained its name. The word now refers to the natural vegetable product in its various forms, to synthetic materials of a similar nature, to compositions based on such materials, to finished products generally, and to specific kinds of finished products. Foreign languages have different terms for these different things but we must suffer the confusion of a single term.

Rubber was first brought to Europe by the early explorers of the tropics where it had been used by the natives since ancient times to make slippers, balls, bottles, toys and dolls. Natural rubber is the product of a wide variety of unrelated tropical trees, shrubs and vines, occurring as a watery dispersion (latex) in a separate system of channels and tubes. It apparently functions as a reserve food supply and as a protective material for the growing plant from which it is gathered by controlled cutting or injury.

Until about 1920, the rubber of commerce was almost entirely the variable product of primitive gathering from wild plants in Equatorial Africa and South America. After many years of development, in the 1920's uniformly high quality natural rubber from carefully managed plantations in the Far East came on the market in sufficient quantity to quickly replace the inferior wild rubbers. Because of wildly fluctuating prices and uncertain supply, the rubber and chemical industries were stimulated to develop synthetic substitutes In the 1930's the first truly useful synthetic rubbers became commercial on a limited scale. In 1942 under wartime stress, a crash program by the federal government cooperating with private industry established the first large scale general purpose synthetic rubber plants to produce the famous GR-S. In the past 25 years, one new synthetic rubber after another has become commercial each with its own specific value to the fabricator.

Practical rubber technology was developed in a limited way in the first half of the nineteenth century by such men as Macintosh and Hancock in England and Goodyear in the United States. At first the products were of limited usefulness. Although they had the unique property of being waterproof, the rainwear, which was the principal product, was intolerably sticky in warm weather and too stiff to wear in cold weather. Modest improvements were made by vapor or liquid treatment of the rubber surface in various processes.

In 1839 Charles Goodyear discovered that if rubber products containing flowers of sulphur were exposed to heat they developed acceptable properties. This was the discovery that firmly established the fabricated rubber products industry. Soon a multitude of small plants in New England and elsewhere were producing footwear, boots, rainwear, medical sundries, hard rubber and simple mechanical items. The Civil War not only proved the value of these new manufactures but made them familiar to soldiers and civilians from all parts of the expanding country.

By 1900 the bicycle craze, rubber tired carriage wheels and the beginnings of the automotive industry opened up the tire market on a large scale. World War I military needs proved the value of truck and bus transportation of goods and people and made the first important pneumatic tire market. Rubber was now big business and could support and encourage industrial and university research in the raw materials, chemical additives, processes, and equipment by many skilled scientists who changed a trial-and-error industry into a highly sophisticated technology. It was none too soon for service conditions were changing rapidly. Expected tire mileage was going up while tire loading and average road speed was steadily increasing. Rubber technology was under constant pressure to convert a relatively fragile composition into engineered products capable of performing reliably under extremely severe conditions.

FUTURE OF THE FABRICATED RUBBER PRODUCTS INDUSTRY

The rubber products industry will enter the 1970's with a half century of sophisticated technology, a wealth of new rubbers, fibers, and other raw materials to utilize, and with major new engineering and design improvements to apply. The problem will be to maintain reasonable prices, service life, reliability and increasing output in the face of increasingly severe performance requirements without aggravating the inevitable solid waste problem of discarded rubber products.

Because of the variety and complexity of the products of the fabricated rubber products industry, it is necessary to evaluate the industry size and growth by the amount of natural and synthetic rubber polymer which is consumed, which is reliably reported. The annual per capita consumption of rubber polymer in the United States has increased from a negligible amount in 1900 to seven pounds per capita in 1930 and to thirty pounds per capita in 1968.

In Figure I-2 the total consumption of rubber polymer is traced from 1958 to the present and projected to 1973. Growth was mildly erratic over the past ten year period but averaged 5.4 percent per year. The projections through 1973 are a consensus of the industry and show a growth rate of about 4.3 percent per year. It is a realistic assumption that the product mix of the industry has not materially changed in the past ten years and will not change in the immediate future, and that the relative waste output has and will remain nearly the same for this mature cost conscious industry. In order to quantify the solid waste problem directly from the fabricated rubber products industry, we have presented in the right hand margin a scale of solid waste in billions of pounds from which the weight in any given year can be estimated.

The anticipated growth changes for the different segments of this industry are discussed in detail in the following specific sections.

Consumption of new rubber by the industry is reported in three parts; tires and tire products, and other products. The categories are not very helpful in detail, but the data does illustrate the very dominant position of tires and tire products. Figure I-3 presents this information from 1958 to 1969 and forecast through 1973 as a percent of total new rubber consumption. Tire and tire products consistently use 62 to 66 percent of all new rubber. Wire and cable use a small part of the total which has remained constant in absolute terms but has declined from three to one percent of the total. The catch-all "other products" uses about a third of the rubber in a great variety of items. Obviously the industry does not anticipate any major shift in product mix.

In the following sections of the report, trends and special conditions in various segments of the overall fabricated rubber products industry are discussed in detail. In these sections the solid waste generated by the operation of typical plants is given in terms of ratio to output, specifically the average weight of solid waste to be disposed of per million pounds of product produced. This should not only be of value to waste control authorities in evaluating their problems, but it is hoped will be of value to industry management in improving their own plant performance.

TIRES AND TIRE PRODUCTS

The tire and tire products industry consists of those manufacturing facilities comprised in the following Standard Industrial Classification (1967 Manual) categories.

30111/30112/30113-11,-13,-15,-17

All pneumatic tire casings including passenger, truck and bus, aircraft, motorcycle and scooter, bicycle, off-the-highway, farm implement, tractor, and industrial types.

30113-33,-35,-41,-51

All solid and semi-pneumatic tires for industrial and highway use, for wheeled toys, baby carriages, bogies, and idler and support rollers.

30114

All inner tubes for pneumatic tires.

30115

All tread rubber for tire retreading slab stock for further processing, flaps, repair materials, and associated products.

This segment produces 70 percent of finished product weight of the entire fabricated rubber products industry and six major companies produce 83 percent of the tires at 42 locations. Ten other companies produce the remaining 17 percent at 15 locations. Usually inner tubes are produced in plants separate from the tire casing plant and some tread stock for retreading is produced in detached small facilities. In general all other solid tires and auxiliary materials are made in the larger plants which produce tire casings. Passenger car tire sizes account for 65 percent by weight and 80 percent by number of all tires manufactured in the United States.

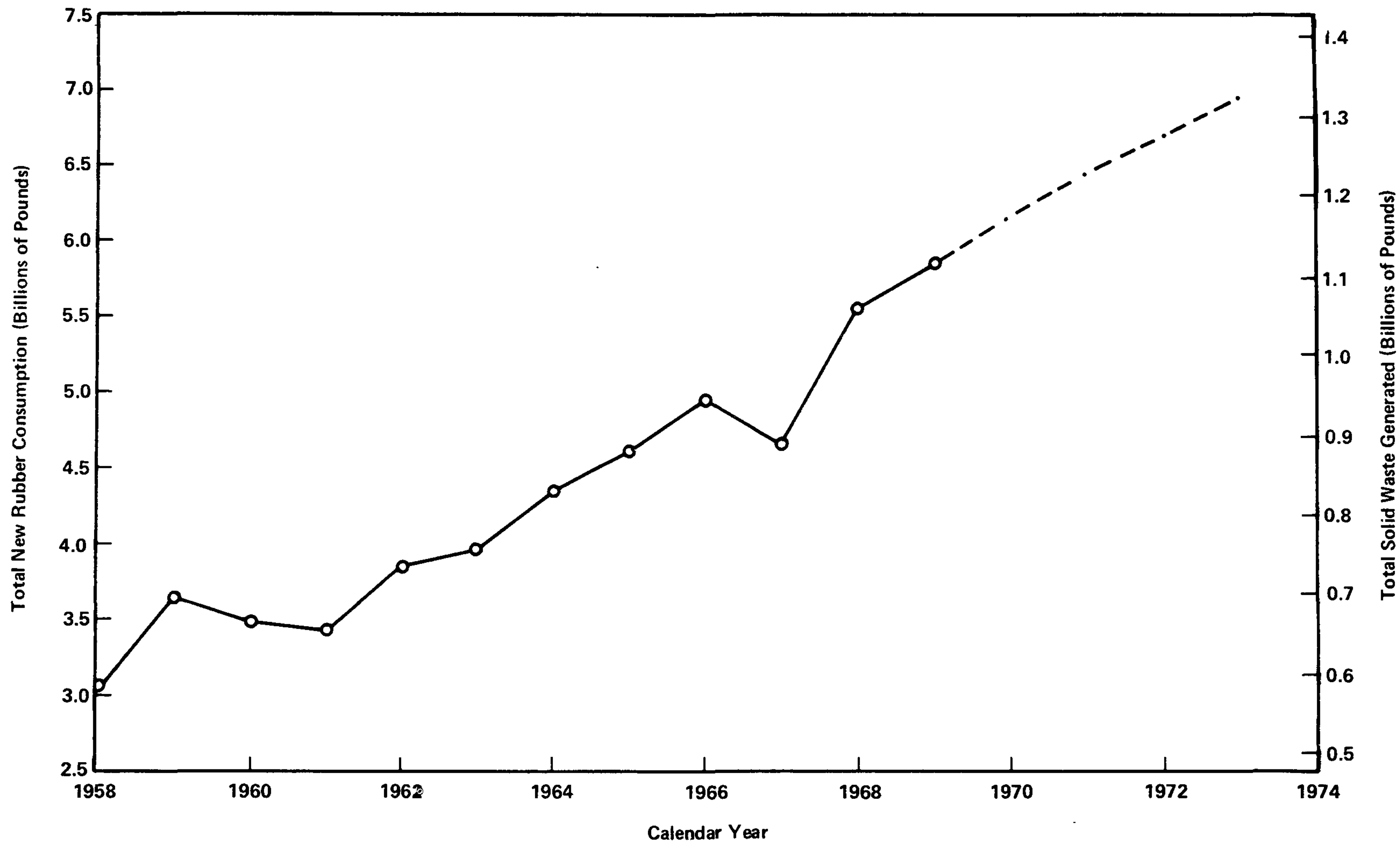


FIGURE I-2. TOTAL NEW RUBBER CONSUMPTION AND SOLID WASTE GENERATION IN THE FABRICATED RUBBER PRODUCTS INDUSTRY

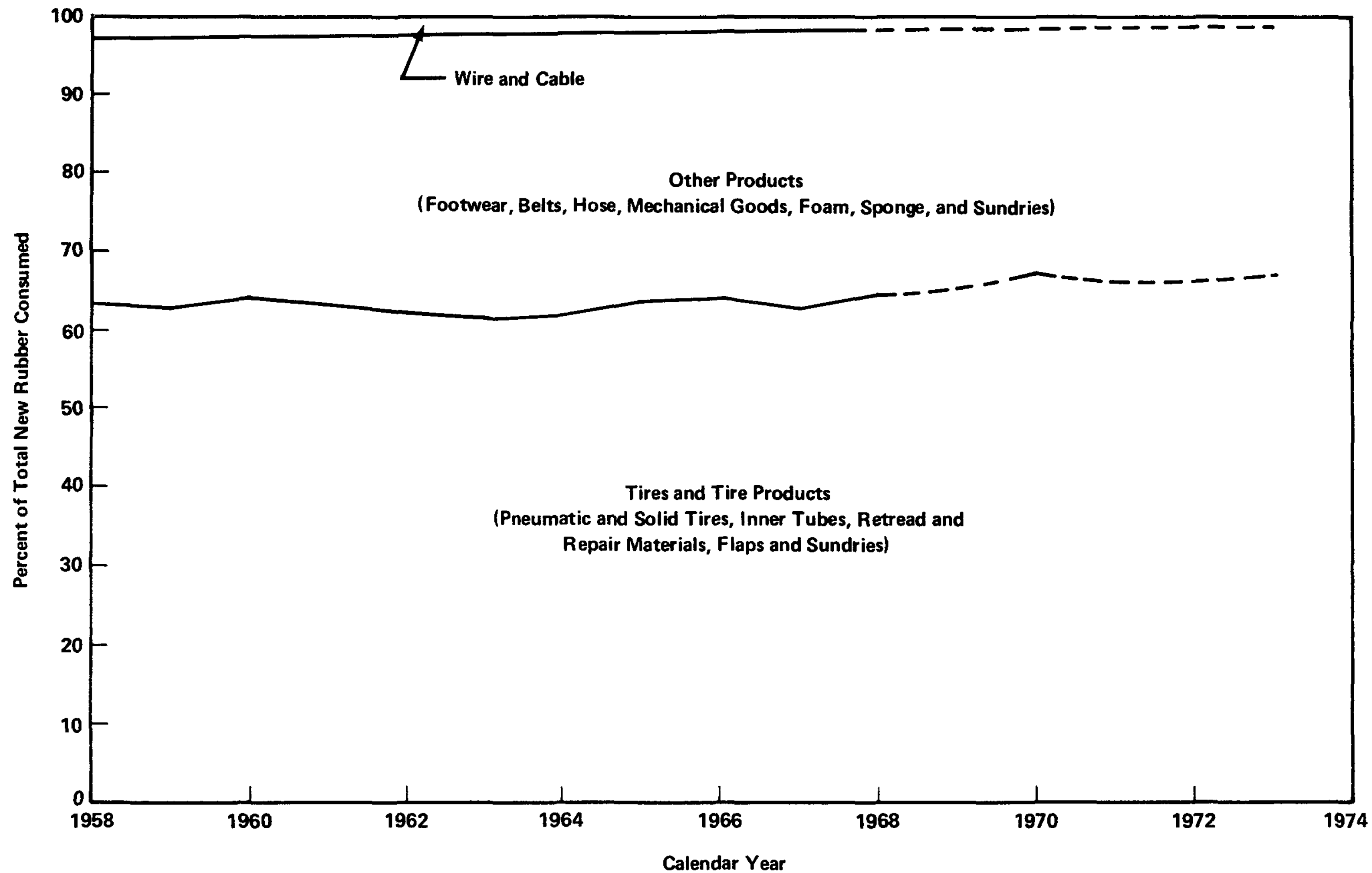


FIGURE I-3. PERCENT OF TOTAL NEW RUBBER CONSUMED

DISTRIBUTION OF TIRE PRODUCING PLANTS IN THE UNITED STATES AS OF YEAR-END 1968*

Company	Location	Units/ Day
Armstrong	DesMoines, Ia.	20,500
	Hanford, Cal.	10,500
	Natchez, Miss.	18,000
	W. Haven, Conn.	15,000
Cooper	Findlay, Ohio	13,000
	Texarkana, Tex.	11,500
Firestone	Akron, O.	27,000
	Albany, Ga.	17,000
	Barberton, O.	8,500
	Bloomington, Ill.	50
	Dayton, O.	20,700
	Decatur, Ill.	22,000
	DesMoines, Ia.	22,000
	Los Angeles, Cal.	15,500
	Memphis, Tenn.	28,000
	Pottstown, Pa.	30,000
	Salinas, Cal.	15,000
Gates	Denver, Colo.	18,200
	Nashville, Tenn.	12,000
General	Akron, O.	9,050
	Bryan, O.	30
	Charlotte, N.C.	11,000
	Mayfield, Ky.	19,800
	Waco, Tex.	16,000
Goodrich	Akron, O.	6,000
	Ft. Wayne, Ind.	18,000
	Los Angeles, Cal.	11,500
	Oaks, Pa.	19,000
	Tuscaloosa, Ala.	21,000
Goodyear	Akron, O.	38,000
	Conshohocken, Pa.	13,500
	Cumberland, Md.	20,500
	Danville, Va.	5,500
	Freeport, Ill.	14,000
	Gadsden, Ala.	44,000
	Jackson, Mich.	30,000
	Los Angeles, Cal.	18,000
	Topeka, Kans.	30,000
	Tyler, Tex.	15,000
	Union City, Tenn.	17,500
Mansfield	Mansfield, O.	14,000
	Tupelo, Miss.	10,000
Mohawk	Akron, O.	6,000
	Salem, W. Va.	4,700
	W. Helena, Ark.	10,000
Uniroyal	Chicopee Falls, Mass.	28,000
	Detroit, Mich.	33,700
	Eau Claire, Wis.	31,000
	Los Angeles, Cal.	16,500
	Opelika, Ala.	13,500
Carlisle	Carlisle, Pa.	
Corduroy	Grand Rapids, Mich.	
Denman	Warren, O.	
		58,800
Dunlop	Buffalo, N.Y.	
McCreary	Indiana, Pa.	
Schenuit	Baltimore, Md.	

*Rubber World Vol. 159 No. 4 page 31, Jan. 1969.

This study was intended to reliably sample the entire tire and products industry by direct interview as may be judged from the following table.

MAJOR PRODUCERS

	Corp.	Plants
Industry	6	42
This Study	5	

MINOR PRODUCERS

	Corp.	Plants
Industry	10	15
This Study	6	

% OF CAPACITY

	Major	Minor
Industry	85	15
This Study	65	10

Table I shows the capacity of all tire producing facilities in the United States as of the end of 1968 and their geographical distribution as publicly reported.

The amount of solid waste generated in the manufacture of one million pounds of tires and tire products is shown below. These are average values for 1968 but because of the similarity of operation from plant to plant, they are representative of most operations in this category. There is little reason to believe that the situation was much different in the past ten years and no major improvement is to be expected in the next few years because this wastage has been recognized as a serious manufacturing cost for many years and is under constant attack. The total wastes amount to about 5.5 percent of the total weight of product made. One million pounds of tire industry product is equivalent to 40,000 passenger tire casings.

Type of solid waste	Pounds of waste per million pounds of product shipped
Paper, cardboard and wood	13,400
Rubber compound	11,900
Textile material	5,900
Metal	9,700
Other	14,000
Total Waste	54,900

The paper, cardboard and wood input waste is largely paper bags in which carbon black, mineral pigments, and chemicals are received. These are of little value for reuse in the paper industry because of severe contamination by the powders they contained. At least in the larger facilities carbon black is now received in dustless bulk shipments in cars or large returnable containers so the raw material bags for this item are eliminated. There is a sizable amount of in-process paper and wood waste from separator paper, temporary wrappings, and card and paper stock used to identify and control in-process materials. All of this paper and wood waste could be handled in suitable incinerators if properly segregated. At present in most cases no attempt is made at segregation, proper incinerators are not available, and the solid waste is handled by general collection, baling or semicompression, and hauling to dumps.

The rubber compound waste includes solids containing appreciable amounts of rubber which makes them unsuitable for combustion in any ordinarily satisfactory incinerator. Not only is the rubber hydrocarbon content such that it burns with an obnoxiously sooty flame, but the gases contain a large concentration of acid and sulfurous gases. The waste is made up of in-process trimmings and molding waste, in-process spoiled stock, curing bags, quality rejects and experimental and test products.

Some of the in-process waste is used up within the plant itself or related operations as raw material in low quality goods such as flaps and light service solid tires and rollers, but this means of disposal is limited by the product mix. Curing bags are a tire-like structure of rubber with some fabric which is inserted in the tire when it is cured to exert internal pressure. For passenger tires, these units weigh 12 pounds apiece and will serve to cure 250 to 300 tires before they must be scrapped. It is estimated that 7 to 8 million pounds of these bags are scrapped each year, but since they can be handled by reclaimers with some difficulty only a part of the curing bags appear in the solid waste figures above.

Finished tire rejects for quality reasons average one percent for passenger tires and less than one percent for heavier duty tires. In addition, there is a fraction of one percent of finished tires which are partially or completely destroyed in testing in the laboratory, on tracks, or in road tests. These cannot be sold as off-quality goods and they are not readily disposed of for reclaiming as new tires are much more difficult to process than are service-aged tires which have undergone desirable physical changes. All of these new unsalable tires are included in the waste numbers above, broken down into their known components.

Textile fabric and tire cord scrap (ends, clippings, defects) which have not been rubberized find a ready market with scrap dealers. Even the uncured tire carcass scrap (trimmings and spoilage) which is 60 percent rubber compound and 40 percent textile material usually can be sold to scrap dealers for resale to the mechanical rubber goods industry. Most of the amount under textile materials would be the textile content of finished goods which cannot be sold.

The metal waste at present is largely the high carbon steel wire from the tire bead. This consists of defective material, in-process waste, trimmings and the wire component from finished good rejects. There is some wastage of metal inner tube valves but this material finds a ready resale as scrap metal and does not appear in the above figures. At one time scrap bead wire could be compressed, baled and sold as scrap steel for use in the steel industry but it was never too desirable because of its bulkiness and of recent years has found no market at all because of changing steel production technology.

Changing tire construction designs may lead to changes in both the quantity and kind of waste from the industry in the future. The changes probably will not have too much effect through 1973 but may be quite important thereafter. Most of the pneumatic tires made through 1968 were of the conventional bias construction in which the carcass was built of diagonal layers of tire cord made of conventional cotton or man-made fibers. In 1969, large numbers of belted bias tires were made in which the carcass is reinforced with circumferential belts of cords of glass fiber, synthetic fiber or even fine steel wire. It is estimated that these tires will give 15 to 40 percent more service life but they will weigh about 18 percent more than the conventional bias tire. There is no reason to believe that the net solid waste ratio will change materially and although fewer units may be marketed the weight of product will remain the same. The only change should be that there will be glass fiber in the scrap which will make it less attractive for resale and more difficult to handle in incinerators.

Another type of construction may be an important market factor by 1973 or later. This is the radial tire in which the cords lie in radial planes which is believed to give better service. These tires are being built in limited quantities at present and because of production difficulties the rejection rates are reported to be three to five times those for conventional constructions. Before this construction becomes commercially feasible, this difficulty must be overcome but there may be some net increase in waste production. In Europe where these tires are already very popular, many of them are made with steel wire in the carcass or in the belt, in addition to the conventional wire bead. If this becomes popular in the United States, it will make even more difficult the problem of selling scrap or disposing of wastes.

In Figure I-4 a schematic outline of the tire manufacturing process is given to show the possible origin of the various types of scrap which will end up as solid waste if it cannot be reused internally or sold for some value. Figures I-5 and I-6 show the historical growth of the tire industry by the two major types along with industry consensus as to future growth through 1973. Figure I-5 presents this growth in terms of unit casings, Figure I-6 in terms of weight of product shipped and weight of solid waste to be disposed of. At one time tire manufacture was dominated by original equipment sales for new vehicles but road mileage of the national fleet has built up so high that tire demand is more nearly related to gasoline sales than to new car production. Also it will be seen that non-passenger tire markets are now growing more rapidly than passenger tire markets. Highway and air transport of goods and people is expanding, farms are using more mechanical equipment which requires pneumatic tires, and construction is moving over to massive pneumatic tired equipment. Not only are the relative number of units increasing, but the relative weight of non-passenger tires is increasing still more rapidly. Passenger tires averaged 22 pounds in 1968, truck and bus tires averaged 75 pounds, and some specialty tires for off-the-road service weigh hundreds of pounds. No substitute for the pneumatic tire would seem feasible in the immediate future. Even air-effect vehicles are said to use up more rubber in their skirts than they would on pneumatic wheels, and their wide acceptance does not seem imminent.

Inner tubes are somewhat different from tire casings in the waste problem generated. They contain very little textile material or metal and are nearly straight rubber compound. The waste is almost entirely paper input from raw materials and in-process trimmings. Inner tube scrap and rejects find a ready market with scrap dealers because they are clean compound and made exclusively from butyl or natural rubber which is very desirable to reclaimers. Scrap valves find a ready market on the metal scrap market. It was not possible to obtain waste data on inner tube production alone so the information is included in that for tires and tire products. Very few inner tubes are now used in passenger tires and then only in special cases such as wire wheel mountings. In 1968, at least 80 percent of truck, bus and heavier tires were operated with inner tubes because of the severe service. Heavy duty tubeless tires are made but the current consensus in the industry is that they will not be a major factor by 1973, if ever.

Tread rubber and repair materials generate little if any waste as they are uncured materials and can usually be reworked. It is estimated that some 20 million pounds of raw material packaging paper must be disposed of and that is included in the tire and tire products total. Tire flaps and sundries generate practically no waste and in fact are a primary means of using up in-process scrap from other tire operations.

RUBBER FOOTWEAR

The rubber footwear industry can be conveniently divided into two parts, following the S.I.C. categories.

30210-11,-13,-15 Canvas Footwear

All footwear made of canvas and rubber including high- and low-cut leisure, sports, and professional. They have textile fabric uppers with rubber soles, heels, and trim.

30210-21,-31,-41,-51 Waterproof Footwear

All protective footwear made largely of rubber, combined with fabric, leather, metal, and other materials. It includes boots and waders, laced boots, buckled and zippered arctics and gaiters of both utility and style grades, and light and heavy pull-on shoe covers.

This report excludes all consideration of the above types of footwear which are made of plastic materials in place of rubber, but which are sometimes made in the same plant. Separate rubber soles and heels or cured rubber slabs from which they may be cut are excluded here as they are classified under mechanical goods as described later.

In 1968 the canvas and waterproof footwear industry produced 500 million pounds of finished product, or 190 million pairs of canvas footwear and 30 million pairs of waterproof footwear.

The coverage of this study's interviews was as follows:

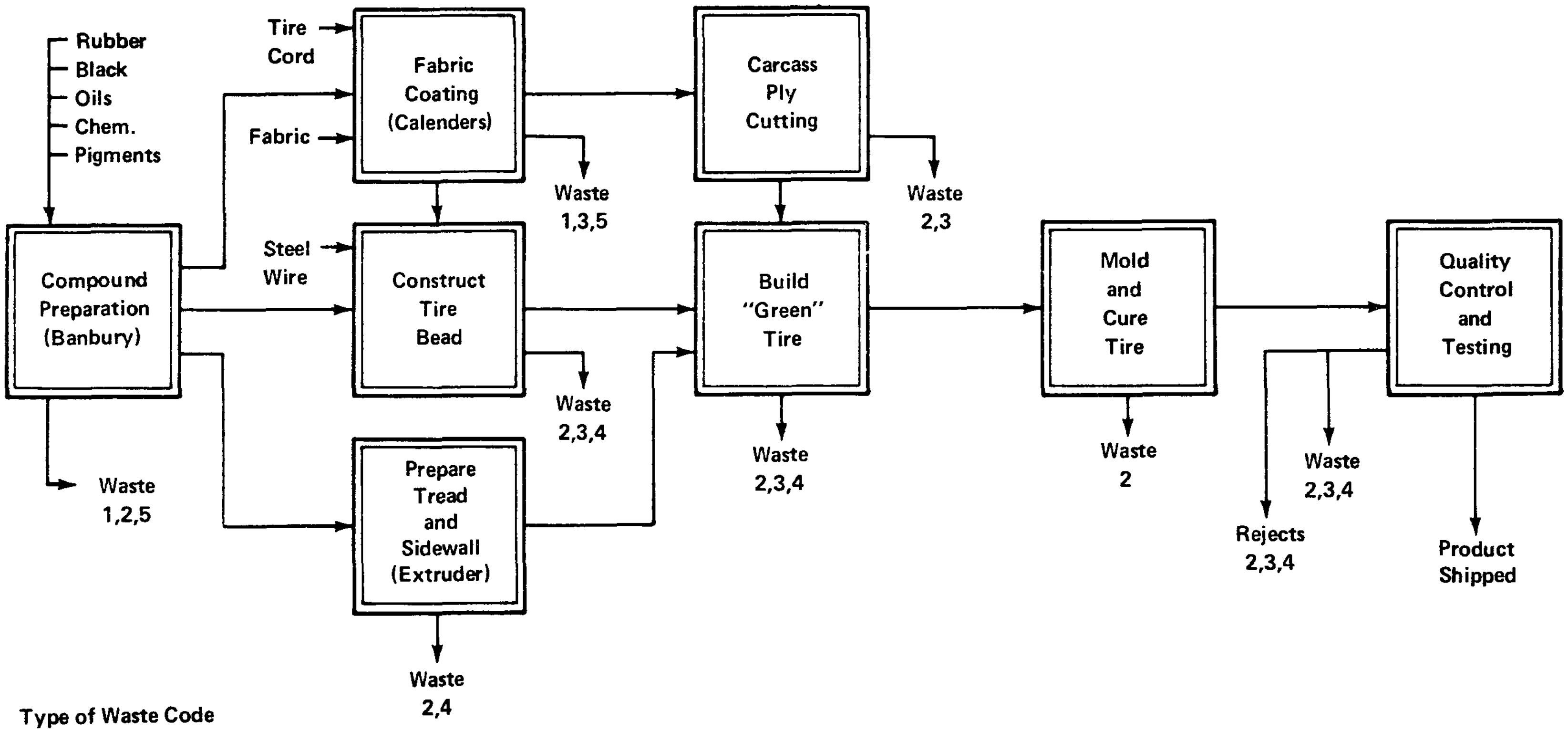
	MAJOR	
	Corp.	**Plants**
Industry	8	12
This Study	4	7

	MINOR	
	Corp.	**Plants**
Industry	38	more than 40
This Study	0	0

	Percent coverage of industry, this report
Industry	
This Study	40

The amount of solid waste generated is shown below. It was not possible to make a distinction between that of the canvas and of the waterproof type as they are made in the same plants.

Type of solid waste	Pounds of waste per million pounds of product shipped
Paper, cardboard and wood	17,000
Rubber compound	90,000
Textile material	66,000
Metal	1,000
Other	35,000
Total Waste	209,000



Type of Waste Code
1–Paper, Cardboard
2–Rubber Compound
3–Textile Materials
4–Metal
5–Other

FIGURE I-4 SCHEMATIC DIAGRAM OF TIRE MANUFACTURING PROCESS

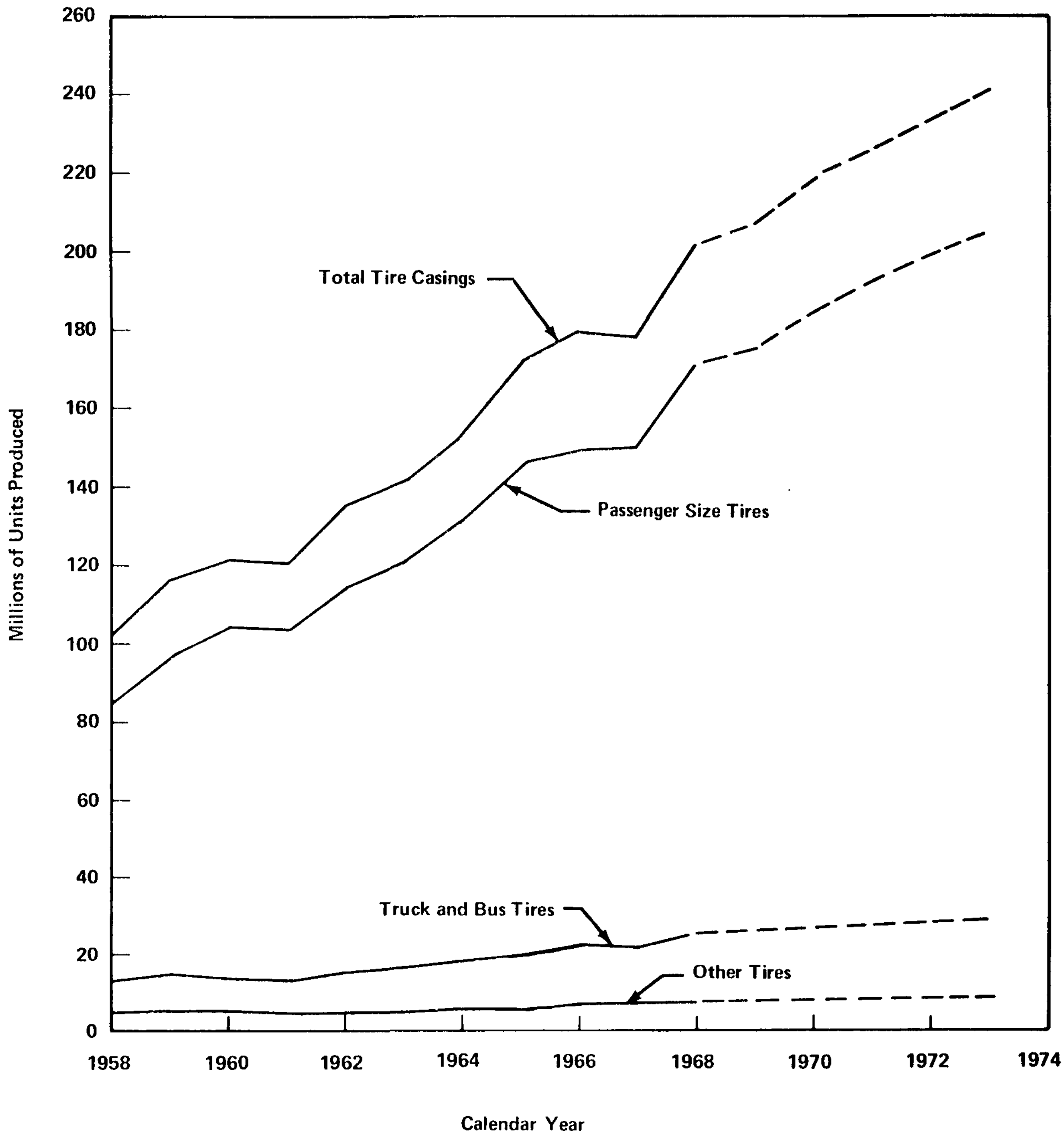


FIGURE I-5 NUMBER OF AUTOMOTIVE TIRES PRODUCED

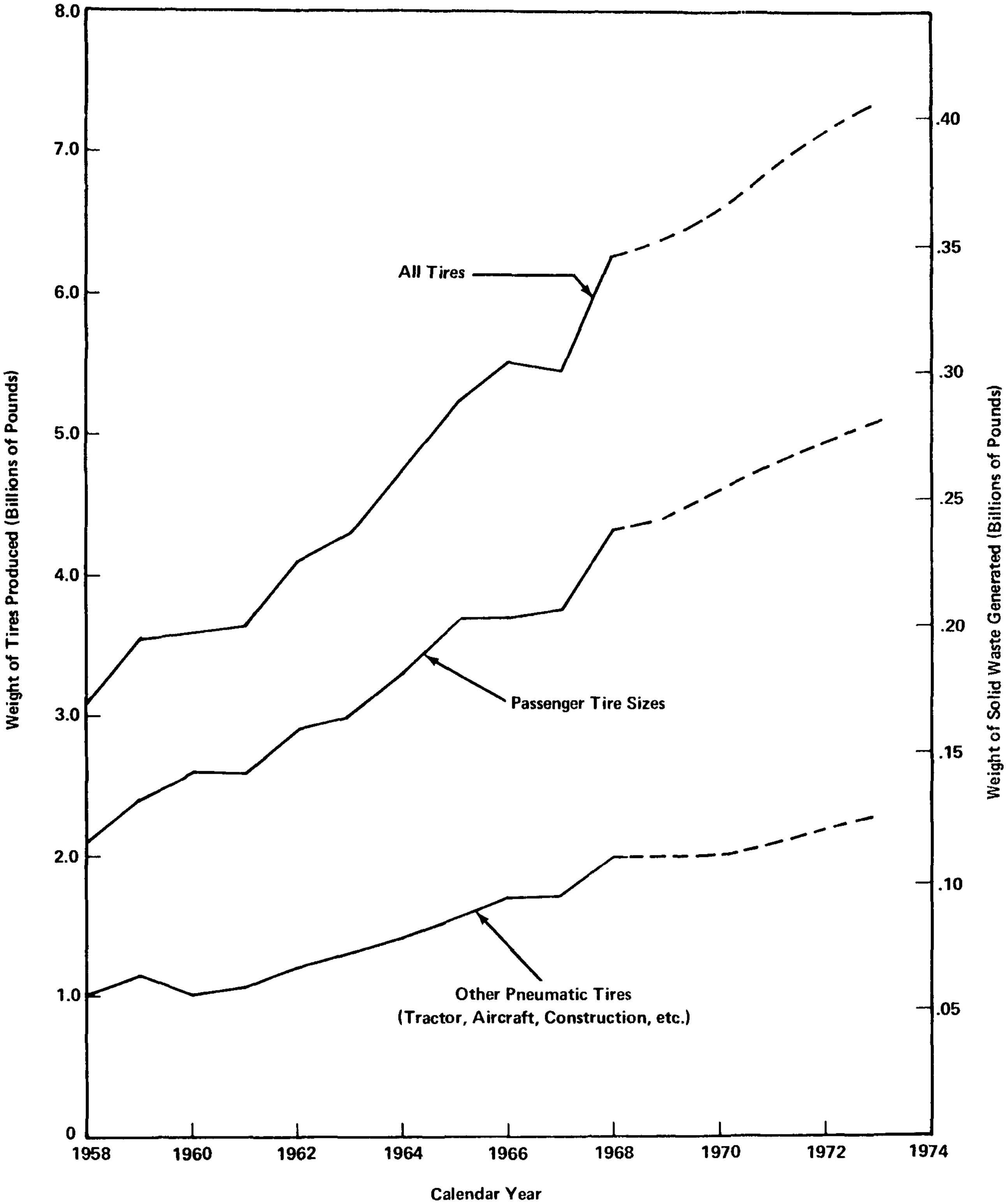


FIGURE I-6 PRODUCT WEIGHT OF TIRES PRODUCED AND SOLID WASTE GENERATED IN THEIR PRODUCTION

The paper waste is comparable to that for tires but little of the raw materials can be received in bulk because of the danger of soiling the product with loose dust. Metal waste is small because few small metal parts are now used, mostly of the zipper type. The rubber compound and textile material scrap is high because the industry produces small units by hand–assembled in a multitude of sizes and styles. Both before and after combining with rubber, a great variety of small pieces must be cut from sheet goods leaving unavoidable waste trimmings. In the compression molding process now common an excess of rubber compound is used which appears as molding waste. Sponge innersoles contribute considerable scrap because of the odd shapes and sizes to which they must be cut. The trend to injection molding in place of compression molding for attaching soles to uppers will reduce the molding waste as the rubber compound quantity can be more accurately fixed.

Some of the rubber and textile waste is ground up and used in hidden parts of footwear. The remainder has no value on the market and must be discarded.

The waterproof footwear industry has declined sharply and the canvas footwear industry has begun to decline slightly because of the competition of imports. Because of the hand work involved lower labor costs off-shore make lower prices possible. The quality is said to be lower but perfectly adequate for the American consumer who is more style conscious than ten years ago and less concerned with durability. Imports account for 10 to 15 percent of the canvas footwear domestic market and 20 to 25 percent of the waterproof market, or a total of about 72 million pounds of imported product.

In Figure I-7 is given a schematic outline of rubber footwear manufacture with the sources of the various kinds of waste. Most production rejects are repaired and sold as seconds and thirds. Rejects that must be scrapped are reported to be less than 0.1 percent of production including those destroyed in testing. Figure I-8 illustrates the history and probable future of the domestic industry in millions of pairs produced. Figure I-9 does the same for product weight and the estimated solid waste generated in operations.

BELTS

The belts and belting portion of the fabricated rubber products industry is comprised in the S.I.C. classification 30691. This includes flat belting for conveying materials and for power transmission, V-belts for automotive, appliance and industrial power use, and a wide variety of belts for toys, business machines, instruments and other devices. They vary in size from complete belts weighing as little as two ounces up to mining conveyor belts weighing up to 12 pounds per linear foot. Belts are generally built of heavy textile fabrics or cord combined with cured rubber compounds but they may include metal wire or cables. This study covered what is estimated to be 85 percent of the production of the belting industry as follows:

MAJOR

	Corp.	Plants
Industry	7	14
This Survey	6	9

MINOR

	Corp.	Plants
Industry	47	47
This survey	3	3

The solid waste generated per million pounds of belt produced is as follows:

Type of waste	Pounds per million pounds of Products
Paper, cardboard and wood	27,300
Rubber compound	41,000
Textile material	25,200
Metal	2,300
Other	30,200
Total Waste	126,000

Raw materials are almost all received in paper bags or cardboard containers. Rubber compound and textile waste is higher than for tires because less standardization and automation is possible, but is much less than for footwear because design is simpler and there is less variety. This waste is largely cured and uncured trimmings and very little of it can be reused in the same plant. The metal scrap is ends and damaged material from those types of belts which use metal reinforcement. The other waste is spilled pigments and earth materials which get mingled in general floor sweepings.

Belts which have minor defects are repaired in the plant and sold as first quality product. Flat belts are made in semi-continuous lengths and major defects can be cut out and the remainder sold as short lengths of first quality material. Splicing of lengths is also possible as they are usually spliced on the job in any case.

A block diagram for belt processing is given in Figure I-10 and past and estimated future belt production by weight of product and estimated weight of solid waste generated is shown in Figure I-11. The belt industry is showing a steady growth supported as it is by the steady growth of the automotive and appliance industry and by the strong trend toward bulk movement of minerals, grain, chemicals, industrial products, and people.

HOSE

The rubber hose segment of the fabricated rubber products industry is comprised in S.I.C. 30692 and is made

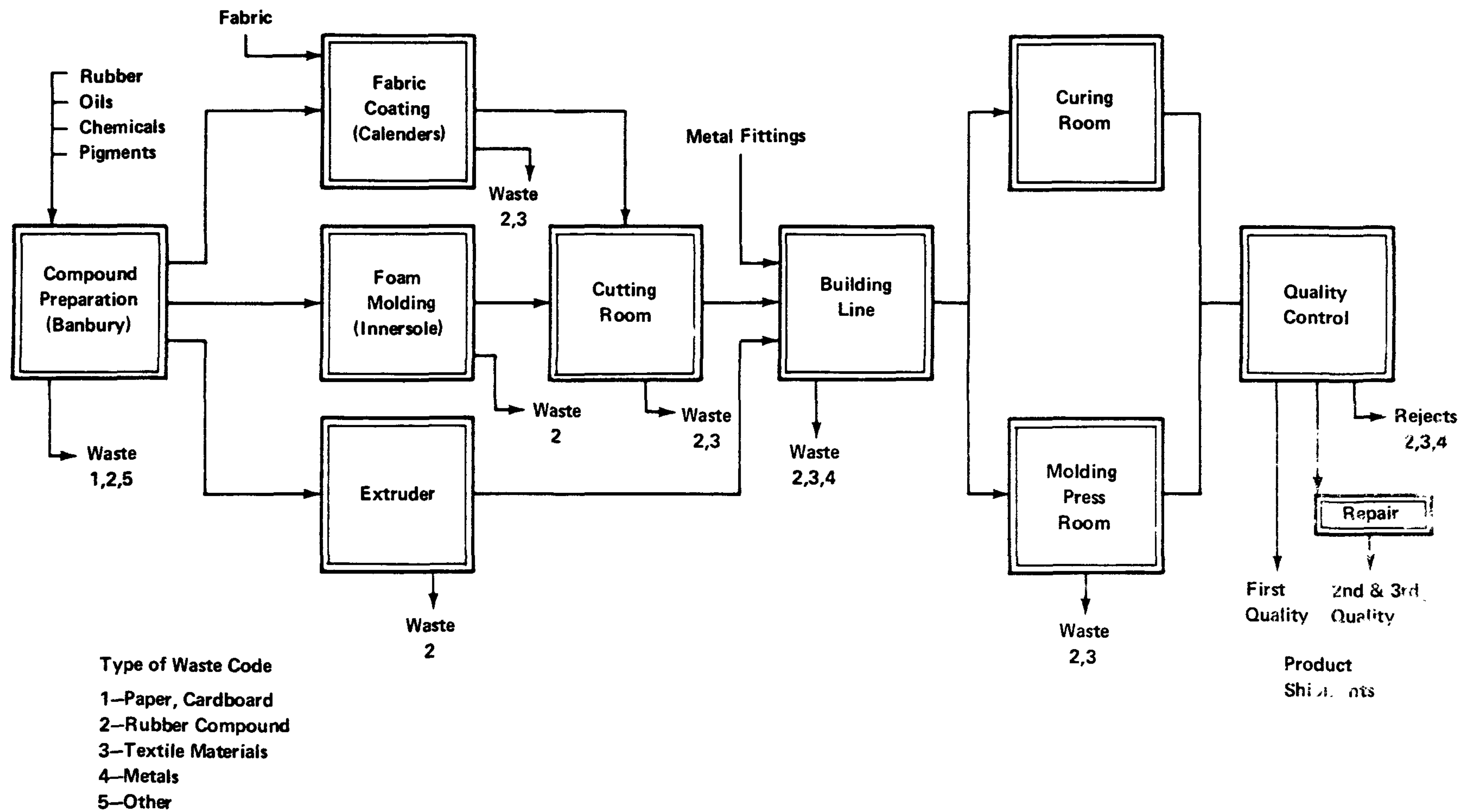


FIGURE I-7 SCHEMATIC DIAGRAM OF CANVAS AND WATERPROOF FOOTWEAR PROCESSES

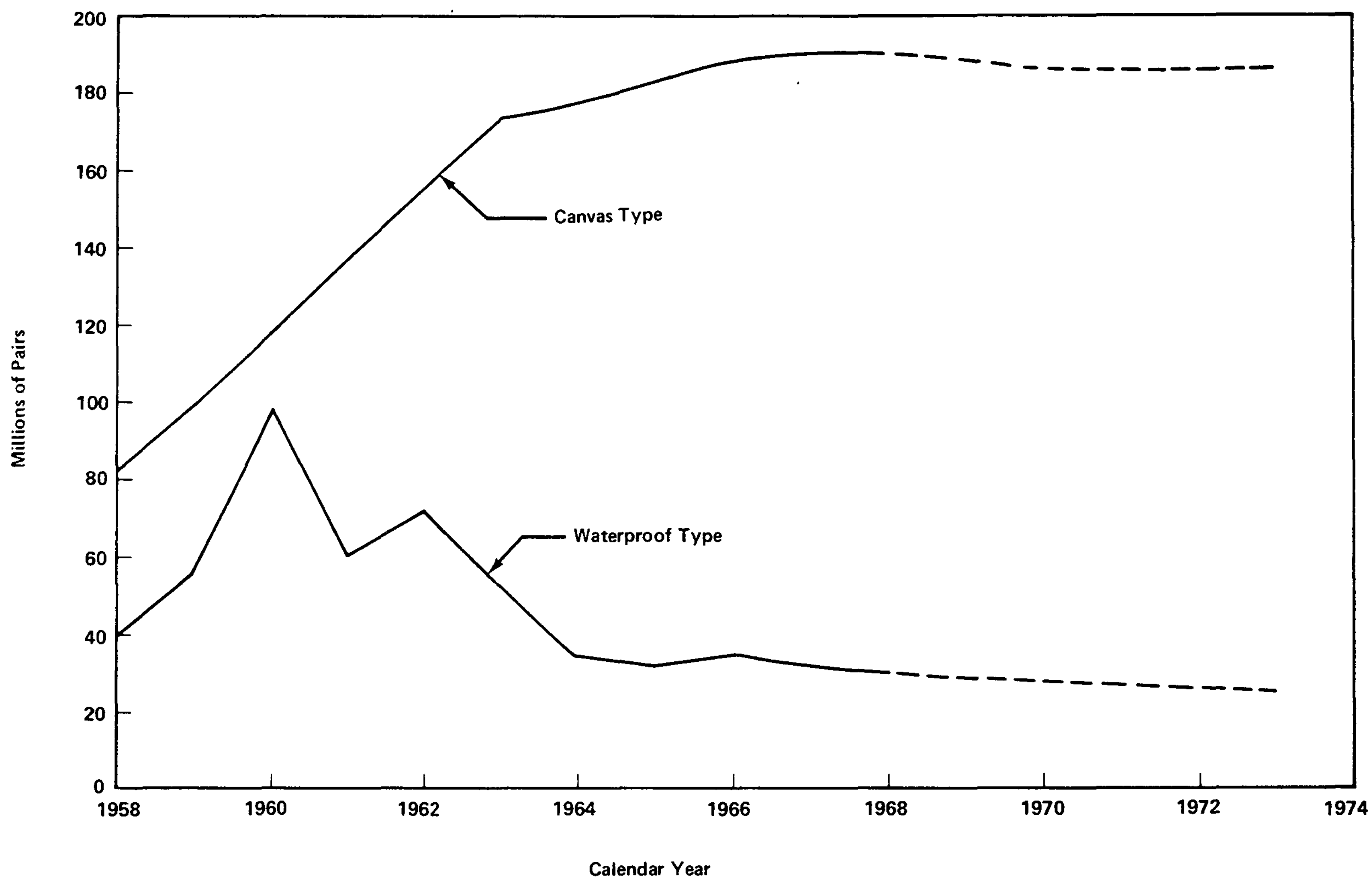


FIGURE I-8 PRODUCTION OF RUBBER FOOTWEAR BY NUMBER

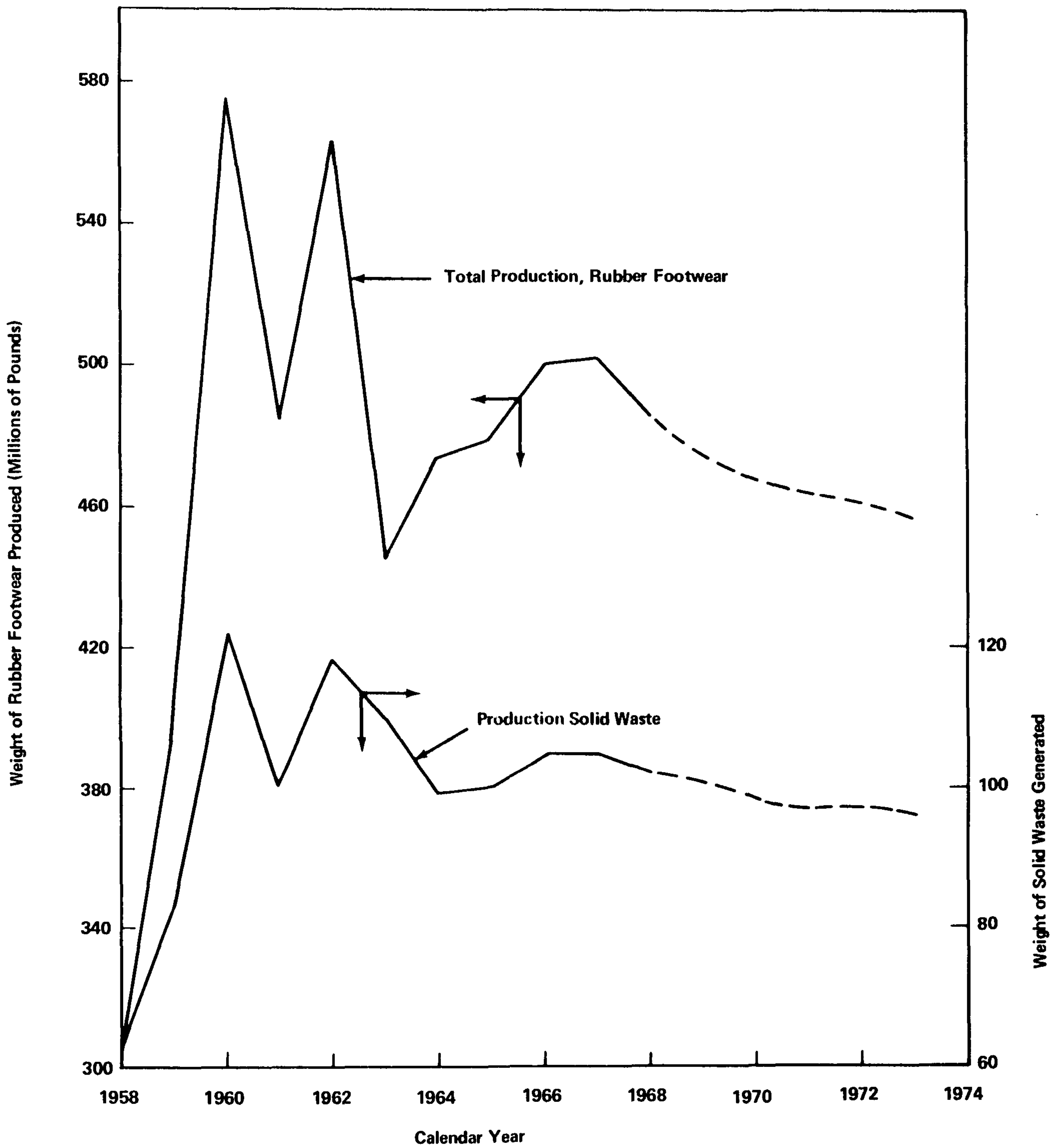
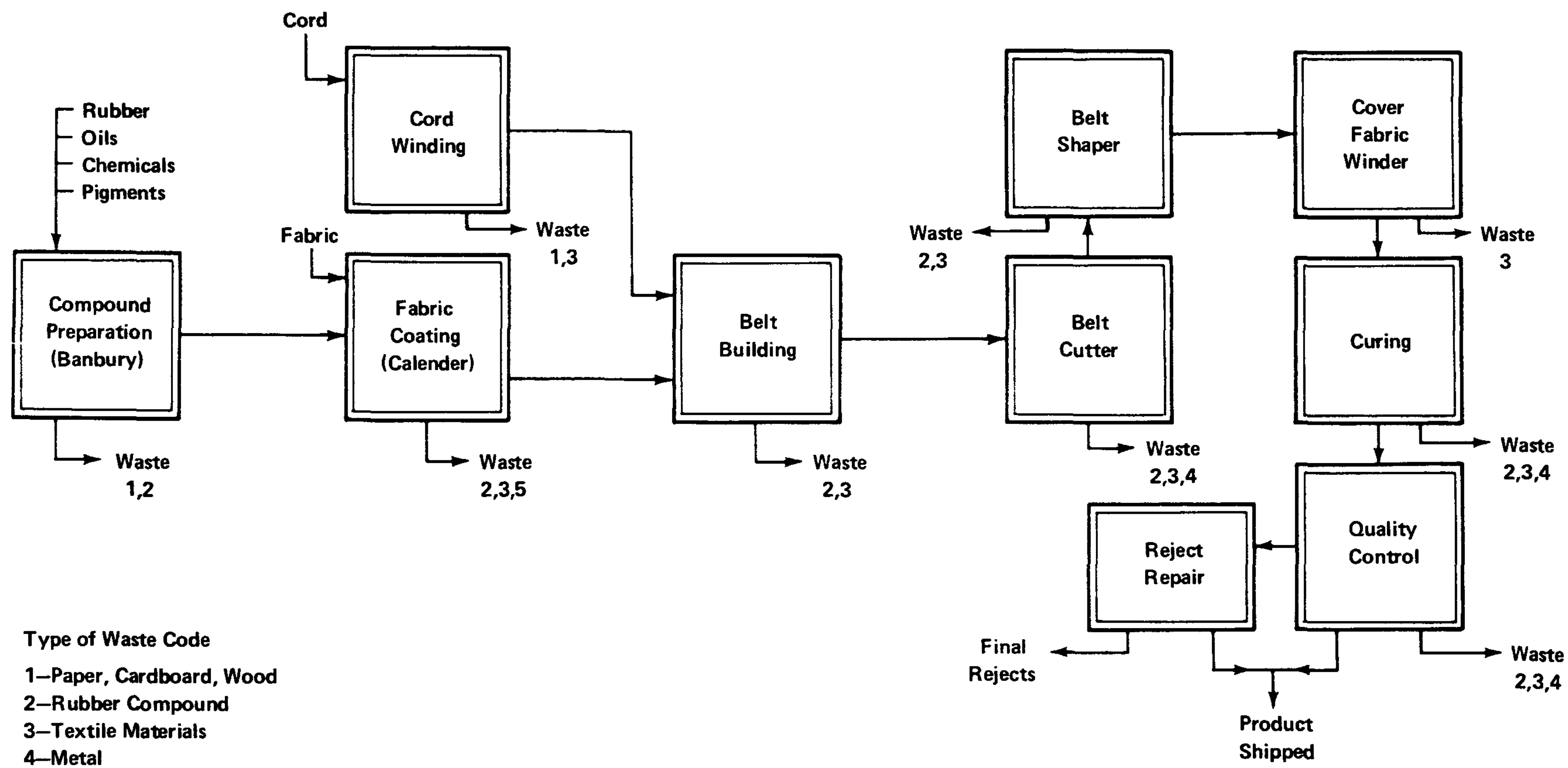


FIGURE I-9 RUBBER FOOTWEAR PRODUCTION BY WEIGHT OF PRODUCT AND SOLID WASTE GENERATED



Type of Waste Code

1—Paper, Cardboard, Wood
2—Rubber Compound
3—Textile Materials
4—Metal
5—Other

FIGURE I-10 SCHEMATIC DIAGRAM OF RUBBER BELTING PROCESSES

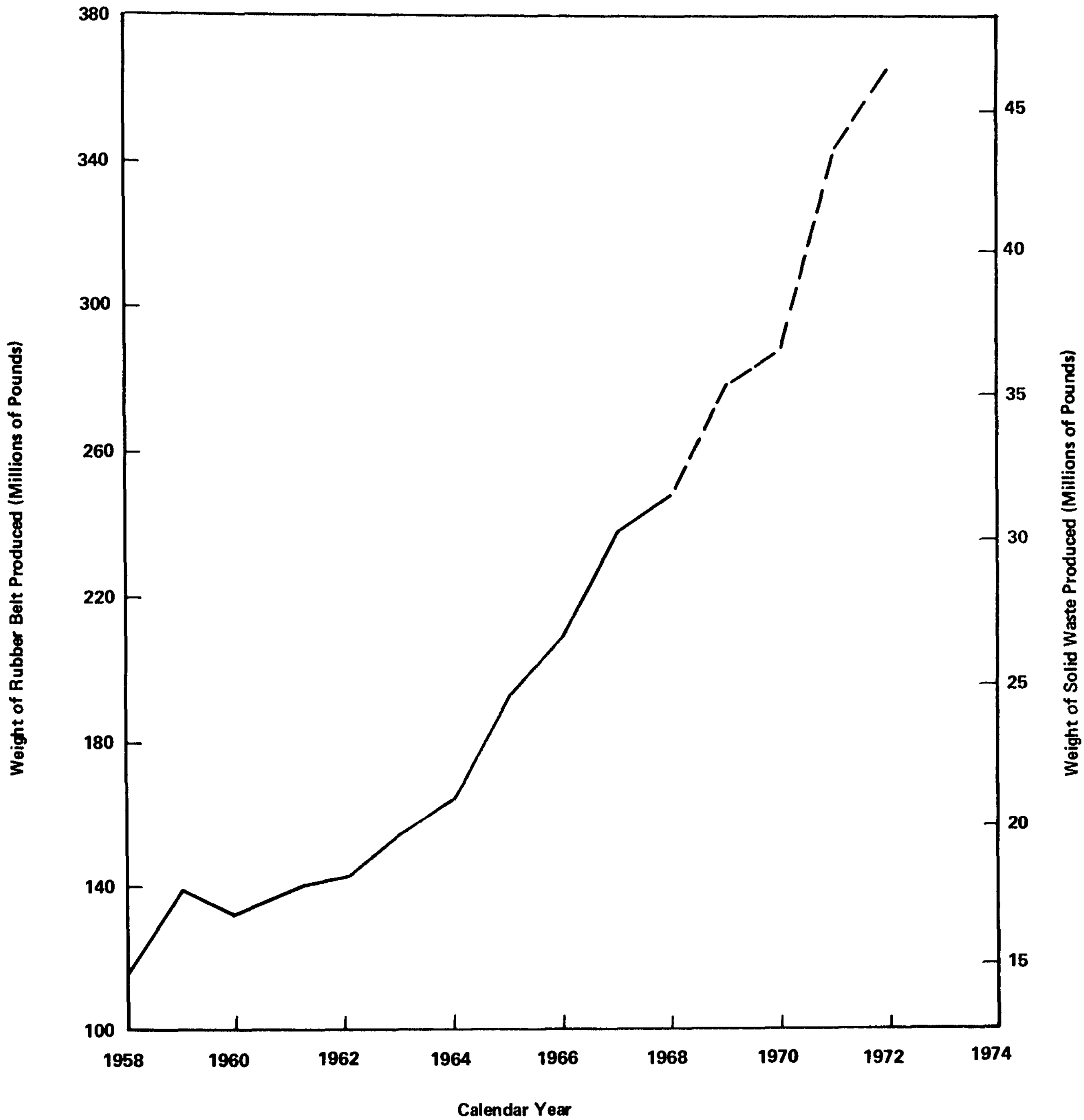


FIGURE I-11 RUBBER BELT PRODUCTION BY WEIGHT OF PRODUCT AND SOLID WEIGHT GENERATED up of all types of household, retail service, appliance, industrial and marine hose and tubings which are made in part of rubber, with the exception of small medical tubing. The types range from very small laboratory and instrument tubings to very large and massively reinforced hydraulic mining and dredging hose. Some types are solid rubber compound, some such as firehose are nearly all fabric with a minimum of rubber, and some are composites heavily armored or reinforced with metal wire. The metal couplings are attached in the factory except for lighter hose and tubings. The one thing in common is that they are intended to convey liquids and gases and are at least semi-flexible.

This survey is estimated to have covered 65 percent of the total production of rubber hose. There are a large number of small specialty manufacturers who could not be visited but their processes would be much the same as those reported. The table below will show the coverage.

MAJOR

	Corp.	Plants
Industry	10	20
This study	8	8

MINOR

	Corp.	Plants
Industry	115	more than 130
This study	5	5

Most of the major producers make a wide variety of hose types in a single plant and they were unable to provide data by type. The average solid waste generated per million pounds of hose produced is as follows:

Type of waste	Millions of pounds per million pounds of product
Paper, cardboard and wood	33,300
Rubber compound	54,700
Textile material	18,300
Metal	10,200
Other	49,300
Total waste	165,800

The paper scrap is largely from raw material packages but contains as well, non-returnable wire reel cores and textile yarn cores. Most of the reinforcing jackets are braided from textile yarns or wire and little or no woven or knit fabric is used. Most of the hose plants are old and not well adapted to automation, a large variety of sizes and styles are made in most plants, and the hose is built to rigid specifications. These factors all tend to make in-process spoilage a serious contributor to rubber compound and textile waste. Since the textile fabric is braided in place, there is little trimming and cutting waste as there is in the other parts of the rubber product industry. There is little possibility of salvaging the steel wire or steel jacket material but the non-ferrous materials in reject fittings are either renovated and re-used as such or sold as high value merchant scrap.

Because of rigid performance specifications and quality control standards rejects are high. In the past it was customary to cut rejects into "short ends" and sell them as substandard lengths for non-specification applications. Because of misuse of these products and severe manufacturer's liability rulings, it is no longer possible to dispose of most rejects in this fashion and they must be spoiled and become solid waste. The finished product rejects that must be scrapped run 8-12 percent of total production and their weight is included in the tabulation above.

Much hose is cured in a temporary lead sheath to permit the use of internal pressure. This lead is stripped in the process and re-used over and over until it is too contaminated to work well. The contaminated lead is sold at scrap metal prices for refining and re-use. Some lead oxides and dross probably get into other waste and is reported as such.

A schematic diagram of hose manufacture is given in Figure I-12 and the history and forecast shown in Figure I-13. The industry is thriving, thanks to growth in automotive and appliance demands–especially automotive air conditioning. The growth in marine shipments of petroleum and chemicals has required large amounts of large hose for product transfer.

SPONGE AND FOAM RUBBER PRODUCTS

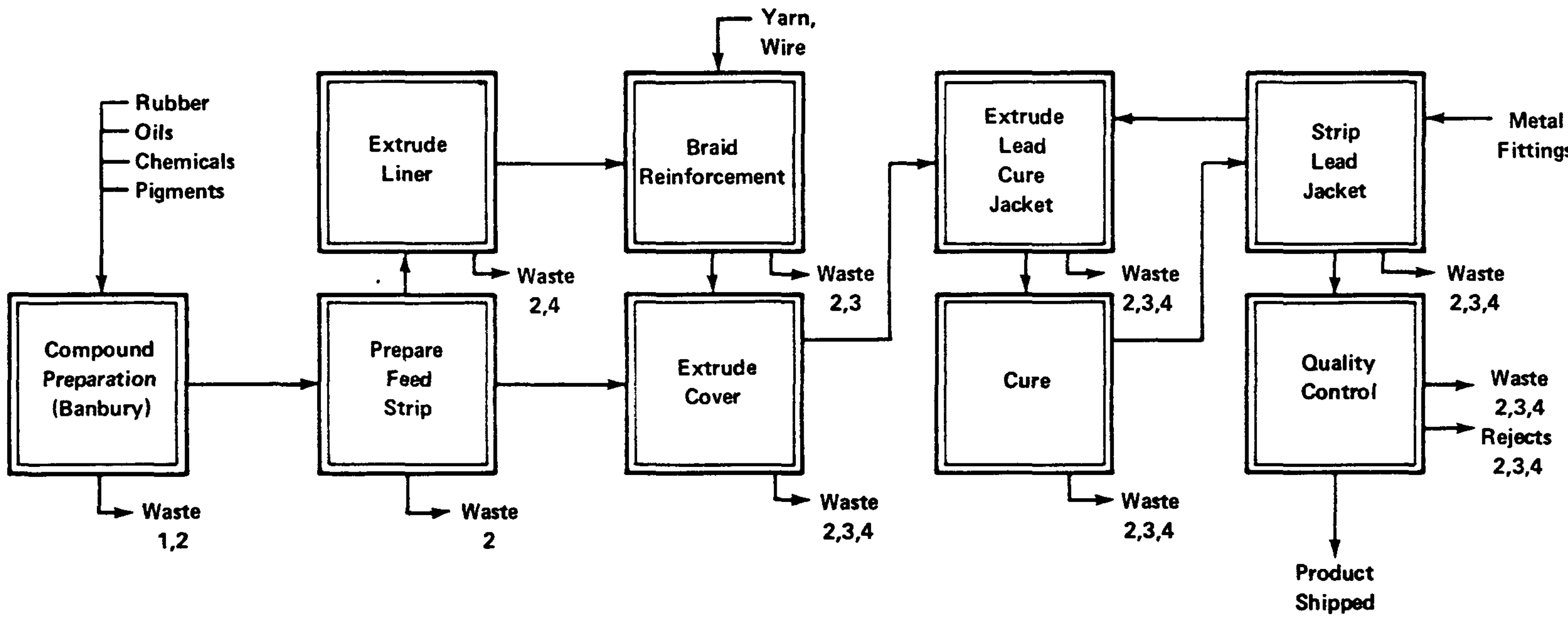
Sponge and foam rubber products are included in S.I.C. category 30693. This includes all the foam products which are made from rubber latex, which is a suspension of natural or synthetic rubber in water, such as cushioning, mattresses, pillows, and carpet underlays. The sponge products which are also included are made of solid rubber which has been expanded by chemical blowing agents and includes various insulation items, flotation items, seals for windows and doors, and carpet padding. The products are essentially rubber compounds as they rarely contain textile materials or metal inserts. Although the range of products is wide, the operating procedures are very similar for all plants. There are a large number of small specialty plants which could not be covered in this survey. It is estimated that something less than 25 percent of the total industry production was included and the extent of the interviews is as follows:

MAJOR

	Corp.	Plants
Industry		more than 125
This study	2	3

MINOR

	Corp.	Plants
Industry		more than 150
This study	4	4



Type of Waste Code

1–Paper, cardboard, wood
2–Rubber compound
3–Textile material
4–Metal
5–Other

FIGURE I-12 SCHEMATIC DIAGRAM OF RUBBER HOSE PROCESSES

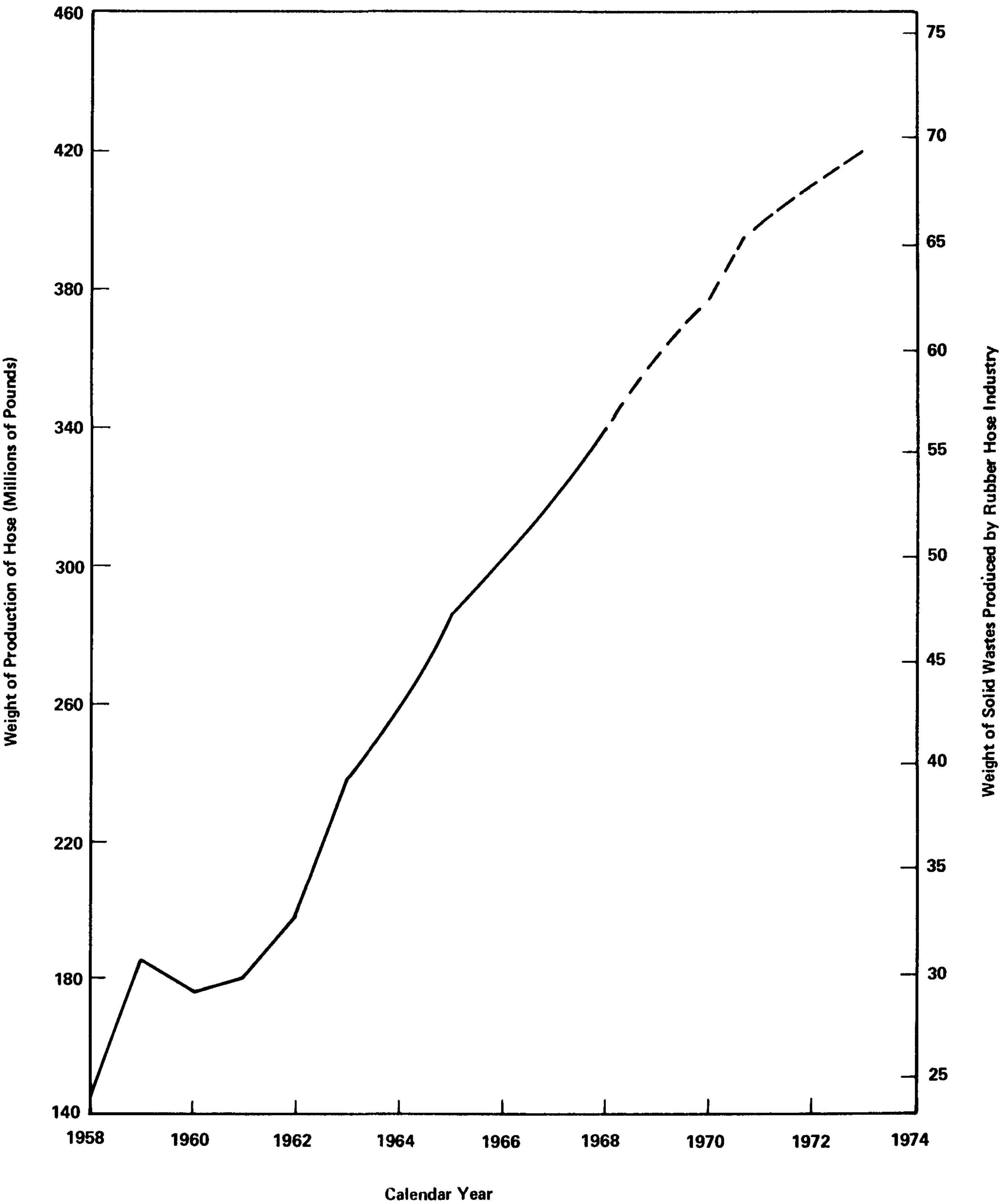


FIGURE I-13 RUBBER HOSE PRODUCTION BY WEIGHT AND SOLID WASTE GENERATED

The solid waste generated per million pounds of product are as follows:

Type of waste	Pounds of waste per million pounds product
Paper, cardboard and wood	16,000
Rubber compound	90,000
Textile material	200
Metal	Negligible
Other	27,000
Total waste	133,200

Since a large part of the raw materials used are received as either bulk liquids (latices) or bulk powders (mineral fillers) the paper waste from raw material receiving is low. The other category includes liquid spillage which promptly dries to useless solid rubber. This is included in "other" with floor sweepings and other incidental waste. The rubber compound waste, which amounts to two-thirds of the total, is imposed by the process and the variety of products made. Foam is molded either in slabs for further division or in complete units such as mattresses, pillows, or chair cushions. In either case the open molds must be over-filled and the excess trimmed away. The slab stock is used as blanks from which a multitude of shapes and sizes are cut on order. This custom sizing makes a large amount of three-dimensional trimmings which do not find a ready market. Because of the low density of foam and sponge, this material is very bulky and expensive to store; if finely ground it can be a serious fire hazard. The ground material cannot be reworked successfully and finds only a limited market as reprocessing scrap. Attempts have been made to bond this foam scrap with more latex to make secondary padding for furniture but it has not been commercially feasible.

Figure I-14 shows the fairly modest growth of sponge and foam products through the years. Growth would have been much greater except for the inroads of urethane foams which have many of the same values but are not included in the rubber products industry.

MECHANICAL GOODS

This segment of the fabricated rubber products industry includes the following S.I.C. categories:

30695 Mechanical rubber goods
30696 Rubber heels and soles
30697 Drug and medical sundries
30698 Other rubber goods

It excludes those groups already described.

Mechanical rubber goods includes tens of thousands of molded and extruded items used by industry and as components of consumer hard goods. It includes such things as seals, rolls, inflatable goods, battery cases, fuel cells for aircraft, dock bumpers, and many others. Rubber heels and soles includes these items and the slab stock from which they may be cut for use by the shoe industry and the shoe-repair services. It is not a part of the rubber footwear industry. Drug and medical sundries are such things as hot water bottles, douches, medical tubings, and prosthetics. Other rubber goods is a large conglomerate of items which defy classification such as coated fabrics, rubber thread, balloons, and custom compounded rubber for others.

There are well over one thousand plants producing these materials to some degree but most of them are small specialists. It is estimated that 35 percent of the production was surveyed for this report as shown below.

MAJOR

	Corp.	Plants
Industry	**13**	**40**
This survey	**10**	**15**

MINOR

	Corp.	Plants
Industry	**1,000**	**more than 1,000**
This survey	**18**	**18**

The solid waste generated by this segment of the industry per million pounds of product is as follows:

Type of Waste	Pounds per million pounds of product
Paper, cardboard and wood	43,700
Rubber compound	93,800
Textile material	28,500
Metal	14,200
Other	68,000
Total waste	248,200

It is impossible to give a representative process description because of the great number of ways of making this conglomerate of items. They usually involve short runs of handbuilt items of considerable complexity. Most of the items are basically rubber compound with fabric and metal inserts and reinforcement. The ratio of waste is the highest for any segment of the rubber products industry for the above reasons and all categories of waste are high. Only in the case of soles and heels can trimmings and rejects be ground and reused in the operation and regrind is said to be 50 percent of the rubber compound waste. The large number of small plants makes it especially difficult to collect and classify the solid wastes generated other than by casual methods.

Figure I-15 illustrates the growth of the industry and of the solid waste generated. The growth is not spectacular as it will have only doubled in quantity in 15 years.

WIRE AND CABLE

The wire and cable industry, which is traditionally considered part of the fabricated rubber products, is

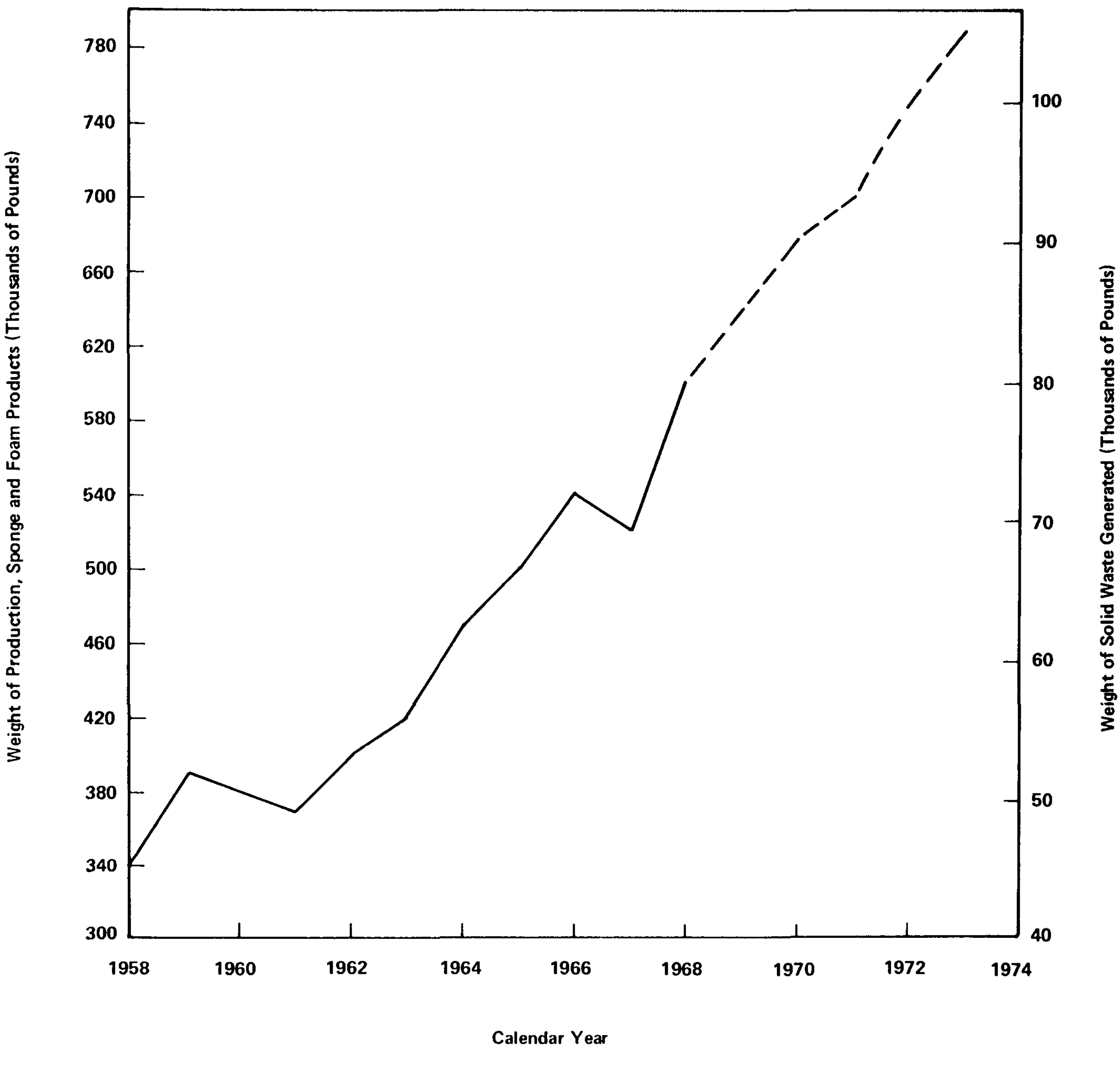


FIGURE I-14 RUBBER SPONGE AND FOAM PRODUCTION
BY WEIGHT AND SOLID WASTE GENERATED

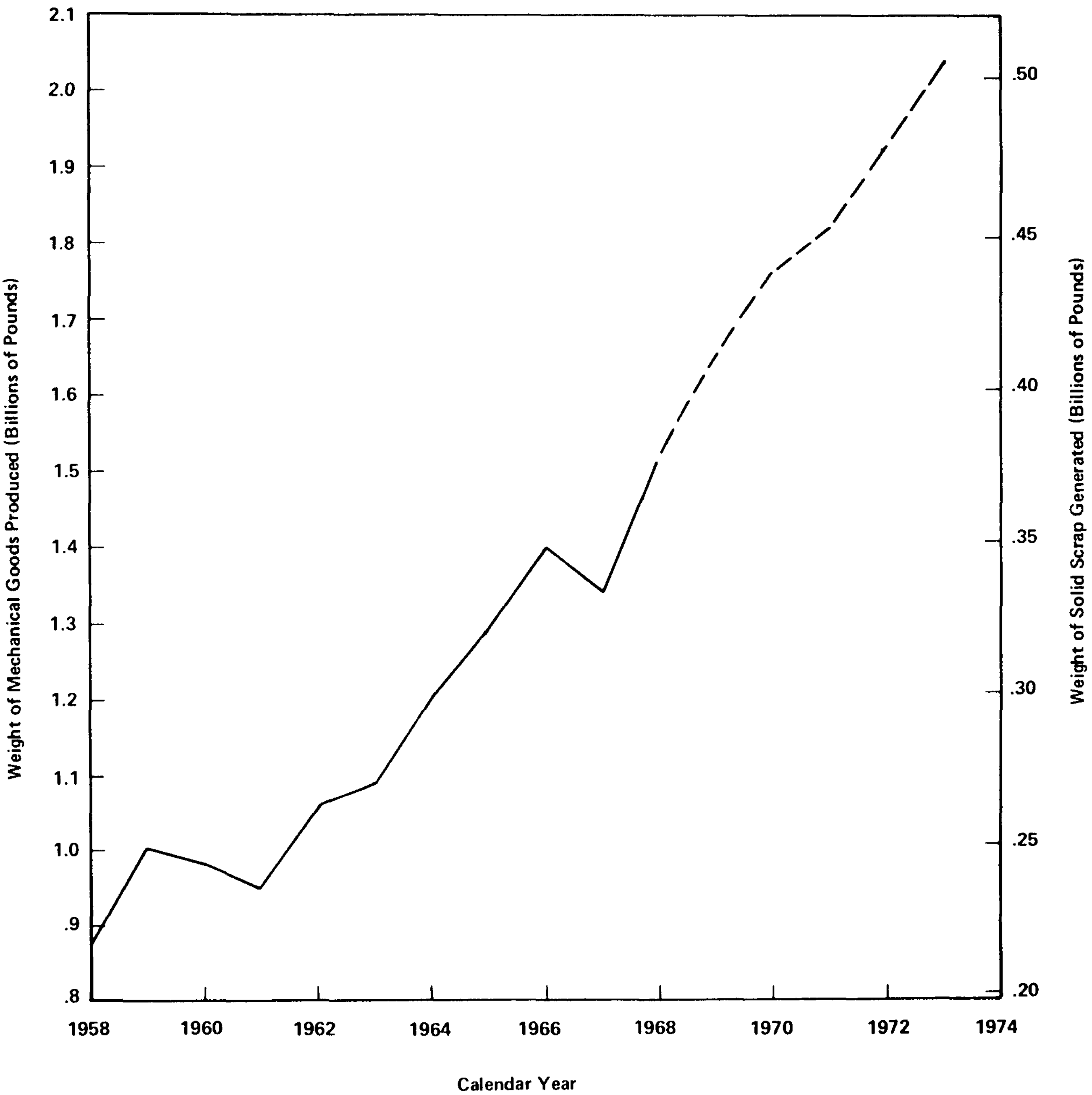


FIGURE I-15 MECHANICAL RUBBER GOODS PRODUCED BY WEIGHT AND SOLID WASTES GENERATED described as S.I.C. 3357, Insulating of Nonferrous Wire. At one time all such power, communication, and other electrical service wires and cable were insulated and jacketed with rubber or rubber-like materials by conventional rubber processes. The rubber component was never very large in value or volume compared to the nonferrous metal used in the industry, but at one time it made up a sizable part of the rubber consumed. In the period covered by this report, the rubber usage is low, varying from three percent to one percent of total rubber consumption, because of its large replacement by plastics in many kinds of wire. The industry does pose a rather unusual disposal problem.

The industry was reluctant to give information for this survey so that not more than 10 percent of the total production is covered, but it is believed it is representative of the whole industry. The coverage was as follows:

	MAJOR	
	Corp.	**Plants**
Industry	7	10
This survey	2	2
	MINOR	
	Corp.	**Plants**
Industry	49	over 65
This survey	1	1

Some .175 million pounds of rubber compounds are mixed in these operations much as in tire plants and applied to the wire and cable in various ways, but usually by simple extrusion. The finished product is of high value and made to exacting standards on a continuous basis. Rejects develop locally in testing and these lengths are cut out. Rejects are stripped of rubber compound, which is discarded and the core rerun. If the core is damaged the rubber compound is burned off and the nonferrous core sold in the scrap metal market. The solid wastes generated in 1968 are estimated below as pounds per million pounds of compound.

Type of Waste	Pounds per million pounds of rubber compound
Paper, cardboard and wood	11,000
Rubber compound	20,000
Textile material	1,000
Other	2,800
Total waste	34,800

These numbers refer only to the rubber compound used and not to the total weight of the industry product. No metal waste is given as this is a concern of the wire industry proper. The paper waste is that from the rubber compound raw materials. The rubber compound is that which is stripped or burned off of rejects. The textile waste is the small amount stripped or burned with the rubber component.

Future consumption of rubber compound by the wire and cable industry should remain where it was in 1968, or decline slowly.

COSTS OF SOLID WASTE DISPOSAL

The unit disposal costs of the solid wastes generated by the fabricated rubber products industry are not related to the product being made or the type of waste as they are invariably mingled. Table I-4 lists in-plant and external disposal costs for twenty-one different plant sites. None are in the same metropolitan area. Specific cities were not named as it would be easy to relate to the companies surveyed. Costs marked with an asterisk are for companies falling within the 219 standard metropolitan areas.

Generally speaking, the costs in metropolitan areas are higher than in the more rural areas of the country with the exception of a few companies who own their own land fill site rather than rent one.

In-plant collection costs include all direct labor, supervision, and overhead for collecting waste from operator's receptacles and delivery to a common pickup point.

Out-plant haulage covers the contractor's price for carriage and dump fees. The contractor sometimes owned the dump, but generally paid the private or municipal fee as part of his price. This cost varies widely with local labor costs, availability of dumps, and distance to available dumps.

It was impossible to obtain any more detailed information as plant accounting systems only provide total weight of waste dumped, total in-plant costs charged to this function, and periodic billings by outside contractors.

COSTS OF COLLECTING AND DISPOSAL OF SOLID WASTES AT INDIVIDUAL PLANT SITES

Plant Site	In-Plant Collection Cost/Ton	Carting & Dumping Cost/Ton	Total Cost/Ton
1	$10	$19	$29*
2	10	6	16*
3	13	8	21
4	20	10	30*
5	10	5	15*
6	13	12	25*
7	7	8	15
8	20	20	40
9	26	13	39*
10	18	4	22
11	27	13	40*
12	15	6	21
13	17	11	28*
14	12	8	20
15	4	13	17
16	25	20	45*
17	25	12	37*
18	NA	NA	13
19	NA	NA	12
20	NA	NA	10
21	NA	NA	3

RECOMMENDATIONS

The following refers specifically to the problem of disposing of the solid wastes generated by the fabricated rubber products industry. The general problem of comprehensive consumer rubber waste disposal is discussed in Part II.

A primary interest of the rubber industry is to reduce the quantity of waste generated. When it is noted that the direct process waste (rubber compound, fabric, metal) amounts to from 3% for tires to 25% for mechanical goods based on weight of finished products, this represents a large cost in raw materials and labor already put into semifinished goods from which there is no possibility of return. In fact, it increases the cost to get rid of them. Through this study no material has been considered waste if it is sold for any value whatever and no manufacturer's value is included in the cost of disposal. The costs of all waste produced and the costs of its disposal are a charge against the product which is successfully produced and marketed. There is no better incentive for minimizing waste than profit pressure.

Management is always aware of the importance of waste disposal as a national problem, but after their best efforts to reduce the volume of their own wastage they feel they have neither time, talent, nor resources to devote to the problem. They do not consider present solid waste disposal means as acceptable, so they simply turn over their solid wastes to a contractor at a price.

The greatest need is for an economical incineration system which will perform within firm long-range and reasonable anti-pollution standards. Only a limited number of rubber products facilities would be large enough to maintain their own incinerator, but in some locations groups of these and related industries could maintain one. For isolated manufacturers, cooperation with municipal operations will be in order. The two important requirements are:

1. Early establishment of practical firm long-term standards for performance of incinerators in respect to pollution control.

2. Support and encouragement of research and design development on proper incinerators especially for operation on solid rubber wastes or a large proportion of rubber. If such incinerators could be further developed to produce process steam, they would be even more attractive as rubber fabricators are large users of low pressure steam and this might offer some return on costs.

APPENDIX A: STUDY METHODS

The first step in conducting this survey was to organize a plan and make a selection of available sources of information with the assistance and advice of experienced research, development and sales personnel of UNIROYAL, INC. and others. Preliminary discussions were conducted with production people of a few UNIROYAL fabricating plants.

The questionnaire included in this appendix was then made up in draft guided by the stated scope of the contract and the realistic situation found in the few operations investigated on a preliminary basis. This draft was then revised after consultation with the project officer and other personnel of the Bureau of Solid Waste Management. The final form included here was then submitted for official approval for use.

While awaiting this approval, all of the available economic information on the entire fabricated rubber products industry was collected and the pertinent details arranged for this report. This includes the sections on rubber consumption, product made, and value of product. This includes past history, the situation in 1968, and a preliminary estimate of the near future. At the same time trade lists of the industry were used to plan a proper cross-section of the industry by size, location, and kind of facility. This plan was made more exhaustive than it would be possible to cover because it was anticipated that some interviews would be refused for one reason or another.

When the questionnaire had been officially approved for use, telephone calls were made to fabricating companies in such a way as to concentrate travel plans with the greatest economy. The initial telephone call in each case was made to the chief officer in charge of production; usually the vice-president for production or his equivalent in smaller companies. There were some refusals for various reasons and in some cases there was referral to some other person who was delegated to handle the matter. In all, in cases where an interview was scheduled, it was done with the knowledge and approval of senior management.

When an interview was scheduled, a copy of the questionnaire was sent to the person to be interviewed for his review and so he could assemble the information necessary.

In no case was the completed questionnaire accepted by mail or by telephone questions. The data for every production facility included was collected by personal interview either at that location or at a central location where data on several facilities was available. In most cases company records or abstracts of these were freely made available to the interviewer and the more generalized information supplied. It was found in practice that the questionnaire was too elaborate for all situations, as some individual questions could not be answered by all individual plants. Also, because of the variations in records from plant to plant, it required some ingenuity to calculate them to a common basis. It was interesting that some forms of information were considered too confidential to disclose at some facilities, but were supplied freely at other facilities.

When most of the planned interviewing was completed, the plan was reviewed for completeness and some additional interviews were arranged to make the survey as balanced as possible by size, kind, and geographical location of the plants surveyed.

When interviewing was well along, collating of the information was started, and when interviewing was finished, all the information was assembled as in the body of this report and cross-checked with the industry economic summary previously made. There was some need to make follow up telephone calls to the people interviewed to clear up questions that only arose after assembly of the information.

It had been hoped to transfer the data gathered on punch cards or some other data processing form so it could be given to the Bureau of Solid Waste Management without identification of the facility involved so that they could use it for further studies without any breach of confidence. Because of the variation in record keeping and the lack of consensus as to what could be disclosed, it was found impossible to design any useful data processing system for further studies.

APPENDIX B: GLOSSARY

Aircraft tires
Specially engineered pneumatic tires for aircraft designed for massive impact loading and minimum total weight.

Air-effect vehicles
Vehicles designed to travel over land or water on a cushion of air rather than on rubber tire wheels

Automotive
Properly any self-propelled vehicle but usually restricted to passenger cars, trucks, buses, and towed trailers.

Banbury
A high powered mixing machine of special design commonly used for blending and mixing rubber compounds.

Bead
The inelastic flanges of a pneumatic tire which firmly seat on the rim flange and securely retain the tire on the wheel when the tire is inflated.

Bead Wire
A high strength carbon steel wire which is precisely coiled to form the core of the bead.

Carcass
Applied to the rubber and fabric body of the tire exclusive of the all-rubber tread and sidewalls

Casing
Restricted to an unmounted pneumatic tire, in contrast to tire which is the general term for the periphery of any wheel.

Chemicals
In rubber compounding the principal chemicals are various sorts of cure accelerators, antioxidants, antiozonants, and other organic chemicals used to protect rubber against degradation by service and environmental agents.

Cord
Tire cord is a specially engineered rope-like structure of high strength made of nylon, rayon, polyester, glass or other fibers

Consumer and industrial products
Consumer products are those which are distributed directly to the ultimate consumer such as footwear, medical supplies, replacement tires, or replacement parts for appliances. Industrial products are those sold to industry as operating supplies or as parts for new composites such as belts, hose, seals, and original equipment tires.

Cores
Are the wood, metal, paper or other sorts of cores on which cord, fabrics, wire and other raw materials are supplied to the fabricated rubber products industry. They are usually returnable and reusable, but if damaged in the rubber plant they are disposed of with the other solid wastes at that location.

Counter Stock
The stiff board-like material made of rubber, textile, and paper fiber and used as protection and stiffening of shoe toes, heels, and uppers. Since it is concealed, much plant scrap is used in its production.

Curing Bag
A tire-like structure of rubber compound and some fabric which is inserted inside an uncured tire when it is placed in the curing mold to provide pressure and internal heat. The curing bag is expendable after several hundred uses.

Cured Stock
Any rubber compound, with or without fabric, which has been subjected to heat and is no longer thermoplastic.

Damaged Stock
In-process material which has been made useless for its intended purpose by accidental semi-curing, by color change, by errors in preparation, by water or steam damage, or other processing accidents. Usually such materials can be blended off in small amounts with fresh material, but some cannot be utilized or sold to others for some value and becomes solid waste.

Dunnage
Wood, cardboard, or paper which is used to secure raw materials or equipment in rail cars or trucks. There is a strong trend to returnable dunnage, but there is still much that must be disposed of at the receiving point as solid waste.

Elastomer
An elastomer is a substance which is capable of being altered by curing to a condition in which if stretched to a limited degree at room temperature it will return to substantially its original dimensions in a short time when released. All of the so-called rubbers and a few other organic substances are elastomers.

Extrusion
A process by which a thermoplastic material is forced through a forming die to produce continuous lengths of pipe, tubes, and a variety of profiles. Extrusion is applied to uncured rubber, to many plastics, to metals, and many other thermoplastic materials.

Fabric
Fabric for the purposes of this report means any sheet goods made of natural or man-made textile fibers by weaving, knitting, braiding, or non-woven processes. It includes fabrics laid in place of tire cord.

Fabricator
For the purposes of this report a fabricator is any installation which receives raw materials or semi-processed goods from others and converts them into complex finished products for consumer or industrial sale.

Farm Tires
Includes all off-the-road tires which are used in agriculture ranging from those on garden tractors to those on massive specialized ploughing and harvesting rigs The heavily lugged tires used on standard size farm tractors account for the largest share of the total weight. Farm tires seldom wear out in the usual sense, but are destroyed by irreparable damage from stones or roots or environmental degradation.

Fittings
Those ferrous, non-ferrous, or plastic parts which are purchased from others and made an integral part of fabricated rubber products. Examples would be brass hose couplings, inner tube valves, metal or plastic zippers for footwear, shoe eyelets, and buckles for arctics.

Flaps
A tape used to protect casings and inner tubes from abrasion of damaged metal wheels.

Floor Sweepings
In this report floor sweepings are the miscellaneous collection swept up by factory and office janitors and consists of spilled raw materials, paper scrap, staples, nails, and earth materials from outside. There is no way of characterizing it except to include it in "other solid waste."

Foam
The cellular rubber product made from liquid rubber latex by whipping air into it, as distinguished from sponge (see below).

Inner Soles
The structural padding in the bottom of all types of footwear. It may be a cushion of sponge rubber or a rigid concealed sheet stock.

Inner Tube
The inflatable torus ring which is the air container in heavy duty tires and in some medium duty tires. They are nearly pure rubber compounds and almost always made of butyl rubber because of its resistance to air diffusion.

Inserts
A wide variety of metal or plastic shapes which are bonded to or contained within the finished rubber article. The threaded closure in the neck of a hot-water bottle is a good example.

Latex
A suspension of very small solid rubber particles in a water solution Natural rubber exudes from the tree in this form and most synthetic rubbers are produced in this form or easily converted to a latex. Latex is used in the manufacture of foam, dipped goods, carpet backings, and other coatings and adhesives. They are distinguished from cements which are solvent solutions.

Mineral Fillers
Fine ground mineral powders which are added to rubber compounds to improve properties, to increase density or decrease cost. Common ones are clays, whiting, magnesia, zinc oxide, asbestos, and lead compounds.

Molding
The process of forming rubber products with heat and pressure in precision formed molds. Various forms of molding are compression, transfer, injection, slush, rotational, and open mold. Compression molding is the traditional process for rubber products, but injection molding is becoming more common because of greater efficiency. Plastics are molded by very similar processes.

Molding Waste
The overflow from the molding process including that from the air release channels built into the mold. Mold waste is always cured so it cannot be conveniently re-mixed.

Natural Rubber
Rubber originating from natural sources, almost entirely the cultivated rubber tree of Southeast Asia, Indonesia, Ceylon, West Africa, and a few minor tropical sources. It is marketed as either solid rubber or the concentrated latex.

Pallets
Wood, paper, or plastic supports for piles of bags, bales, or rolls of raw material to facilitate semi-automatic handling. They may be either disposable or returnable. One-trip pallets or damaged returnable pallets become solid waste at the point of delivery.

Pigments
Are strictly speaking organic or inorganic powders used to color rubber products They include many mineral products such as titanium oxide or zinc oxide which make white products. The terms pigment and mineral filler are often used interchangeably.

Pneumatic Tires
Tires containing an enclosed air space and having an elastic and resilient body, the combination giving a smooth jolt-free motion to vehicle on rough road-beds.

Polymer
A high molecular weight material made up of similar repeated units of simple structure. All rubbers are polymers but the term includes most plastics and many biological materials.

Product Package
Most consumer items and many industrial products are marketed in some type of package for protection, identification, or customer appeal. The package may be a cardboard box, a paper jacket, paper wrapping, or a multitude of other types. Sometimes a group of boxed items are shipped together in an outer case. This material becomes solid waste at the point of ultimate consumption and its weight is omitted from any numbers in this report as it is obviously not a waste generated by the fabrication of rubber products.

Quality Control
This incorporates all physical, chemical, or service testing of raw materials, in-process material, and finished product to insure that products meet the desired or required test specification. It would include all research and development products where this work is associated with a producing facility. Much of the raw material and in-process material could be returned to process, but much would be subjected to curing for test purposes and this, together with spoiled finished product, would be disposed of as solid waste.

Reclaimed Rubber
The product of physical or chemical processes which convert scrap rubber products from any source into material which has a limited use as a raw material for the fabricated rubber products industry and certain other industries. It will be discussed in detail in Part II of this report; in Part I it is considered as only another raw material.

Rejects
Finished product which is judged by test to not conform to established quality standards. In some cases a reject can be repaired (belting and hose), or sold commercially as second or third quality (footwear), or reprocessed (heels and soles) In many cases repair or sale as off-quality cannot be tolerated and the item must be made unserviceable and disposed of as solid waste (tires, inner tubes, hose).

Retreading
The process by which sound tire carcasses which have had the tread worn beyond safe levels by normal operation are rejuvenated by molding on a new tread equivalent in safety performance to the original.

Rubber
An unfortunately vague word having many different common and technical meanings. Originally meaning the crude natural product. It now covers all the synthetic elastomers, compounds of them, and fabricated products. It also refers to the "rubbery" properties of things that may not be elastomers at all. Then specifically it may refer to such things as waterproof footwear, prophylactics, and many other items.

Rubber Compound
Intimate mixtures of elastomers, oils, mineral fillers, pigments, chemicals, sulfur, and other modifying materials. It usually refers to uncured material.

Rubber Mill
An open mixer for making rubber compounds consisting of two powered rolls operating in opposite or the same directions, at various rotational ratios, and either smooth or grooved in various ways.

Semi-pneumatic
A tire of heavy construction having an air space within it usually at atmospheric pressure. They provide much less cushioning than pneumatic tires and are used on light weight equipment or industrial units.

Separators
Sheets of plastic, paper, or treated fabric which are used to temporarily separate prepared pieces of tacky uncured rubber prior to assembly. The trend is to plastic film which can be recovered after use and reprocessed in the fabricating plant as many as six or eight times. Treated paper and fabric can be used over several times, unless it has been cut, and then must be discarded as solid waste.

Solid Tires
A solid mass of rubber built up on the rim of a metal wheel with no substantial air space. Usually limited now to small heavily loaded wheels and rollers such as aircraft tail wheels, industrial tractors, and conveyor rolls and casters.

Sponge
Cellular rubber products made from softened solid rubber products containing chemical agents which decompose to gases during the curing process.

Tire Accessories
Products associated with tires and wheels exclusive of casings and inner tubes. Includes retreading compound, flaps, repair patches, and cement, and a variety of small specialty wheels and parts.

Tread
That part of the tire casing which comes in contact with the road It contains no fabric and is specially designed for abrasion resistance and maximum skid resistance under all driving conditions. This part of a sound tire can be effectively replaced by retreading.

Trimmings
Almost all fabricated rubber products are assembled from sheet or strip rubber compound, fabric or metal by hand or semi-automatic operations. This requires much hand or machine trimming of excess material to make the final shapes required. Much of these trimmings may be reprocessed but the remainder is discarded as solid waste.

Wire and Cable
This includes all electrical conductive power, communication, and electronic wires and cables. At one time all the insulation and jacketing of the non-ferrous conductor was based on elastomers but now much of the elastomer has been replaced by plastics such as polyolefins and polyvinyl chloride which do not require a curing stage as elastomers do. The remaining use of elastomers is in applications where its abrasion resistance, moisture resistance, and electrical properties are superior at lower cost. The performance specifications in most of this industry are very rigid.

Rubber Reuse and Solid Waste Management

Part II

WASTE RUBBER AND ITS REUSE: 1968

Part II of this publication (SW-22c) was written
for the Federal solid waste management program by
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Preface

This report on solid wastes of the Rubber Industry was prepared by Uniroyal Chemical, a division of Uniroyal, Inc. pursuant to Contract No. PH 86-68-208, with the Federal solid waste management program (now part of the U.S. Environmental Protection Agency). The statements, findings, conclusions, recommendations, and other data in this report are not necessarily those of the Agency, nor does mention of commercial products imply endorsement by the U.S. Government.

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New Brunswick, New Jersey

Midwest Rubber Reclaiming Co.
East St. Louis, Illinois

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Bucyrus, Ohio

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Denver, Colorado

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College Park, Maryland

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Washington, D.C.

The Rubber Reclaimers Association, Inc.
New York, New York

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Summary

This report outlines the waste rubber product disposal problem, the present areas of waste reuse with future trends, and potential future areas of collection and reuse. The base year was taken as 1968.

Section I presents (a) the geographic distribution of two categories of rubber waste, one category being more easily collectable than the other; (b) the collection methods presently used for waste now reused and (c) the wastes consumed by the three major users.

Section II details one of the waste users, the Reclaim Rubber Industry, its history, the wastes used and created, the processes used, and the industry trend.

Section III details the Retread Industry, the largest single user of rubber waste, its history, wastes used and created, the process and industry trend.

Section IV outlines the smallest of the waste reusers, the Tire Splitting Industry.

Section V is an analysis of the various methods of waste collection and reuse which might be used for mitigating the problems caused by rubber product waste.

Section VI presents some specific conclusions and recommendations for further action.

Section I

Of the 10.7 billion pounds of rubber products produced in 1968, after wear allowed for in vehicle tires, approximately 10.3 billion pounds will ultimately become a waste disposal problem.

Approximately 6 billion pounds will be various types of tires for automotive, truck and farm vehicles. It is mainly this type which is presently used in any significant quantities by the three major waste reusers, amounting to 1.95 billion pounds.

Approximately 11% of this collected waste* or 213 million pounds is subsequently rejected for various reasons by these industries as waste for disposal.

The overall net waste for disposal is then estimated at 8.6 billion pounds consisting of 4.3 billion pounds of tires and 4.3 billion pounds of other rubber product waste.

Twenty million pounds of new waste are created during the reuse of the remaining 1.7 billion pounds of rubber waste.

Section II
Over the past 10 years, the Reclaim Industry produced between 550 to 650 million pounds per year of useable product primarily from rubber waste and rubber industry scrap. The Reclaim Industry waste consists of 62 million pounds of unused waste and 13 million pounds of newly created waste.

During this 10 year period, reclaimed rubber as a percent of new rubber polymer has decreased from 18% to 10% indicating a loss of market or usefulness to the rubber industry. It is anticipated that the pound volume will continue to decrease in the near future.

Section III
The largest users of rubber waste are the tire retreaders who accumulated 1.6 billion pounds of road worn tires. Approximately 1.56 billion pounds were recycled back to consumers with the addition of approximately 530 million pounds of new tire tread. The remaining 0.04 billion pounds of worn tires were rejected as unsuitable for retreading. The tread rubber added to the 1.56 billion pounds of tires is included in the 10.7 billion pounds of new rubber products made in 1968. Newly created waste was 4 million pounds. There has been a steady though small increase in the numbers of tires being retreaded every year particularly the heavy service truck type tires and this increase is expected to continue. Without this recycle of worn tires back into service, it is logical to assume that more new tire production would be necessary to satisfy the market thereby increasing the future tire waste from 6 billion pounds per year to well over 7 billion pounds.

Section IV
The tire splitting industry uses rubber waste, mainly tires, to produce rubber washers, gaskets, shims, automotive tail pipe hangers, and the familiar door mats. Of the 57 million pounds consumed by the industry, 14 million pounds were converted into finished products, 36 million pounds were sold to reclaimers as selvage, and 7 million pounds were returned to waste. There was 3.6 million pounds of new waste created by this industry. Without past history on volume of waste consumed, it is difficult to establish industry trend, however, it is an industry expectation that volume will continue to increase.

Section V
It is suggested that the rubber waste program be divided into two categories, tire waste and others. A collection system already exists for waste tires to serve the three major users, collecting approximately 30% of those available. It may be possible to expand this system as a nucleus for collection of the remaining 70%. The "other" category will be extremely difficult to collect and sort into useable waste. Alternate collection systems and storage sites are considered. Methods for facilitating disposal of rubber waste through incineration or land-fill were considered including stationary and portable shredders; the use of shredded waste in roads, crash barriers, as a mulch or road banks was also considered as well as the longer range potential outlets as pyrolysis to either chemicals or fuel gasses.

Section VI
Seven specific recommendations are presented for future study. The logistics of waste collection oriented primarily to tire accumulation should be investigated. A study based on the reverse logistics of new tire distribution is suggested. Facilities for shredding and densifying waste followed by incineration or conversion to other useful products are discussed. The use of waste rubber in asphalt roads will require specific studies and test roads. It is also recommended that the Bureau of Solid Waste Management maintain surveillance over legislation, industry standards, and technological changes to ensure that the solid waste problem is not inadvertently aggravated.

Introduction

This report outlines the entire Waste Management problem concerned with discarded consumer rubber products based on products manufactured in 1968 and waste products also reused in 1968.

While the rubber products industry has been growing at a steady pace as described in Part I of this report, the waste reuse or management in pounds in recent years has remained virtually constant. The overall effect is a lower percent of waste reused. The three largest (virtually 100%) users of waste rubber products show the following usage changes between 1963 and 1968 respectively. Reclaimers produced 0.629 billion pounds vs. 0.576 billion pounds. Retreaders reused 1.43 vs. 1.56. No comparative data are available for splitters which is small usage by comparison. The overall total was 2.06 billion pounds reused in 1963 vs. 2.13 billion pounds in 1968.

Although minor favorable cost differentials may exist between reused rubber products such as reclaim and retreaded tires, other disadvantages – real (potential by lower quality) or imaginary (second class reused stigmatism) – have precluded any significant growth in usage.

While waste rubber products are not unique with respect to other types of waste, they have inherent in them many of the difficult disposal characteristics of the others. They come in combination with other materials as fibers and metals; are made in various sizes and shapes; are scattered over the length and breadth of the land; are not easily degradable in land fill type operations where the large items such as automotive tires have the added disadvantage of resisting compaction; and although readily combustible they contribute substantially to air pollution problems when burned in ordinary, low quality incinerators. To put this survey into perspective, Section I of this report details the geographic location of the waste, subdividing the waste into two categories. The first is all tires which constitutes approximately 59% of the total waste and which is more readily collected and reused. The second category is the broad "Others" which covers a multitude of rubber products, difficult to collect, sort, and reuse in any foreseeable outlet. Section I also outlines the three major industries engaged in the reuse of waste rubber products.

Section II covers one of the waste converters, the Reclaim industry, its history, the wastes used and created, an outline of processes and equipment used, and the industry trends. Sections III and IV similarly outline the other two major uses of rubber waste, the Retreaders and Tire Splitters respectively.

Section V outlines some broad solutions to achieve more effective waste management with specific conclusions and recommendations listed in Section VI.

A Glossary and a Bibliography, subdivided in various topic classifications, are included in the two Appendices.

Section I
Waste Rubber: 1968

DISTRIBUTION OF SCRAP RUBBER PRODUCTS

During 1968, 10.7 billion pounds of rubber products were produced in the United States. On the assumption that unless reused for another purpose after wearing out, the rubber product will be discarded in the same locale as purchased, the geographic waste distribution can then be determined. Based on information on product sales by country and metropolitan areas, TABLE II-1 details the distribution by states. The distribution is further subdivided into two categories, Tire and Others. The assumption is that the first category is more easily collected and lends itself more readily to reuse while constituting 59% of the total 10.7 billion pounds of discarded rubber products. The basis for these assumptions will be further developed in subsequent portions of this report. The Tire category includes passenger, truck and large tractor tires and the Other category includes all the remaining rubber items such as innertubes, garden hose, hot water bottles, mats, windshield wiper blades.

Also included in TABLE II-1 is the product distribution per capita and per square mile of each state area. This is an indication of each individual state's disposal problem particularly by land-fill; from a high of 41,650 pounds per square mile per year for New Jersey, neglecting the 677,970 pounds per square mile for Washington, D.C. to a low of 20 pounds per square mile per year for Alaska, where land is undoubtedly less expensive than in New Jersey. It is interesting to note the higher per capita usage of rubber products in the predominantly rural areas of for example Wyoming, 72.4 pounds per capita per year and Montana, 70.1. This is primarily due to the large number of farm implements owned by residents in addition to the automobile and usual home rubber products and to the low density of population and consequent greater motor vehicle use per capita to participate in the daily life of a typical community.

These figures are not adjusted for the waste consumed by the major converters. They do not include the retreaded tires which are being recycled in the amount of 1.6 billion pounds in 1968 compared to total new tires of 6.0 billion pounds. While the 1.6 billion pounds are not disposed of in 1968, tires recapped in previous years will be, therefore the overall net waste is considered to be the 6.0 billion pounds. It can be assumed that the Retreaders are uniformly distributed over the country. However, the next largest consumer, the Reclaimers are not uniformly distributed, with a high concentration in the Ohio and Northeastern sections. Since waste converted by them is normally not drawn from distant points, it therefore seems logical to assume, since accurate data could not be developed, that the waste disposal problem in these areas is reduced. A listing of Reclaimers is noted in Section III.

The third largest consumer, the Parts Industry, although small by comparison, is mainly located in the Chicago-St. Louis areas.

Another method of analyzing the distribution data clearly emphasizes the logistical problem in collecting the rubber product waste. In Fig. II-1 the United States is subdivided into standard census geographic areas. The circles within these areas represent groups of metropolitan districts with a 100 mile radius whose total rubber product usage is at least 1% of the nation's total, each one percent equivalent to 100 million pounds per year. Percentages shown within the circles do not include usage in rural or small towns within the circle, which is included in the total percentages for the specific geographical area. It is noted that 51% of the waste is included within the 20 circles with the remaining 49% thinly spread over the remaining areas. The mid-Atlantic axis (Boston-Wilmington) accounts for about 15% of the total. The mid-West axis (Milwaukee-Chicago-Detroit-Cleveland-Pittsburgh) accounts for about 9%. The remaining two-thirds of the waste however is widely distributed over the remaining isolated metropolitan circled areas or the rural-small town areas in between.

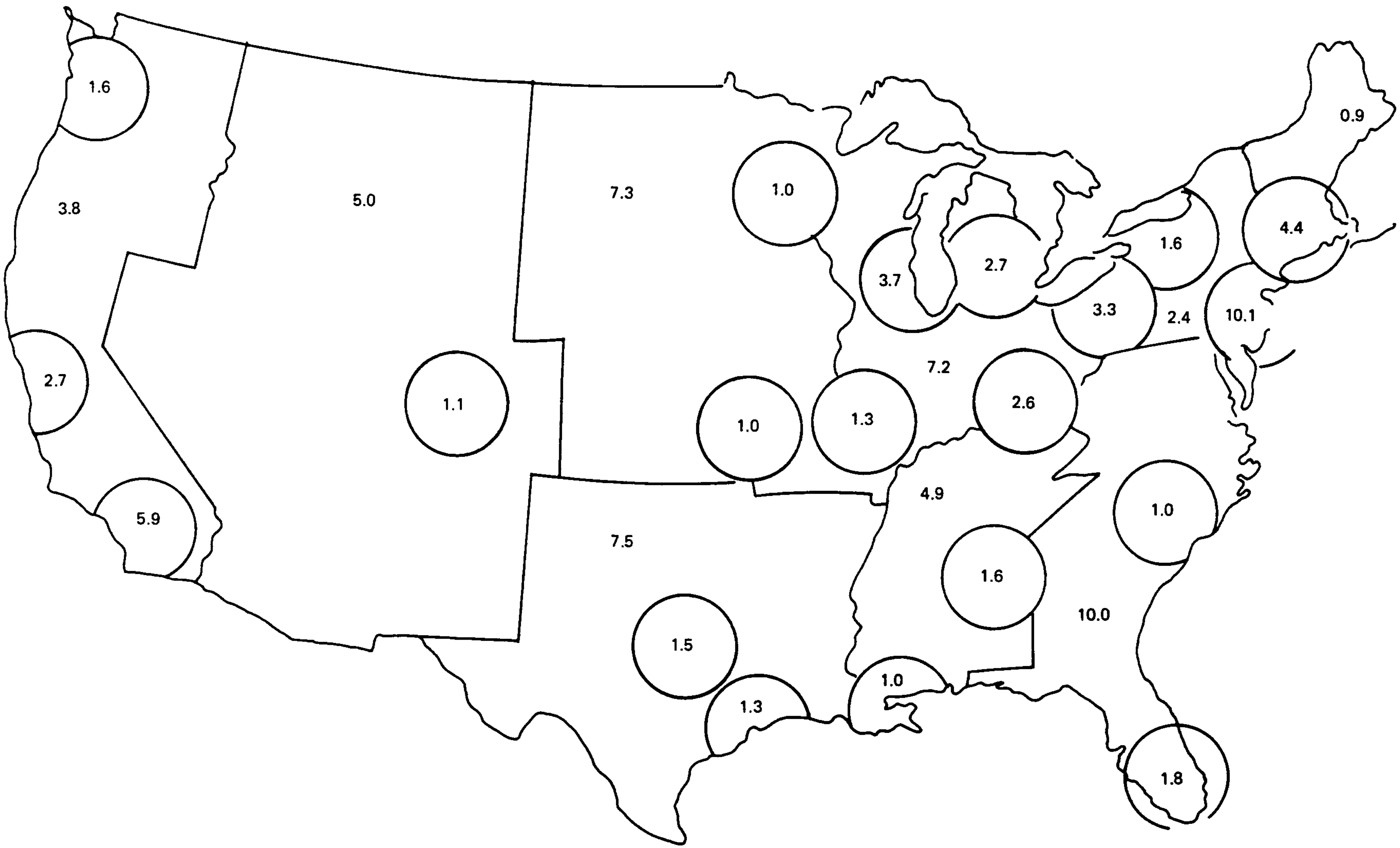


FIGURE II-1 GEOGRAPHICAL PERCENT DISTRIBUTION OF WASTE RUBBER

The number indicates the percent of the nation's waste rubber located within the cirlce. The remaining numbers indicate the percent waste rubber located outside the circles but within the bordered areas.

TABLE II-1

DISTRIBUTION OF CONSUMER RUBBER PRODUCT WASTE BY STATES

STATE	TIRES* (thousand pounds)	OTHER	TOTAL	AVERAGE LBS/CAPITA	AVERAGE LBS/M12
Alabama	98,060	77,790	175,850	50.6	3,410
Alaska	6,600	5,390	11,990	45.0	20
Arizona	71,960	30,770	102,730	57.7	900
Arkansas	72,850	42,300	115,150	56.5	2,170
California	598,730	374,410	973,140	49.7	6,130
Colorado	100,860	41,460	142,320	65.7	1,370
Connecticut	76,670	60,260	136,930	47.6	27,336
Delaware	15,210	10,690	25,900	49.2	12,590
Florida	194,640	118,000	312,640	50.7	5,340
Georgia	126,020	94,030	220,050	49.2	3,740
Hawaii	12,760	15,000	27,760	40.7	4,320
Idaho	29,730	15,810	45,540	62.0	550
Illinois	289,330	240,200	529,530	50.0	9,400
Indiana	163,220	111,130	274,350	54.5	7,560
Iowa	130,990	65,820	196,810	67.4	3,500
Kansas	90,570	51,720	142,290	60.3	1,730
Kentucky	90,780	72,230	163,010	52.1	4,040
Louisiana	116,670	77,360	194,030	52.4	4,000
Maine	30,650	23,080	53,730	55.8	1,620
Maryland	95,670	73,940	169,610	46.7	16,040
Massachusetts	123,740	122,670	246,410	48.1	29,840
Michigan	239,360	186,350	425,710	50.4	7,300
Minnesota	133,070	81,200	214,270	58.3	2,550
Mississippi	69,800	51,720	121,520	52.2	2,550
Missouri	194,830	103,000	297,830	61.5	4,270
Montana	37,020	16,240	53,260	70.1	360
Nebraska	73,000	33,760	106,760	69.2	1,380
Nevada	19,650	7,000	26,650	53.1	270
New Hampshire	19,000	14,530	33,530	49.8	3,600
New Jersey	181,940	114,460	326,400	47.6	41,650
New Mexico	37,960	22,650	60,610	58.7	500
New York	370,520	400,050	770,570	45.1	16,070
North Carolina	133,900	108,560	242,460	49.4	4,600
North Dakota	29,260	15,000	44,260	65.5	630
Ohio	328,370	231,230	559,600	53.4	13,580
Oklahoma	100,720	55,140	155,860	59.8	2,230
Oregon	85,430	41,890	127,320	59.8	1,310
Pennsylvania	330,710	269,700	600,410	52.8	13,244
Rhode Island	23,350	20,520	43,870	50.5	36,140
South Carolina	56,650	56,850	113,500	46.6	3,650
South Dakota	32,390	16,240	48,630	68.1	630
Tennessee	124,000	85,050	209,050	53.4	4,950
Texas	380,010	228,240	608,250	54.4	2,280
Utah	42,500	20,940	63,440	58.3	750
Vermont	11,230	9,000	20,230	49.6	2,100
Virginia	117,470	94,460	211,930	47.7	5,190
Washington	105,290	68,000	173,290	55.2	2,540
West Virginia	48,800	44,020	92,820	53.8	3,840
Wisconsin	111,770	94,030	205,800	50.6	3,670
Wyoming	16,850	7,700	24,550	72.4	250
Washington, D.C.	28,400	18,380	46,780	56.9	677,970
Total	6,018,960	4,269,970	10,288,930		
Percent	59%	41%	100%		

The weight of rubber "lost" through tire wear has been deducted from these figures.

*Passenger, Truck and Large Tractor.

COLLECTION OF CONSUMER RUBBER PRODUCT WASTE

Aside from automotive tires and innertubes, there is apparently little other segregated collection of the nation's worn rubber articles. Tires and innertubes are collected or accumulated mainly by tire stores, gasoline stations, fleet operators, and retreaders. When a tire is worn out, it is usually changed or replaced by a new tire at one of these commercial operations. Few tires are replaced by motorists themselves. This practice normally results in tire accumulations at convenient pick-up points. In areas where tires are a disposal problem, however, it is a common practice for the station attendant to put the worn tire back into the trunk of the customer's auto and the tire ends up unsegregated in the residential solid waste. When innertubes are no longer required they are usually saved by the motorist against the day when he may need it again for a leaking tire, for a swimming tube, or for a use to be determined. It invariably ends up later in residential waste.

Almost all other types of rubber waste (excluding rubber waste from the rubber industry) from worn rubber products are easily disposed of in mixed waste. For example, discarded rubber gloves, boots, mats, floor coverings, cart or transporter tires and wheels, power drive belts, wire, and others are disposed of indiscriminately. Small scrap articles of this type are easily discarded in mixed trash. Tires, however, are not so easily discarded and are usually collected separately. By comparison, waste from the rubber products industry in the form of selvage or rejects, is more easily collected in segregated, re-usable form. Most manufacturers, with economic incentive, make concerted efforts to lower their costs by selling this segregated waste to reclaimers or other industries which can use them.

Scrap rubber must be collected in a controlled way to be efficiently reclaimed. The bulk of rubber waste that is reprocessed today is collected by local used-tire merchants. These merchants purchase worn out tires and tubes and manufacturer's rejects and scrap. The used-tire merchant sells reusable casings to retreaders and the remainder to scrap rubber brokers. Brokers operate on a national and international scale, purchasing scrap rubber from merchants and making volume sales to reclaimers and other waste rubber consumers. This system permits the waste consumer to buy in large quantities at fairly stable prices from established brokers instead of bartering with a number of small merchants. Having determined their usual requirements, reclaimers and other purchasers will usually place standing orders with brokers who will further place orders with merchants.

A typical example of a haphazard, costly collection of waste rubber is probably exemplified by the victory rubber drive of World War II. Although many millions of pounds were collected, only a small quantity could be reclaimed. Rubber boots with straps or buckles and bicycle wheels, for example, were difficult to separate from the contaminating metals and serious production problems arose from inadequate sorting. Other than the tires and innerturbes collected it is reported that substantial quantities of mixed wastes were discarded after the emergency was over; the economics precluded any future use.

PRESENT REUSE OF WASTE RUBBER

The area of significant usage of waste rubber products, and incidentally also scrap from the rubber product industry, occurs in three major industries Retreaders, Reclaimers, and Tire Splitters. Retreaders, the largest of the three, extend the useful life of worn tires by placing new tread on the old carcass. The second largest, the Reclaimers, after removing non-rubber components such as metal and fabric, convert the rubber into a reusable form so it may be worked back into conventional rubber products. The Tire Splitters cut out small rubber parts mainly from the carcass and tread areas of waste tires. These three significant industries consumed waste in 1968 approximately equal to 20% of the new rubber products produced in that year.

Table II - 2

WASTE RUBBER USED AND AVAILABLE: 1968

		Billions of Pounds	Percent
Tread Loss (Tire Wear)*		0.43	4.02
Waste Rubber Reused by:	Reclaimers	0.54	5.05
	Retreaders	1.56	14.58
	Tire Splitters	0.05	0.47
Total Weight Reused or Worn Away		2.58	24.12
Weight of Waste Rubber Left for Disposal		8.12 **	75.88
Total		10.7 ***	100.0

*Through oxidation and wear of tires on the nation's highways (approximately 8 lbs. per year per driver) 434,000,000 lbs. of rubber polymer were converted to dust and gas.

**Does not include weight of tires retreaded in previous years which were discarded in 1968. Does not include waste accumulated and not disposed of in previous years.

***Consists of approximately 10.7 billion pounds of discarded products and 0.4 billion pounds of rubber products industry waste rubber compound.

A more detailed breakdown, based on the two waste categories of tires and other, is more specific as to the quantities of each category consumed by the three waste users and also includes new waste generated to arrive at the overall net effect of these industries. TABLE II-3

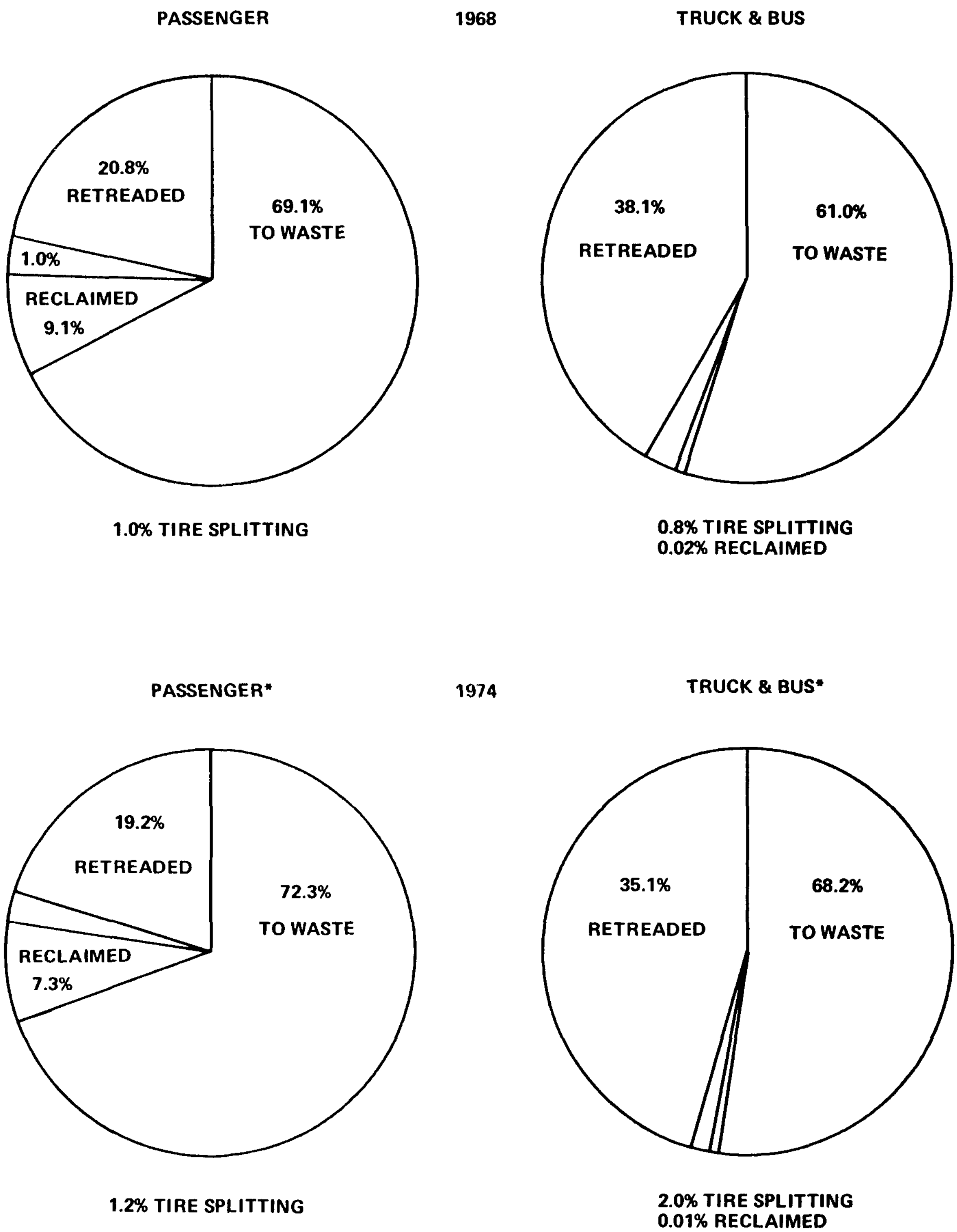
For tire waste, 1.95 billion pounds are collected out of the total of 6.02 billion pounds available, of which 1.80 billion pounds are used or sold to other uses. There are 0.20 billion pounds of collected tires unsuitable for reuse for various reasons and which are returned to waste. Approximately 0.02 billion pounds of new waste are created during the waste conversion. The net effect of this reuse is a waste reduction from 6.02 billion pounds per year to 4.24 billion pounds, a 30% reduction.

With the projected increase in tire production and little if any increase in waste tire usage, the percent tire waste used is expected to decrease from 35% in 1968 to 33% in 1974, excluding the new waste created by the three users. Figure II-2

TABLE II-3
TIRE AND OTHER WASTE REUSE
(billion pounds)

	TIRES			**Sub-Total**	**OTHER**	**Sub-Total**	**TOTAL**
Rubber Waste Available				6.02		4.27	10.29
	Reclaimers	Retreaders	Splitters		Reclaimers		
Collected for Reuse	0.30	1.60	0.05	1.95	0.12		
Reject to Waste	0.06	0.13	0.01	0.20	–		
New Waste Created	0.01	0.01	–	0.02	–		
Reused or Resold	0.20	1.56	0.04	1.80	0.12		

FIGURE II-2 DISCARDED TIRE DESTINATION



*Based on the production of 220 million passenger tires

*Based on the production of 32.5 million truck tires.

Section II

The Reclaimed Rubber Industry

HISTORY OF THE RECLAIMED RUBBER INDUSTRY

The rubber reclaiming industry has always followed scientific developments in the raw rubber industry with developments of its own. It was not long after rubber trees were commercially tapped and dry rubber marketed that a method was devised to solvate waste latex and put it back to good use. Later, Sir Thomas Hancock, father of the United Kingdom's rubber industry, devised a horse driven machine which resolved all his waste rubber into a solid mass by pressure and heat. This enabled him to return the waste back into the elastic thread he was producing at the time. In 1839, the foundation of present rubber technology came into being when Charles Goodyear discovered vulcanization. Prior to this development, rubber items were very responsive to weather. They became soft and sometimes smelly in hot weather and rigid and inflexible in cold weather. Vulcanization, or the treatment of rubber with heat and a curative, i.e. sulfur, produced a practical rubber product with none of these drawbacks.

A mechanical method for reclaiming rubber now came into being and articles which did not contain fabric or very little fabric were ground up and used as filler in new rubber. Car springs, large molded blocks of rubber used in journal boxes of horse cars, were a source of fabric free rubber and even today, "ground spring" is a term used to describe any ground up fabric free rubber.

In 1870, W.N. MacCartney heated ground scrap with a solvent until the rubber dissolved. One of the first reclaims was produced upon evaporation of this solvent. Even earlier, in 1846, Alexander Parks boiled waste in Muriate of Lime. Both these methods fell to the background while the easier mechanical process, suitable for its time, predominated. Following the mechanical method the next major development was Hiram L. Hall's Heater or Pan Process. The patent was issued in 1858. Hall ground the rubber and placed it in shallow pans. The pans were now placed in a closed vessel where steam was directed onto the rubber. Although, not stated, it is believed that he also added oils to help in the heat transfer. The Pan Process was relatively simple. With little machinery required, a good reclaim could be made and today approximately 34% of all reclaim in the United States is made in this manner.

The "ground scrap" Hall used was essentially fabric free. It came from rubber boots and shoes, the largest rubber commodity available at that time. Family incomes were supplemented by women and children, who pulled rubber from the fabric at home and later sold it to reclaimers. Rubber footwear production, at an annual rate of 1 million pairs in 1840, was to rise to 50 million by 1900. The scrap supply was changing, however. In 1900 carriage tires and solid rubber truck tires appeared. Later, in 1905, the pneumatic tire appeared. Tires, reinforced with fabric, carbon black and heavier cures, became predominant. The foremost problem was fabric. The stripping of rubber from fabric by hand was now becoming impractical. Tires, the new major sources of scrap, forced reclaimers to look for new and better ways to recover the rubber. A new and better way had been found much earlier however, by a young man named Eugene H. Clapp. Mr. Clapp in 1868, had developed and set up a small apparatus for separating fiber by means of air. Briefly the whole rubber article was ground up and subjected to an air blast. Here, the lighter, more responsive fabric "blew away" from the heavier solid or nearly solid rubber particles. Machinery was not developed during those years to make use of Clapp's idea. Today his air separation principle combined with fine grinding is widely used for fabric removal. In 1873, Guggenheim and Lowry treated rubber waste with an 8-10% caustic solution to destroy any wool present. After washing, they treated the scrap with 15-20% sulfuric acid solution to destroy any cotton. The resultant reclaim was of poor quality.

In 1881, Colonel N. Chapman Mitchell secured a patent for the Acid Process. Essentially he boiled the ground rubber scrap in a 20% sulfuric acid solution which destroyed any cotton and/or wool fabric present. Afterwards the ground scrap was washed, dried, heated with oils and milled. A study of the history of reclaiming will show that many people had done work with caustic and sulfuric acid solutions and as a result of prior work of others and improperly drawn patents Mitchell was dragged into long and costly litigation. He did, later on, form the first company organized exclusively for the production of the acid process reclaim. His process was used primarily for rubber goods of low sulfur content. The acid process was impractical for scrap high in sulfur such as tires. The excess sulfur in tires and other goods could not be removed by the acid but, on the contrary, would combine chemically with the rubber during the heating process in open steam with the result that further vulcanization instead of devulcanization would occur. Because of this, a contemporary development, the Alkali Process would become the single most successful method of the time. Arthur H. Marks patented this process in 1899. The process involved the heating of ground rubber waste with a 3 to 16% caustic solution at 344-370°F for twenty hours. The sulfur in the scrap dissolved into the caustic solution and any fiber present was destroyed. The heating was carried out in an apparatus specified in the patent. It consisted of a closed vessel contained in another vessel into which steam was introduced Defiberization, desulfurization and devulcanization were completed in one step with this process. The next year Marks received a patent for a horizontal, rotating digester which except for a few changes, is essentially the apparatus used to produce 58% of the reclaim in the United States today.

This leads us to the last major development in the early years of reclaiming. Robert Cowen was issued two patents in 1900 on the strainer. A rubber strainer is similar to the meat grinder a butcher uses today to produce the strands of ground meat sold in markets. Prior to its manufacture, all contamination had to be picked out by hand creating a bottleneck in production. Forcing the rubber through a screen which held back contaminants enabled the reclaim industry to improve production considerably.

The development of the synthetic rubber industry in the United States forced reclaimers to do considerable research on the reclaiming of blends of different rubber polymers. Prior to synthetic rubber development, natural rubber was the only polymer present. This rubber could be reclaimed by heat alone. Heat however, tends to harden most synthetic polymers. Also, the methods of grinding the scrap had to be revised since natural rubber absorbs oils and reclaiming catalysts much faster than synthetic rubber, the natural rubber part of the reclaim will be more depolymerized than the synthetic and the final reclaim will be nonhomogeneous. To overcome this the rubber mixture is now ground to a smaller particle size in order to present a larger surface area for absorption. Eventually, certain diterpenic acids were found which, in general, retarded the oil absorption of vulcanized natural rubber scrap and thereby permitted a more uniform distribution of reclaiming oils in the scrap components. Finally, the use of caustic or alkali solutions as defibering agents was almost totally eliminated as caustic hastened the heat hardening of SBR rubber and other synthetics. As a result, the neutral process is now used for defibering employing metal chlorides such as zinc or calcium for the removal of fabric.

THE RECLAIMED RUBBER INDUSTRY

The members of this industry, more commonly known as "Reclaimers", for the purposes of this report, are limited to those who are predominantly concerned with the conversion of used or rejected rubber products into re-usable materials. These materials are usually reused in the same or products similar to those from which they were "reclaimed" i.e. scrap tires are reclaimed and converted to a soft workable state wherein they are capable of being blended into tire compounds for new tire manufacture. It is also inherent in the reclaimed rubber industry, that some materials are produced which are not reused in the rubber industry but in other industries. Some examples are adhesives, wire covering, pipe covering, brake linings rubberized asphalts and tars. However, this is a small portion of a "Reclaimers" operations.

There are fourteen rubber reclaiming companies in the United States operating twenty individual plants, with a reported employment of 1812 people (Table II-4). Recently two of these plants were reported closed and another is rumored to be closed in the near future. Most "Reclaimers" are also members of the Rubber Reclaimers Association (RRA). The RRA reported an overall capacity of 825 million pounds per year in 1968. Historical production in pounds and as a percent of 1968 capacity is noted and graphed in TABLE II-5. The two plants reported to have closed recently further reduce the capacity reported in 1968. Previous years capacity is also known to have been somewhat larger but was reduced to the 825 million pound figure by the closing of two major plants, one in California and the other in New York. The geographic distribution of the remaining eighteen plants is mapped in Figure II-3 and indicated a similarity to the distribution of the rubber producers.

TABLE II - 4

RECLAIM

PLANT LOCATIONS

1. H.Muehlstein and Co.
   Jersey City, N.J.
2. Uniroyal Chemical Div. Uniroyal, Inc.
   Naugatuck, Conn.
3. Boston Woven Hose and Rubber Div., American Biltrite Rubber Co., Inc.
   Cambridge, Mass
4. Biltrite Rubber Co., Inc.
   Stoughton, Mass.
5. U.S. Rubber Reclaiming Co.
   Vicksburg, Miss.
6. Midwest Rubber Reclaiming Co.
   E. St. Louis, Ill.
7. Midwest Rubber Reclaiming Co.
   Chester, Pa.
8. Midwest Rubber Reclaiming Co.
   Barberton, Ohio
9. Centrex Corp.
   Findlay, Ohio
10. Gates Tire and Rubber Co.
    Denver, Colo.
11. Goodyear Tire and Rubber Co.
    Akron, Ohio
12. Goodyear Tire and Rubber Co.
    Gadsden, Alabama
13. Laurie Rubber Reclaiming Co.
    New Brunswick, N.J.
14. Nearpara Rubber Co.
    Trenton, New Jersey
15. Swan Rubber Co., Div. of Amerace Corp.
    Bucyrus, Ohio
16. Bearfoot Sole Co.
    Wadsworth, Ohio
17. Xylos Rubber Co., Div. of Firestone Rubber Co.
    Memphis, Tenn.
18. Xylos Rubber Co., Div. of Firestone Rubber Co.
    Los Angeles, Calif.

19. Xylos Rubber Co., Div. of Firestone Rubber Co.
Akron, Ohio

20. B.F. Goodrich Industrial Products Co.
Akron, Ohio

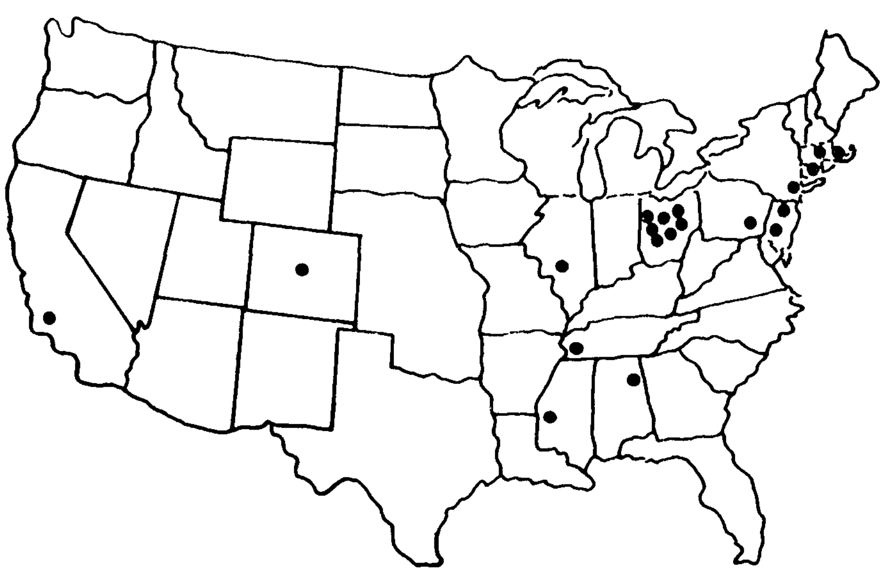
TABLE II - 5

The United States Production of reclaimed rubber is listed below as a percentage of the total capacity of the industry.

YEAR	PRODUCTION (million pounds)	PERCENT OF PRODUCTION CAPACITY
1958	581.5	70.3
1959	457.3	55.3
1960	655.9	79.2
1961	591.0	71.0
1962	628.4	75.6
1963	630.4	76.0
1964	618.8	75.0
1965	627.8	75.5
1966	621.3	75.0
1967	545.8	65.7
1968	575.0	69.3
1969-1974	560.0 (est.)	(67.5) (est.)

FIGURE II-3

The location of the twenty reclaiming plants presently in the United States are shown below:



RUBBER WASTE INPUT

Reclaimers use two categories of waste: those items reported in Part I as Rubber Products and whose useful life is completed and some scrap items of the Rubber Products Industry. In the latter category are included defective manufactured items, selvage, cleanouts, etc. These were not reported as original waste in Part I as they are normally disposed of directly to a reclaimer or to independent agents selling to reclaimers. A breakdown of the reported Reclaimers 1968 usage in these categories indicates 43.7% usage of rubber product waste and 7.5% of producers waste as shown in TABLE II-6. The balance of 48.8% consumed was not reported by composition but is known to be a mixture of both categories. It can undoubtedly be assumed that the total industry usage is in the ratio of 43.7% to 7.5% of product waste to producers scrap.

TABLE II - 6

1968 RUBBER WASTE USAGE BY RECLAIMERS

DESCRIPTION WASTE RUBBER PRODUCTS	WEIGHT (million pounds)	
Worn Tires		
Passenger	141.1	
Truck, Bus, Tractor	.2	
Retread Buffings*	.1	
Tire Parts, Peelings*	8.2	
Other Tire Parts	39.8	
Inner Tube – Natural Rubber[1]	9.5	
Inner Tube – Butyl Rubber	53.5	
Sub-Total	252.4	43.7%
Rubber Manufacturing Scrap		
Rejected Tires*	23.9	
Mechanical Product Scrap	11.2	
Other*	.3	
Raw Polymer*	7.6	
Sub-Total	43.0	7.5%
Other Rubber Consumed[2]		
Sub-Total	281.1	48.8%
Grand Total	576.5	100.0%

*Definitions listed in Appendix 1.

[1] Poundage shown contains a small quantity of factory rejects for which there is no separate data.

[2] Composition not reported but known to be a mixture of worn products and manufacturer's by-products.

Road worn tires are generally available in sufficient quantity within 300 miles of individual reclaim plants. This does not apply to the concentration of plants in the Ohio area. The delivered cost of tires may vary from $7-14 per ton depending on freight costs.

Tires other than passenger types, such as truck, bus, and off-the-road are also generally available in quantity with the delivered cost being approximately equal to the passenger tire. Reclaim usage of these larger types is small however, due to the added handling and processing costs.

Retread buffings are readily available as a source of ground rubber without fiber. The cost is approximately $25-35 per ton depending on freight charges.

Tire parts are a by-product of the Splitting Industry. They are a good source of fabric free tire treads or "peelings". Tire carcass selvage has value approximately equal to worn tires. Natural rubber innertubes are restricted in availability as production of these tubes is now limited. Due to demand for this type reclaim for adhesives, scrap prices are $120 to $160 per ton. Considerable quantities of this scrap are imported to meet the demand. Butyl rubber innertubes, more available than natural tubes, are at a slightly lower cost of $100 to $120 per ton. Considerable quantities of butyl rubber tubes are also imported to fill demand. Scrap collection costs and procedures for both types of tubes restrict higher use of domestic scraps.

Most producers scrap tires are directly shunted to reclaimers at a price comparable to price of worn tires. Without exception this is the case where the tire manufacturers have an internal reclaim plant. Only steel reinforced tires and tires with safety barriers are discarded as these are too difficult to reclaim with existing equipment.

Other than road worn tires and innertubes, little, if any, other used consumer type rubber products are collected and reprocessed by reclaimers. Any consumer type rubber products which are used consist mainly of factory rejects and selvage types which are picked up at the factory. Only in this manner can collection costs be held down and products grouped into categories which can be handled and processed by the reclaimers into suitable reclaims, i.e. two different items such as a rubber mat and a hot water bottle may require different reclaiming chemicals and processes. Prices for scrap depend largely on type, color and transportation costs and will vary from $15 to in excess of $100 per ton.

Sophisticated elastomeric polymer products such as those made from silicones and fluoroelastomers, are presently small in comparative volume. Availability is again restricted to the factory reject type of scrap. More particularly here, cross contamination with other types of polymers would be particularly disastrous negating many of the advantages of reclaiming these types of polymers. Due to their specialized nature, these polymers are usually reclaimed on consignment for the company supplying the scrap.

Raw polymers as a by-product from polymer producing plants are available in considerable quantity. Costs vary depending upon the type and transportation.

INDUSTRY SOLID WASTE

Since the Reclaim Industry normally literally "feeds" on waste, the solid waste produced by the reclaim industry itself consists of that portion of the original waste which cannot be converted into a reusable product.

During 1968, the Reclaim industry converted approximately 576 million pounds of waste rubber products and Rubber Product Producer waste into approximately 574 million pounds of saleable, reusable products. During the conversion, 75 million pounds of solid waste were generated. The majority of this waste, however, consisted of nonrubber components removed from the waste taken in.

TABLE II-7 summarizes the sources of solid wastes generated by the Rubber Reclaiming Industry itself and FIGURES II-4,5,6 illustrate the sources of these wastes in the three major reclaiming processes as well as the flow of materials thru these processes.

The weight of oils and compounding ingredients which were later added into the rubber product to assist production and meet customer needs, nearly equaled the weight of nonrubber and waste components removed.

UNCONVERTED WASTE (62 million pounds)

Thirteen million pounds of ferrous and nonferrous scrap metals were removed from the waste rubber taken in. The ferrous metals, mainly the steel bead wire from tires, may be reused during periods of need and high scrap steel value. The need has presently been reduced, partially by the new technology of steel production.

The nonferrous scrap has been more readily reused. The copper innertube stem scrap which is the predominant nonferrous scrap, having a higher value, is more easily reused. The weight of textile and textile-rubber mix separated from the original waste came to 37 million pounds in 1968.

The textile fibers partially separated from worn tires are usually a mixture of all types of fibers used in tire manufacture. This will include rayon, nylon, polyester and glass with a small amount of cotton. As new fibers are introduced into tire manufacture, they will show up in the textile mix.

Due to the mixed nature of the textiles, the amount of entrained rubber carrying over, and the short length of the fiber normally coming from conventional fiber separation equipment, the mix has little value for reprocessing. It may have some value or usage potential in nonwoven mat applications i.e. insulating board. Another considered area is as an agricultural mulch.

The waste rubber discarded (12 million pounds) is predominantly unusable scrap tires consisting of the studded snow tire or steel wire belted types. These are sorted from shipments of worn tires and discarded. It is highly doubtful that development of methods to convert these into reclaims would effectively reduce waste.

NEW WASTE (13 million pounds)

Packaging material waste amounted to 8 million pounds in 1968. Packaging waste is usually reduced by bulk handling of all materials and by reusable containers. These aspects of material handling are beyond the scope of this report.

Other scrap (5 million pounds) involves office paper, pallets, strapping and miscellaneous items which are typical in many other industries.

TABLE II - 7

RECLAIM INDUSTRY SOLID WASTE - 1968

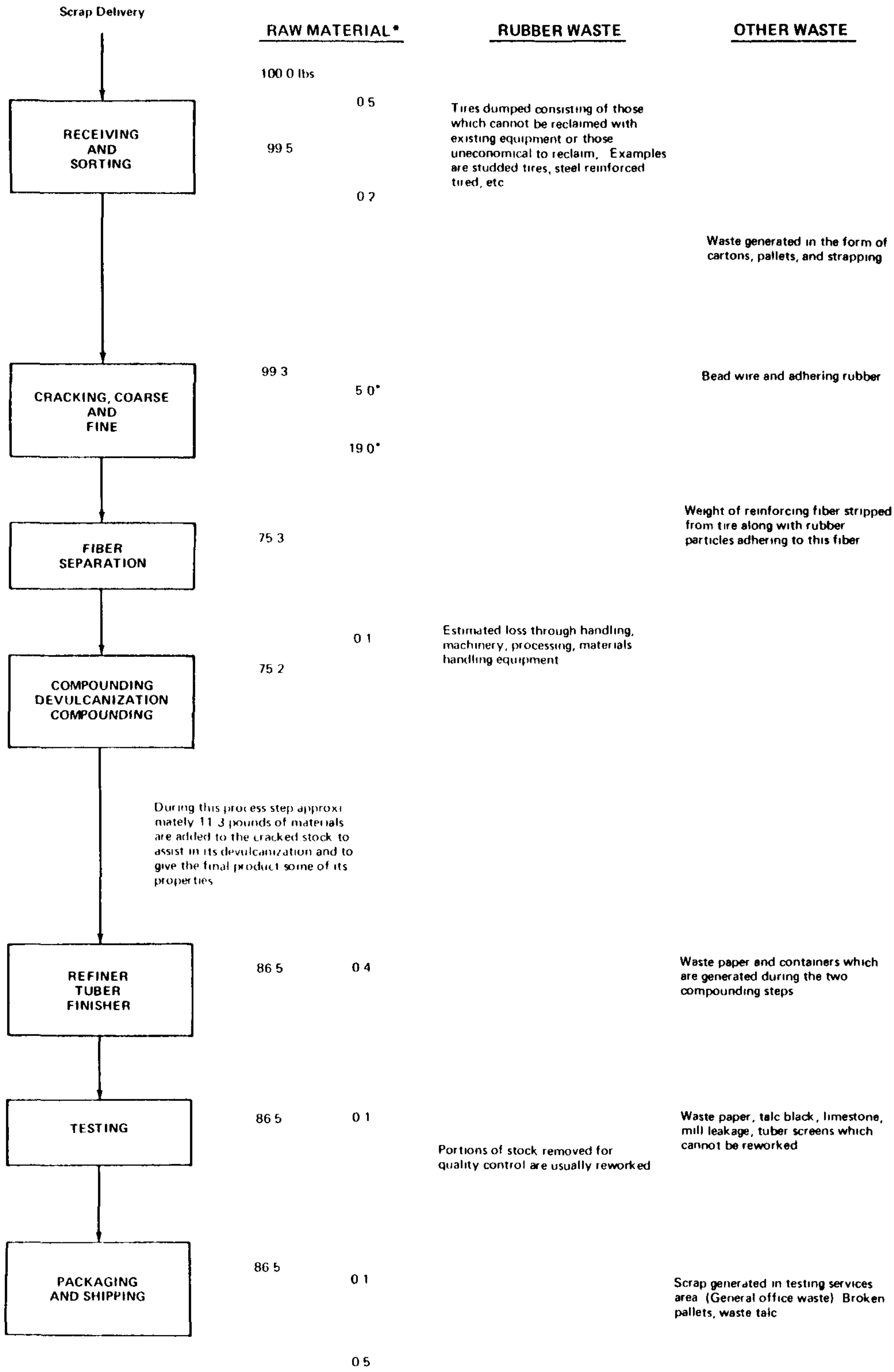
Description	Weight (Million Pounds)	%
From Original Waste		
Ferrous & Non Ferrous Metals (a)	13.2	17.6
Textile & Textile-Rubber Mix (b)	37.1	49.3
Rubber (c)	11.6	15.4
Sub-Total	61.9	82.3
New Waste		
Packaging Materials	8.0	10.7
Other	5.3	7.0
Sub-Total	13.3	17.7
GRAND TOTAL	75.2	100.0%

(a) Predominantly ferrous bead wire from tires, remainder mainly nonferrous value stems from natural and butyl tubes.

(b) Textiles and Textile-Rubber mixtures predominantly from processes using mechanical separation of textiles from rubber. Source mainly from tires.

(c) Predominantly worn tires which cannot be suitably reclaimed, i.e. studded winter snow tires and steel wire re-inforced tires.

FIGURE II 4 DIGESTER OR WET PROCESS

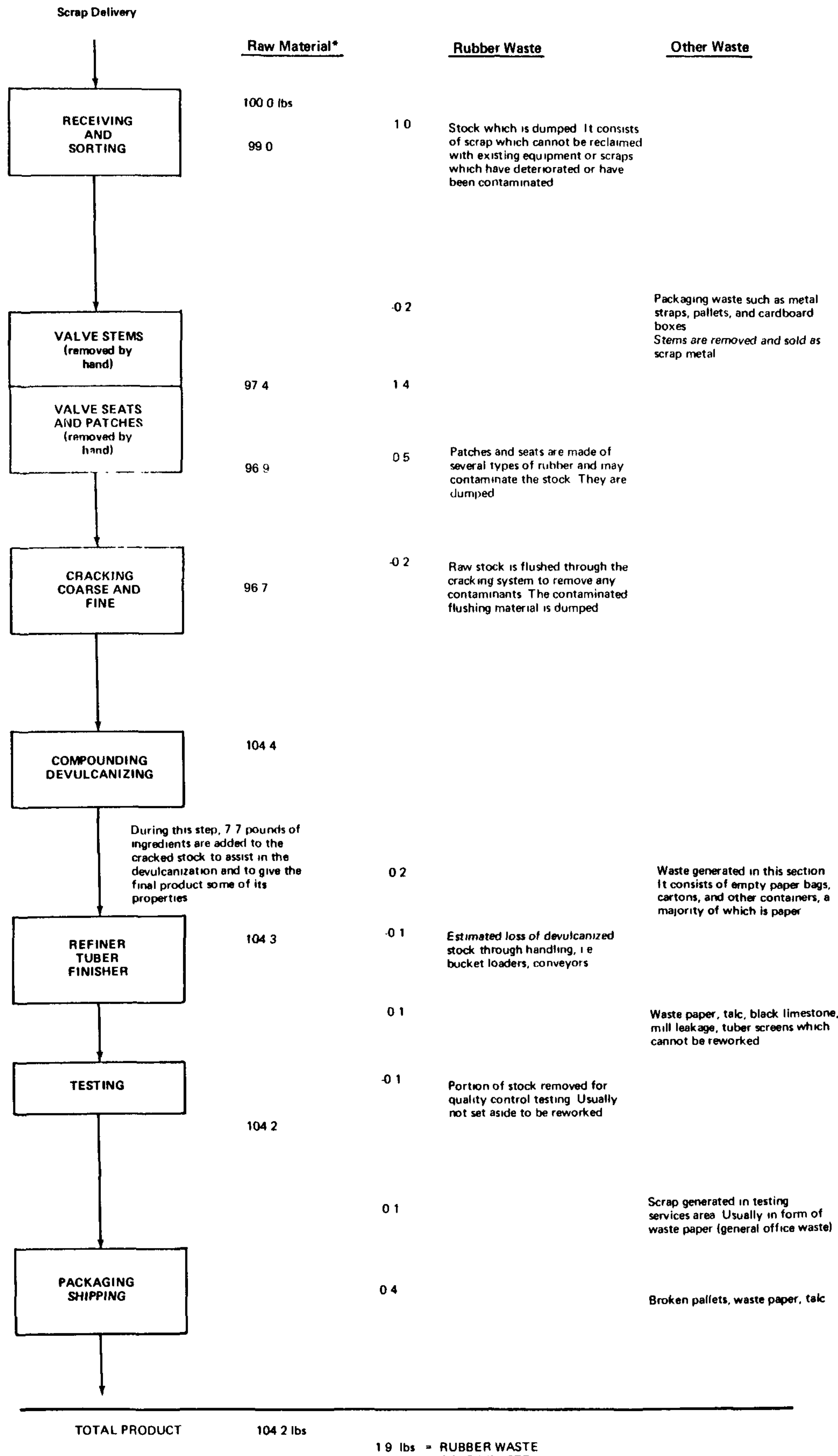


TOTAL PRODUCT 86 5 lbs

0 6 lbs RUBBER WASTE
25 3 lbs OTHER WASTE

*If the raw material does not contain any reinforcing fabric or metal, this weight (5 0 + 19 0 lbs) will be deducted from the OTHER WASTE total and added with additional compounding ingredients to the total product weight

FIGURE II-5 PAN OR DRY PROCESS



*The raw material used in this example consists of inner tubes.

FIGURE II-6 RUBBER CRUMB PROCESS

Process Step	Raw Material*		Rubber Waste	Other Waste
Scrap Delivery	100.0 lbs.			
RECEIVING AND SORTING		-0.7	Stock loss usually due to deterioration or discoloring of material, contamination, or discontinuance of product line.	
	99.3			
		-0.2		Waste generated in form of waste paper, wire strapping, broken pallets, etc.
CRACKING COARSE AND FINE	99.1	-0.2	Raw stock is flushed through the system to remove any contamination. This flushing material is discolored and/or contaminated and cannot be used. It is dumped.	
	98.9	-0.1	Estimated loss through machinery and materials handling equipment.	
TESTING	98.8	-0.1	Portion of stock removed for quality control testing.	
		0.1		Scrap generated in testing services. (Usually in form of general office waste)
SHIPPING AND PACKAGING	98.7			
		0.1		Broken pallets, waste paper, talc, strapping.

TOTAL PRODUCT 98.7 lbs

1.1 lbs. = RUBBER WASTE
0.4 lbs. = OTHER WASTE

* **The raw material used in this chart consists solely of rubber polymer which does not contain any reinforcing fabrics or metals. If the raw material selected does contain metal or fabric then the weight of this material must be deducted from the final product weight and this separated metal or fabric becomes other waste.**

THE RECLAIMING PROCESSES

An indication of the state of technological development of the reclaims industry can be obtained from a study of the reclaim processes. The following processes are itemized in chronological order of events leading to the reclaiming of waste rubber. However, not all reclaimers may use all of these processes nor the same equipment. The individual process and its equipment may vary from company to company but the end result is comparable. Items such as product blowers, conveyors, manpower, numbers of machines and their productivity, in-plant trucking, storage areas, inspection stations, cleaning and maintenance stations are not included but are assumed to be required at the discretion of the reclaimer.

The three basic processes used are digester (wet), devulcanizer (dry) and mechanical. A generalized material flow pattern for each process indicates the differences between each (Figure II-7). All three processes do contain some common steps and process equipment. The first step is to separate the many wastes into four basic streams such as tires, tubes, mechanical scrap and miscellaneous. Part of this step includes the removal of the brass and steel valve stems from the tubes and these stems are either sold or discarded as waste. Also, the bead wire from the tires is removed and discarded as waste. These metals were once more widely sold as recoverable waste. The metal removal is usually done manually but some bead wire is removed by machine.

After separation, the wastes are size reduced, through two basic types of machines, crackers or hammer mills. The cracker is a two roll machine, having working roll lengths of 30" to 42" and diameters of 18" to 32" depending upon the individual reclaiming company. Each roll is corrugated or fluted axially and each roll rotates at a different speed to effect a friction ratio. As the waste is dropped into the cracker, the two rolls, which rotate in opposite directions, force the waste to pass between them. The slower roll corrugations momentarily "hold" the waste while the faster roll corrugations shear, slice, crush and abrade the waste much like a pair of scissors. The process continues until all the material passes through a classifying screen of some predetermined size. Some reclaimers further reduce the waste size down to less than 10 mesh having secondary and tertiary crackers. As the size of the waste becomes smaller, the corrugations or flutes on the cracker rolls become smaller and smaller to increase the grinding efficiency. If tires are the waste material, the separated bead wire which serves to hold the tire firmly to the rim of the automotive wheel, is removed by hand after two or three passes through the crackers unless the bead wire was cut out before the size reduction process. The action of the two rolls actually peels or scrapes the rubber off the wire, leaving only residual amounts with the metal. The bead wire is then scrapped.

The term hammer mill covers a family of several machines, in essence a high speed rotating drum which either hammers or impinges the scrap with pivoting "T" or "I" bars or with knives mounted on the periphery of the drum. There may be stationary knives located on the frame within which the drum revolved, with or without a perforated screen or plate that retains the scrap in the work area until the scrap is size-reduced to pass through the screen or plate. The machine containing drum knives, may have a special feeding device at the inlet side of the machine to control the input feed of a long strip or the like, to uniformly control the size of slicing much like a meat slicer.

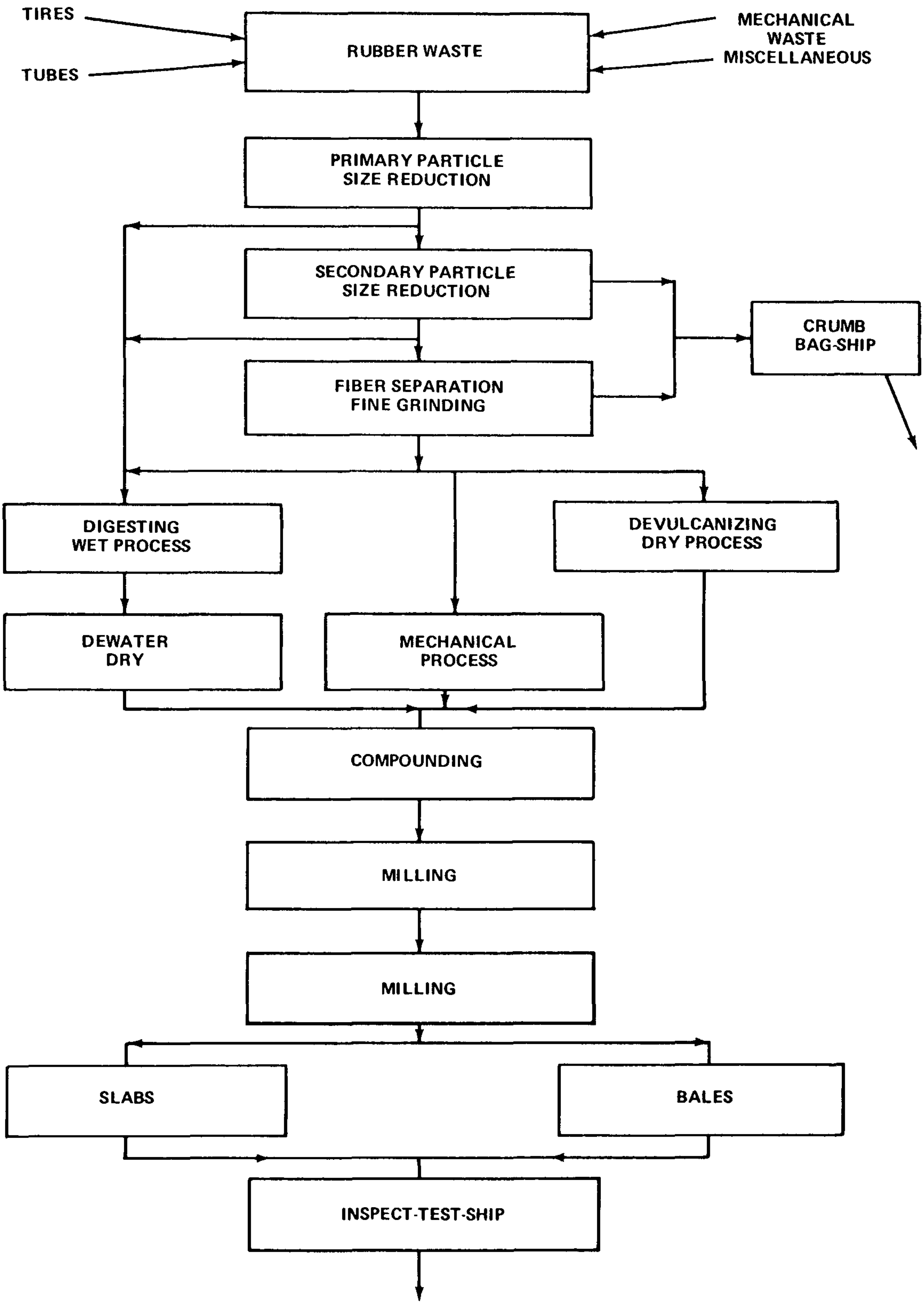
Once the size reduction process is completed, the fiber containing wastes may require either the additional process of mechanical fiber separation or chemical degradation and washing out of the fiber in the wet process. This washing sequence creates an effluent problem. The mechanical separation sequence is used by most reclaimers to circumvent the water pollution problem inherent in the digester or wet process. The fiber separation and fine grinding process is, therefore, associated primarily with scraps which contain reinforcing fiber materials such as cotton, rayon, nylon, polyesters, fiber glass and metal. In order to efficiently size reduce the waste before the actual reclaim process, the scrap must be separated from the reinforcing materials immediately after the initial size.

The input stream to the fiber separation process is first separated into different particle sized streams by a screener with several screen decks. These streams are fed onto air separation tables which effectively separate loose fiber pieces from clean rubber pieces by vibration and air flotation. The entire band of rubber/rubber-fiber/fiber is broken up into separate streams where the clean rubber is removed from the system. The fiber and rubber-fiber pieces are then fed into hammer mills for a hammering or scraping action. The degree of scrapping and size reduction is governed by the peripheral screen or perforated plate. After the material has been hammered or scraped sufficiently to pass through the screen, it is then fed to sifters or beaters. These machines, by a gentle beating, permit loose particles of rubber to be separated from the fiber and pass through a retaining screen while the fiber is conveyed to the end of the beater. The separated rubber is sometimes considered clean and is removed or if not clean enough, it is recycled to the screeners. As to the fiber, it is recycled either to the screener or to another set of hammer mills.

The last phase of the fiber separation process is baling the waste fiber that is removed from the scrap. This baled fiber is usually made up of small strands, less than 1½" long, and contains a very small amount of entrapped rubber. If there is a market for this fiber, it is reused, otherwise it is discarded. In some instances, the fiber is further processed by passing it through a carding machine to further cleanse the fiber for reuse.

The fiber separated rubber is conveyed to a storage bin for further size reduction. This size reduction is in the form of fine grinding. Crackers, much like those used in primary size reduction, with very small axial corrugations permit size reduction of the rubber to -30 mesh or smaller. Hammer mills as described earlier can also be used for the finer grinding of the rubber but are not as efficient as crackers.

FIGURE II-7 RECLAIMING PROCESS CHART



Material that has gone through the crackers or hammer mills is then screened. Particles that pass through the screens are considered product while the remaining material is recycled for further size reduction. This clean and fine ground rubber crumb is now ready for the heat of the reclaiming or softening (devulcanization) process.

The three processes used for reclaiming and the approximate percentage of reclaim made by that process are as follows:

Digester or Wet Process 58%
Devulcanizer or Dry Process 34%
Mechanical Process 8%

The actual reclaiming process is basically a softening of the rubber scrap for reuse in other products.

In the digester or wet process, an agitated vessel, usually jacketed for heating, is used. Scrap is placed in the vessel with water and reclaiming oils, heated for a specified time and then discharged as a slurry into a blowdown tank.

The blowdown or discharged rubber is extremely hot causing the vapors to be superheated. These vapors are subsequently condensed and the volatile oils recovered for reuse. Air pollution is virtually eliminated. The now softened rubber is mechanically de-watered and dried by various means such as hot air ovens, tray dryers, etc. prior to further processing. In this process, scraps used usually contain reinforcing fabric which is degraded and washed out by the action of the water, chemicals, and heat.

The devulcanizer or dry process is the second most important reclaiming process, and is used when there is no reinforcing fibers included in the scrap, such as tire innertubes, mechanical scrap or fiber separated fine ground tire scrap. In this process, fine rubber particles are premixed with reclaiming oils and placed in stacked shallow pans, or in an open cylindrical boat, both of which are usually mounted on wheels so that they can be rolled into a horizontal autoclave. After a heating period, the autoclave is opened and the reclaimed or devulcanized scrap is unloaded and cooled, ready for further processing. Generally there is no need to dry the discharged material unless the steam used is not superheated.

The mechanical reclaiming process, unlike the other two preceding processes, is continuous and also uses fabric free wastes. The fine ground wastes are continuously fed into a high temperature-high shear machine with the reclaiming oils. The rate of devulcanization is controlled by the speed of a screw, while the compression and temperature is maintained constant. The discharged reclaimed rubber needs no drying and is ready for further processing.

The reclaimed or softened rubber from any of these processes is rarely used without subsequent compounding which is necessary to impart special physical properties to the finished reclaims. There are many types of machines to mix the compounding ingredients into the softened rubber before final processing. The actual ingredients to be added are in the form of low and high viscosity, heated and unheated liquids; granular and powdered fillers, pellets, etc. These ingredients must be thoroughly dispersed into the softened rubber. The mixers most commonly used to incorporate the fillers into the rubber are either horizontal or vertical ribbon, or conical rotating blenders. The horizontal mixer, the most popular, is an enclosed rectangular box with a rounded bottom having the mixing accomplished by a horizontally driven continuous ribbon, paddles or the combination of the two. Some units are batch mixers while others are continuous, depending upon how the inlet and discharge ports are positioned and the length of the machine. Conical rotating blenders are cylindrical with the entire enclosure rotated between centers concentrically or eccentrically.

Once the rubber and compounds are mixed, these materials, must be intimately blended and massed. This is sometimes done continuously, as in the mechanical reclaiming process, but in the other processes it is done separately. The two basic massing machines used are the Banbury and the extruder. The Banbury is a heavy duty machine with counter-rotating blades that is self-cleaning and imparts a high shear to the feed material. The shear may be altered by moving the ram up or down to change the pressure exerted on the material being massed. This machine is a batch type but recent developments can make these machines continuous by the use of twin screws to feed the material into the body of the Banbury. Usually it takes between 1 to 3 minutes to mass the material in the batch machine while the continuous unit does it in a shorter time. The other massing machine, the extruder, is much like any other extruder except that for rubber massing, a compression ratio of 3:1 to 5:1 is required and the length to diameter ratio is much higher. It is a continuous process machine and more reclaimers are converting to this mode of massing.

The massed reclaim is then refined and strained to complete the process. Refining imparts a smooth uniformly clean quality to the rubber, with the rubber sheeted into a very thin film from .002" to .010" thick. The strainer removes foreign materials such as glass, metal, wood or sand from the rubber, using screens of 10 to 40 mesh opening. The amount of milling depends upon the size of the reclaimed rubber particles and the degree of milling required by the customer. The finer the grinding in the earlier processing, the less refining is required.

The strainer is a heavy duty extruder with the screw seldom exceeding a 2:1 compression ratio. Some strainers have flared heads to increase the screening area and capacity, while others have hydraulic or electric activated heads to permit faster screen changing.

Refiners or refining mills are similar to the crackers described earlier, except the rolls are smooth. Some reclaimers refine their rubber with only one pass through the mills while others pass the rubber through mills for three or four passes. In these cases, the rubber is milled for the extra passes to smooth out the large rubber particles and to form a relatively thin sheet which can then be strained. After straining, the rubber may be given more passes in the mills to further squeeze the small rubber particles to form a very smooth homogeneous sheet.

The finishing operation may be combined with the refining and straining but for clarity it is separated in this report. Each reclaimer may complete his reclaiming operations in either of two ways – by sending his product to the customer in the form of slabs, stacked on pallets, or in bales. Slabbed reclaim is made on a mill and the discharged sheet is wrapped on a rotating drum of a specified diameter, until the proper thickness is required. The wrapped layers or sheets are then cut off the drums, forming a solid slab of a certain length, width, and weight. The slabs are then dusted to prevent sticking to each other, tested and shipped to the customer. Baled reclaim, is similar in the milling sequence, except the thin milled sheet is conveyed to a baler, where the rubber is compacted to form a bale. The bale is then encased in a bag, stacked on a pallet and sent to customer after testing.

Another reclaim process not discussed in detail is crumbed rubber waste (Figure II). This material is any type of non-reinforced rubber, not softened like regular reclaim, but finely ground in cracker mills to a very discrete particle size, bagged and sent to the customer.

TRENDS IN THE RECLAIM INDUSTRY

Despite the steadily increasing production and use of rubber products in the United States, the trend is downward for recycle or reuse of waste products as reclaim. As a percent of new rubbers produced, reclaim has declined from 19% in 1958 to 10% in 1968. (Figure II-8) Some of this reduction is probably due to development of new rubbers not compatible with present reclaims. Undoubtedly, the major reductions were caused by cost, quality, or esthetic reasons. A comparison of the reclaim usage in 1960 with 1967–'69 (TABLE II-8) indicates substantial reductions in some usages by application. Competitive materials as rugs, colored plastics have reduced usage in automotive mats and mechanical parts from 105 million pounds in 1960 to approximately 55 million pounds. Similar reductions are noted for other mechanical goods, hose, shoe heels and soles, and hard rubber products. In general the tire and innertube application consumption has remained virtually constant at the 380 million pound level.

Whole tire and butyl reclaimed rubbers are incorporated in innerliner compounds to reduce cost, improve processing and improve air retention (butyl reclaim).

Improved compounds and constructions which minimize the liner requirements have resulted in some reduction in liner compound and also the reclaim. Increased flexing and heat buildup caused by lower tire pressures, low aspect ratios, and higher speeds have resulted in a trend towards the substitution of new rubber for the reclaimed rubber in the innerliner.

FIGURE II-8 RECLAIM CONSUMPTION AS A PERCENT OF TOTAL NEW RUBBER

TABLE II-8

RECLAIM CONSUMPTION BY PRODUCT

	'60	'67	'68	'69*
Tire & Tire Repair Mat'l		364.3	385.3	377.4
	380.6			
Innertubes		15.2	30.0	18.6
Auto Mat & Mech	104.8	55.8	57.6	55.3
Hose, Belt	36.1	26.2	24.9	31.8
Mechanical Goods	52.6	31.8	23.5	32.9
Non Automotive				
Cements & Dispersions	15.7	16.4	18.4	19.7
Heels, Soles	17.0	8.7	11.4	5.6
Hard Rubber	26.2	14.3	7.4	6.7
Rubber Surface	–	4.9	5.1	3.3
All Other	22.9	11.0	12.1	8.3
Total	655.9	548.6	575.7	559.6

*RRA Estimate

Despite the usual cost reduction and improved processing advantages to tire carcass production, the increased heat buildup reported for these compounds containing reclaimed rubber has resulted in some reduced usage in carcass compounds. Sidewall compounds which have traditionally contained large amounts of reclaimed rubber to control shrinkage of the extruded sidewall, eliminate mold blemish and lower costs, are also undergoing a trend towards reduced usage. This again is due to the requirement for compounds with increased resistance to the flex cracking brought about by the increased flexing in lower pressure tires, wide oval types, and the increased ozone concentrations in the atmosphere. The low abrasion resistance of compounds containing reclaimed rubber limits its use to very low levels to control shrinkage in the first line treads. Larger amounts of reclaim are used to lower costs of lower quality tread compounds. Fine ground tire peelings are being added to tread compounds with satisfactory results.

The reclaimers are continuously conducting programs to develop improved reclaimed rubbers for tire usage and improved tire compounds utilizing reclaimed rubber. However, the speed with which major changes in tire constructions are being made, particularly toward constructions with increased flexing, has made instant demands for compounds with improved physical properties which the tire compounders have often obtained by reducing the amount of reclaimed rubber. The relatively low price of reclaimed rubber does not seem to provide the incentive for these compounders to increase the usage nor do the low profits of the reclaimers justify additional expenditures to carry out the necessary development program.

Some of the required developments include:

1. Improve resistance to flex cracking in liner and sidewall compounds.

2. Improve low and high temperature liner compounds.

3. Study of reclaim in carcass compounds.

4. All of the above will require both laboratory work and extensive service tire testing.

5. Lower cost reclaim rubber.

A number of other products which have traditionally used large quantities of reclaim are also using less reclaim at the present time.

Hard core soft tread tires are being molded from compounds containing lower levels of reclaimed rubber and are also being replaced by plastics in many applications.

The change from calendered black rubber to carpet and plastic mats in automobiles and trunk mats has resulted in a large cut-back in reclaimed rubber usage.

More competitive synthetic rubber prices are allowing the compounding of semi-pneumatic tires with low levels of reclaimed rubber thus reducing usage in a previously major market.

The light colored natural rubber scraps required for reclaimed rubbers for cements and dispersions are no longer in constant supply and scrap costs are generally high, effectively restricting the production of these reclaims. Light colored synthetic scraps cannot be formulated into reclaims for adhesives due to limited tack and solubility and are generally too high priced for use in reclaims to compete with new SBR.

Ground rubber waste has many present reuse applications due to its lower cost. Without any additional reclaiming costs other than segregation, fiber or metal contamination removal, and grinding, it is useful and competitive to other materials for molded rubber applications. The lower transportation cost advantages of bulk shipments of this crumb rubber cannot easily be achieved due to the ICC regulation classifying this material with a yellow label as inflammable.

Reclaimed rubber formerly used in hard rubber products, battery cases, combs, etc. has been almost completely replaced by new rubbers and plastics due to the lower and product cost possible with these materials.

In general it can be seen that the low SBR prices are allowing compounding in competition with reclaimed rubber and until there is a definite economic advantage for reclaimed rubber no trend toward increased usage can be anticipated.

PROCESSING ADVANTAGES AND COST SAVINGS

The use of reclaimed rubber whether as a source of rubber hydrocarbon or as a compounding ingredient will usually result in compounds with lower overall costs and improved processing characteristics.

Traditionally one of the main advantages of reclaimed rubber has been the competitive lower cost. This is no longer true with respect to material cost due to the low priced, oil extended synthetic rubbers. Even with this fact established, the stable low price of reclaimed rubber offers an advantage in helping stabilize new rubber prices and providing a firm base for estimating cost.

The chemical action of the reclaiming process combined with the extensive mechanical refining and the presence of fillers results in a product with low nerve. This low nerve is responsible for many of the processing advantages gained from the use of reclaimed rubber. Reclaimed rubber compounds generally process faster in extrusion and calender operations with significant reduction in shrinkage and die swell and improvement in gauge control. Heavy gauges can be calendered blister-free at high rates when reclaimed rubber is added. These compounds also exhibit less heat build up during processing and will cure uniformly in fast higher temperature cycles.

Reclaimed rubber's low nerve can reportedly reduce the fabricator's power costs as much as 35%. The peak horsepower demand, which usually determines the electrical cost rate, is also significantly reduced, increasing the savings. It has been estimated from experience that a reduction of one minute per batch in mixing time by the use of reclaim in standard compounds reduces costs by as much as four dollars per ton of compound and permits an increase in thruput rates of up to ten percent.

Other dollar savings are realized from the faster processing of extruded and calendered stocks; less rework due to out-of-specification processed parts; short and safe high temperature cure cycles; and fewer defective finished parts.

Following is a list of technological and marketing advances which reclaimers recommend as ways to improve the consumption of their products:

a) The establishment of standard specifications for reclaims to be established by the Rubber Reclaimers Association. Reclaimers will produce these at their discretion for general market consumption in addition to their regular customer-oriented reclaims.

b) The improvement of abrasion resistance: Although the reclaimers mills do a very thorough job of mixing reclaim components, high magnification inspection reveals "pockets" of carbon black, fillers, oils, etc. These pockets readily abrade and a more thorough method for dispersion must be sought.

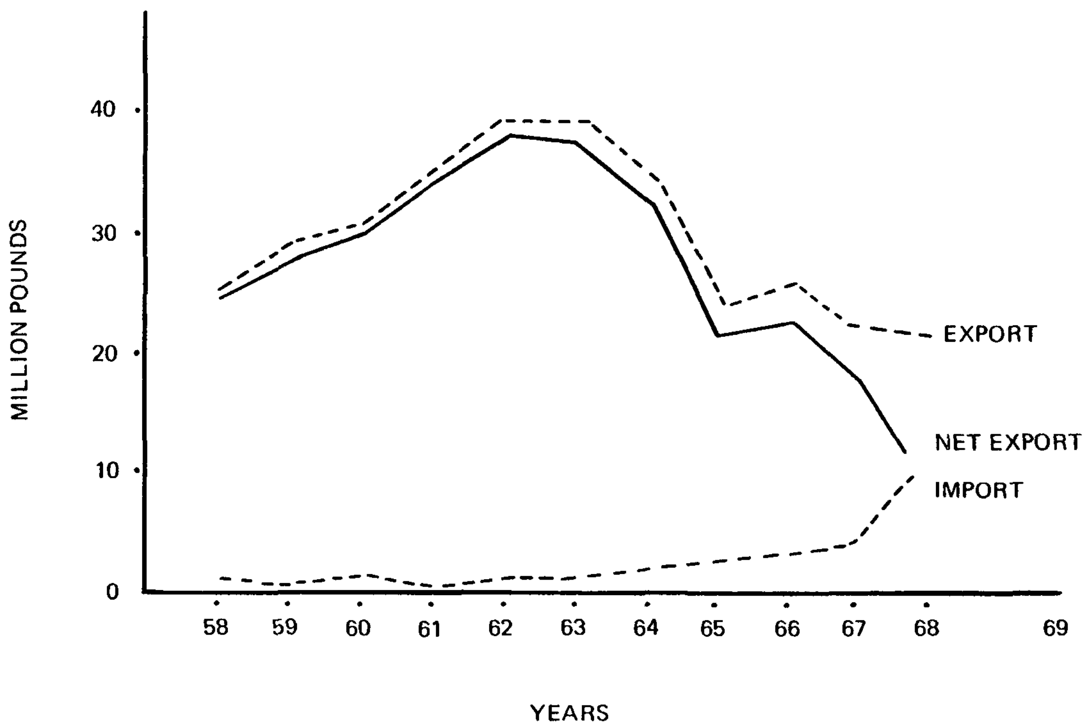
c) Improved heat resistance. The need for products with improved heat resistance has forced a change from natural rubber, SBR and related reclaims to newer specialty heat resistant elastomers.

d) Public education: The quality of reclaim should be stressed and its false reputation as a cheap diluent minimized. An image as a technically desirable raw material should be emphasized. These two objectives would be aided by the establishment of reclaim standards for quality and performance.

RECLAIM EXPORTS/IMPORTS

The increasing availability of local scrap tires, expansion of reclaiming facilities, and generally lower wages have resulted in the production of more and lower cost reclaims outside of the United States. These factors have caused a sharp and steady decline in the export of reclaims and are probably also responsible for the increase in reclaim imports. It is apparent that the overall effect will be that imports will exceed exports in the near future and that this change will be reflected as a reduction in domestic reclaim production. (FIGURE II-9)

FIGURE II-9 RECLAIM EXPORTS/IMPORTS



Section III
The Retread Industry

TIRE RETREADING HISTORY

Tire retreading had its beginning over 60 years ago. The first retreads were produced by cutting off the remaining old tread, buffing the surface and applying a layer of vulcanizable cement on the tire. Then a tread which had been previously vulcanized was buffed, cemented and placed around the tire. A flexible steel coil was placed inside the tire and the assembly was wrapped with canvas strips like a bandage. The tire was then placed in a kettle or tub and vulcanized with live steam. In 1912 "Dry Tread Cures" were introduced. Here, an unvulcanized tread was placed on the buffed tires. The tires were then placed in a quarter circle mold where a portion of the tread was cured. After one section was cured the tire was turned in the mold and the cure continued until all sections of the tread were vulcanized. Heat was supplied by coal or gasoline fired boilers. The pressure necessary to vulcanize the rubber to the tire was applied by clamps and sand bags placed inside the tire. In the early 1920's the first full circle retread mold appeared and retreading began to progress. By 1926 a mold in the shape of a circular heater was introduced that, fitted with various aluminum forms, could retread several sizes of tires. This was developed into a clam shell type of mold with boilers operated by a small gas or oil burner.

THE RETREAD INDUSTRY

A retreader converts worn tires by applying new tread compound in such a manner as to make the tire reusable. Depending on the number of times the individual tires are retreaded, the useful life of the original tire is substantially extended.

In the years 1930 to 1940 passenger tire retreading grew at a rate of 10% per year. By 1944 – when World War II production was at its height – retreads accounted for 30 million units. Following a large drop in production after the war, the retreading industry has since grown at a rate of approximately 3% per year.

The estimated number of passenger car tires retreaded increased from 29.9 million units in 1958 to approximately 36 million units in 1963 and has remained fairly constant since that time. The larger sized truck tires retreaded has increased steadily from 7.3 million retreads in 1958 to 9.7 million in 1968 (TABLE II-9).

A comparison of retread versus new tire production indicates retread passenger tires constitute approximately 17% of tires in use. Retread truck tires constitute 28% of tires in use. Without the retread industry, all tires now retreaded would have been added to solid wastes in the year retreaded and new tire production would have been increased to replace them, adding still further to the solid waste disposal problem.

TABLE II-9

PRODUCTION OF RETREADED TIRES
(Millions of Tires)

	Passenger Car Tires	Truck
1958	29.9	7.3
1959	32.4	7.6
1960	30.6	7.4
1961	31.9	7.6
1962	34.5	7.7
1963	36.3	7.5
1964	36.0	8.0
1965	36.0	7.6
1966	35.3	8.0
1967	34.5	9.3
1968	35.8	9.7
1969*	36.5	10.0

*Estimated

There are approximately 8,500 retread plants in the United States of which 8,000 are independent dealers and retreaders. The balance are operated by large tire companies and other mass marketing organization or chains.
The estimated daily capacity is 211,650 units, equivalent on an annual basis to 50-60 million units depending upon the number of days operated. Capacity utilization is then calculated to be approximately 85%.

Usage of Rubber Waste

A majority of retreaders receive their tires from scrap dealers. The next largest source for retreaders is turn-ins, tires left at the store when replaced by new ones. Steel reinforced tires are presently being retreaded, however studded tires are done only on request from specific customers.

Tires actually successfully retreaded and put back into service accounted for 1.242 billion pounds recycled in 1958 and 1.560 billion pounds for 1968. (TABLE II-10). This usage does not include any units rejected as being unsuitable prior to retreading or the estimated 3% rejected after retreading. Usage is calculated by multiplying the number of reported retreaded tires by 23 pounds for passenger tires and 76 pounds for truck tires. This is the average original weight minus 8% and 8½% tread loss respectively.

TABLE II-10

WEIGHT OF WORN TIRES USED IN RETREAD INDUSTRY

THOUSAND OF POUNDS*

	Passenger tires	Truck tires	Total
1958	687,700	554,800	1,242,500
1959	745,200	577,600	1,322,800
1960	703,800	562,400	1,266,200
1961	733,700	577,600	1,311,300
1962	793,500	585,200	1,378,700
1963	834,900	570,000	1,404,900
1964	828,000	608,000	1,436,000
1965	828,000	577,600	1,405,600
1966	811,900	608,000	1,419,900
1967	793,500	706,800	1,500,300
1968	825,400	737,200	1,560,600
1969	(839,500)	(760,000)	(1,599,500)

(Estimated)

*The tread rubber added to the casings is included in the 10.7 billion pounds of new rubber products manufactured in 1968.

Very little solid waste is created by the retread industry. The largest waste item is tread buffings generated during the preparation of the tread surface prior to application of the new tread. The old surface is buffed with wire brush wheels hence the term "buffings" for the abraded rubber dust. Approximately 1½ pounds and 4 pounds of buffings are produced from passenger and truck tires respectively. Calculated buffing weights based on tires processed indicates a waste increase from 74 million pounds in 1958 to 92 million pounds for 1968, or approximately 6% of the weight of the waste tires recycled (TABLE II-11).

TABLE II-11

BUFFINGS PRODUCED ANNUALLY
Millions of Pounds

	Passenger	Truck and Bus	Total
1958	44.9	29.1	74.0
1959	48.7	30.5	79.1
1960	45.9	29.7	75.7
1961	47.8	30.3	78.1
1962	51.7	30.9	82.6
1963	54.4	29.9	84.3
1964	54.0	31.9	85.8
1965	54.0	30.2	84.2
1966	52.9	32.7	85.1
1967	51.7	37.1	88.8
1968	53.7	38.8	92.5
1969	*54.8	*40.0	94.8

*Estimated

In 1968 reclaimers reported using 97,378 pounds of these buffings equivalent to less than 1% of years total. It is known however, that substantial quantities of this material are used in other industries i.e. brake lining, asphalt composition, etc. No reported data is available.

Rejected retreaded tires amount to about 3% of those retreaded. This is equivalent to 550,000 pounds of waste per year consisting of approximately 90% old waste tires plus 10% of new tread rubber added to tire.

Less than 5% of total industry waste has been reported as being from packaging materials. This is equivalent to approximately 4 million pounds per year.

Total industry waste in 1968 was 99.3 million pounds of which 95 million pounds was unused tire waste (TABLE II-12).

TABLE II-12

Total Waste From Retreading Industry – 1968

Thousand of Pounds

From Waste Tires	**weights**
Buffings	94,750
Rejected Retreads	550
Subtotal	95,300
New Waste	
Packaging	4,000
GRAND TOTAL	99,300

PROCESSES

The retreading of a tire today involves several steps. First the old tire is inspected. Without a sound casing or tire carcass all other production efforts and controls are of no value. There must be no cuts or deterioration of the reinforcing fabrics. Air is injected into the shoulders of the tire to detect hidden ply separations, the major cause of tire failure. The tire is now vented in the bead area. This will allow trapped air to escape during the molding process or during highway flexing. Any trapped air could expand to cause ply separation. The tire is now buffed. All the remaining tread is ground off in this step. After buffing, the crown is cleaned with a stiff wire brush to remove any rubber dust. The next step is to measure the tire. Tires have a tendency to "grow" after some road use. This growth can amount to 7% of the tires original width. After this measurement, the wall thickness of the tire is determined. This is necessary in order to select the correct curing rim and assure a tight fit of the tire in the matrix. Vulcanizable rubber cement is now sprayed on the tire. Strips of tread rubber are wound circumferentially around the tire. This tread rubber called "fast cure", was introduced in 1957 and cuts the vulcanization time 20%. From here the tire goes into the mold where is is cured. Later it is inspected and made ready for delivery. One third of the retreaders today "program" the tread on. In this method, a thin strand of tread stock is slowly wound around the tire. The machine operator selects the profile he wants built onto the tire and the machine automatically wraps the rubber strand around until the exact contour is built up. The curing and inspection steps follow.

The next major process in use is called the "Bandag". It is used primarily on truck and bus and larger tires. The tire is prepared as usual and a partially cured tread is placed on the tire. The tire is now cured in a much shorter time. The shorter cure helps to extend the life of the tire as heat deteriorates the tire rubber, and also weakens the fabric. A shorter cure time has another advantage in that it helps to achieve better production rates from expensive curing apparatus.

TRENDS IN THE INDUSTRY

There are many factors that are limiting the retread industry growth and hence the reuse of road worn tires. ([1]) It was noted that passenger tires retreaded have plateaued out at approximately 36 million units from the period 1963 to the present. The main growth in units recycled has been in the larger size, truck tires. However, in terms of percent of new tires recycled, passenger tires have dropped from 25% in 1963 to 17% in 1968. Truck tire recycle has also dropped from 32% to 28% (FIGURES II-10 and II-11). There are many reasons for this lower reuse of waste tires. In general, the average passenger tire customer views retreads as a "second class citizen" of the tire world. This connotation evidently arises from the idea that "used" materials are always inferior to new materials regardless of the quality of the new materials. With respect to tires, it may also be related to some poor customer experience as far back as the customer may remember, possibly to the post World War II period before the industry reached its present level of sophistication. The growth of units recycled in truck and airplane type tires however tends to negate this type of thinking. Users of these tires are looking for service and cost and are not hesitant to retread tire casings more than one time if possible.

The apparent reluctance to accept retreaded passenger tires as readily as truck type tires are accepted may be valid by reason of quality differences. It has been noted that these larger tires require larger equipment and hence may only be handled by larger retreaders, those who may have more sophistication than some of the smaller shops. Also the shortage of suitable passenger tires available for retreading may lead to relaxation of standards.

Retreaders in general try to retread only the best grade of tires, eliminating the lower cost, lower quality, lines of new tires. Testing of the better grades also eliminates many tires as unsuitable for retreading due to damaged carcasses, etc. The approximate 20% level of retreaded tires from all new tires manufactured leads one to believe that this level may not be easily exceeded, because of excessive carcass abuse in normal service. Retreading can only replace tread wear and cannot correct other damage.

Most competition comes from 3rd and 4th line new tires specifically designed to compete in the "retread" cost market. These tires, carrying the name brand of a national company are backed by national advertising and distribu - tion. The small retreader competes against these with a brand-less tire. There is some "name" retread competition by national tire companies, selling retreads on their own brand carcasses.

A more complete review of the myriad of problems is available in the literature([1]). The major problems are inherent in the complexity of tire sizes, tread widths, etc., and the variable expansion of the tire carcass during its original use. This forces the good retreader to measure each tire, maintain a large inventory of molds, juggle his inventory to maintain balance of salable sizes etc. Any future tire quality specifications may also complicate the retread industry.

All of these factors have tended to increase the cost of retreading whereas the selling price has not increased proportionally thereby putting the squeeze on the industry profits. There is some feeling in the industry that this profit squeeze may have led in some instances to lowering of quality. If there is any basis in this viewpoint, it can only lead to reinforcing the "second class" status of the entire industry.

Some representatives of the industry believe that reason - able, workable standards for the industry could lead to increased usage of retreads by improved quality, and better acceptance by the public through improved reliability. Unworkable standards may conversely seriously restrict the largest single converter of tire waste.

([1])Braner, H.H., An Analyses of the Domestic Retreading Industry, Ranno Printing Co., Englewood, N.J., 1965

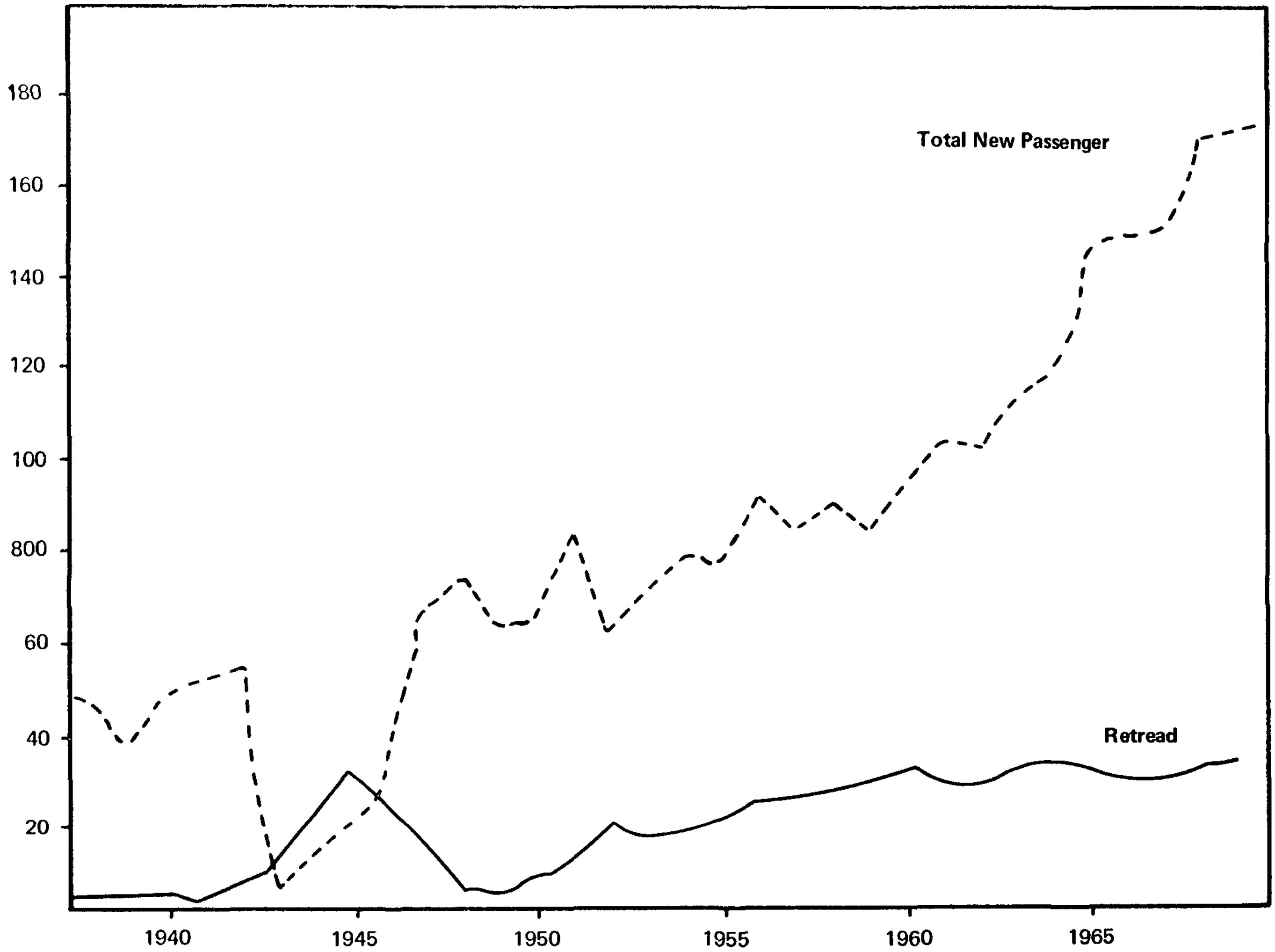


FIGURE II-10 DOMESTIC PASSENGER TIRE SHIPMENTS AND RETREADS
(MILLION UNITS)

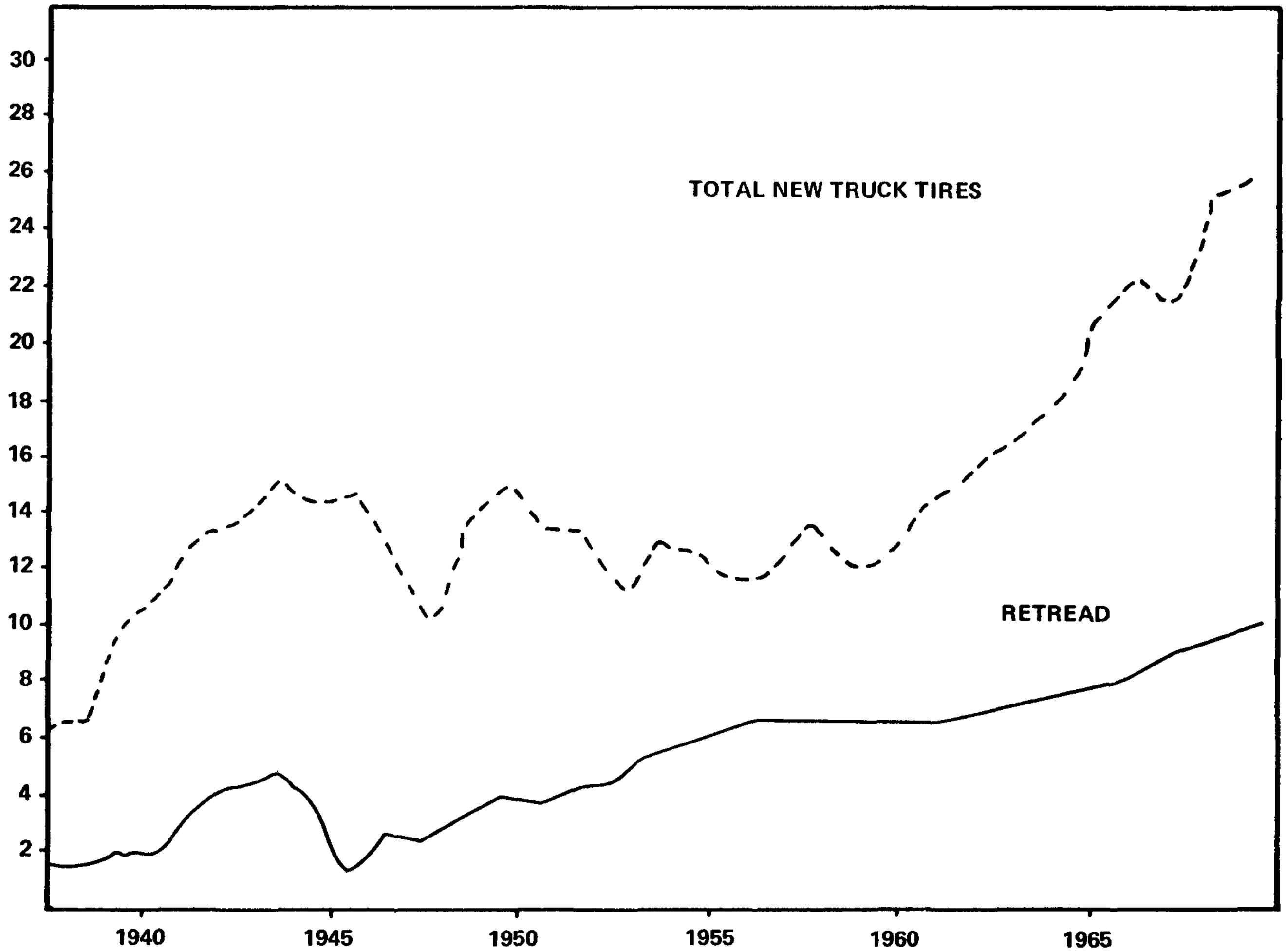


FIGURE II-11 DOMESTIC TRUCK TIRE SHIPMENTS AND RETREADS
(MILLION UNITS)

Section IV

The Tire Splitting Industry

HISTORY OF TIRE SPLITTER INDUSTRY

Around 1915 when tires became available in large quanti - ties, the forerunners of tire splitters called tire pullers came into being. The industry consisted of pulling the cotton fabric off old tires, thus separating certain plies of fabric from each other and from the tread and sidewall. The bead was first removed to make the carcass flexible. Bead removal was first done by hand and later by machine.

John Ball discusses the operation in his book "Reclaimed Rubber, The Story of An American Raw Material." R.R.A. New York 1947. "The pulling of tires was first done by hand, then with a pulley attachment, and later by a simple motor driven machine. The elementary methods were quite satisfactory as long as the fabric used in tires was square woven duck, which has good strength and cohesion in any direction to withstand the sudden pull or jerk." The introduction of Weftless Cord in tires instead of square woven duck made it very difficult to separate plies and tire splitting instead of tire pulling came into being around 1925 when machines used to split hides and leather in tanneries were employed to split tires. During the war years, the prices of blowout patches and reliners, both typical products of tire splitters became very high. As a result, tire splitting became a very big business and in the summer of 1945 over 125 splitters were in operation. They accounted for about 1/3 of all the tire scrap received by the reclaimers.

TIRE SPLITTER INDUSTRY

A portion of the nation's waste rubber is consumed by the tire splitting industry. These little known companies use worn-out bus, truck, and passenger tires. The bead wire is removed by cutting or stamping; the tread is cut and peeled off the tire carcass and the remaining carcass is slit into three sections, the crown or tread and the two sides. These carcass sections are now planed to uniform thickness and placed in a press which die cuts out the final product. Typical products are gaskets, shims, automotive tail pipe insulators, and the familiar door mats. Circular and square pieces are also stamped out and bolted or pinned together to form items such as conveyor rollers for handling produce, light load V-belts, and bumpers for docks and loading platforms. Today there are three tire splitters in business (Note 1.) Each, however, has an optimistic view of his market and production and sales increases of 10 to 30% are expected.

A total of 239 people are employed in the tire splitting industry, 29 of which are salary and 210 are wage. All of these companies are located within communities of 100,000 population or more. During the year 1968, splitters consumed 39 million pounds of passenger tires and 15 million pounds of truck and bus tires, are normally accumulated within a 100 to 200 miles radius from their production facilities. The cost, up to $15/ton-delivered, is somewhat higher than the average cost of scrap tires to conventional reclaimers.

Note 1

1.	A. Lakin & Sons, Inc.	Chicago
2.	A. Schulman, Inc.	E. St. Louis, Ill.
3.	A. Baker Manufacturing Co.	South Bend, Ind.

SOLID WASTE & BY PRODUCTS FROM INDUSTRY

Of the 57.5 million pounds of scrap tires consumed by the industry, 14 million pounds were converted into finished product (25%). The remainder was converted into 36 million pounds (63%) of useable by-product which was sold to reclaimers. The remaining 7 million pounds (12%) was returned solid waste. (TABLE II-13) In addition to the 7 million pounds of rubber waste not used, the industry created three and one-half million pounds of new waste. (TABLE II-14)

TABLE II-13

TIRE SPLITTERS-MATERIAL BALANCE (in 1000 pounds)

PRODUCTS	
Split Tire Products	13,980
By Products-To Reclaimers	
Tread peels (a)	8,200
Carcass Selvage (b)	27,892
	36,092
SOLID PROCESS WASTE	
Bead Wire (c)	4,480
Tires Unsuitable For Splitting (d)	2,980
GRAND TOTAL TIRES PROCESSED	57,532

(a) Tread portion of tires which is peeled off.

(b) Remainder of tire carcass after parts are die cut out.

(c) Bead wire portion of tires including rubber and fabric covering which is cut from tire. Also includes 660,000 pounds of process waste, selvage, which is lost as floor sweepings. This is disposed of with normal trash.

(d) Unused tires which are sorted from purchased scrap tires as not being worthy of splitting, mainly studded winter tires, steel re-inforced tires, and tires too small to process.

TABLE II-14

TIRE SPLITTING INDUSTRY WASTE
(in 1000 pounds)

SOLID PROCESS WASTE	WEIGHT
Unuseable Tires	2,980
Bead Wire & Bead Rubber	3,820
Process waste, selvage, sweeping	660
Sub-total	7,460
OTHER SOLID WASTE	
Packaging Materials	1,660
Other Categories	1,920
Sub-total	3,580
Grand Total	11,040

The overall industry material balance then becomes

57,532,000 lbs. scrap tires accumulated
13,980,000 lbs. of parts produced and sold
36,092,000 lbs. of by-products sold mainly to reclaimers
7,460,000 lbs. of scrap tire waste dumped
3,580,000 lbs. of new waste dumped

The overall reduction in total waste accomplished by the industry is 46,492,000 lbs. By-products sold to the re - claimers, however, may create additional waste to those industries, particularly in the testile portion of carcass selvage. The 11 million pounds of industry waste are disposed of in sanitary land fills at a cost of 0.4 to 0.9 cents per pound. One company uses its own trucks and labor for dumping.

Section V

Mitigation

SOLID WASTE RUBBER MANAGEMENT PROGRAM

The data of this report suggests the possibility of classifying the entire waste rubber program into 3 broad areas:

a. Waste from the Rubber Industry
b. Automotive Rubber Waste
c. Consumer Rubber Waste

The Rubber Industry, as in any cost conscious industry, makes every effort to effectively reduce cost through reduction in waste product and re-use where possible. Some types of waste are kept segregated and sold to other processors for reuse such as the reclaimers. The second classification, that of Automotive Waste Rubber, is more easily segregated and accumulated after use than Consumer Waste. In addition a system already exists for the collection and utilization of this type. Consumer Rubber Waste is undoubtedly the most difficult to categorize due to the multiplicity of products and non-existence of segregation and collection facilities. While many of these consumer rubber products are reused in the reclaim industry when available as rubber industry waste, it is apparent that mixtures of these products are not easily nor economically reclaimed in any conventional manner. Any re-use of this vast mixture will undoubtedly be based on new techniques for new products. It is then recommended that the latter 2 divisions be reviewed with regard to:

a) Collection
b) Shipping
c) Storage
d) Potential Reuse
e) Ultimate Disposal

COLLECTION

The present method of collecting automotive rubber waste, predominantly tires, as outlined in Section I, could serve as a nucleus for further expansion. The method which accounts for approximately 30% collection of old tires for use in the 3 major reuse industries, should not require considerable revision to account for higher collection percentages. Scrap merchants presently gear their collection to reuse industry demand with the demand being filled from nearby areas to minimize shipping costs. Since collection is the reverse logistics of rubber products distribution, a procedure developed to minimize costs, a detailed study of this distribution may lead to more economical collection methods. It has been suggested that convenient and suitable collection sites would be automotive service stations and tire sales stores.

Other suggested collection sites are municipal disposal areas and unused armed forces areas.

Rubber waste such as tires, innertubes, and auto mats would account for approximately 68% of the rubber goods produced annually. To be accumulated automatically at these points, an economic incentive for this type of collection would have to be created by either new uses for these wastes which would cover the collection costs or an incentive to the consumer which would insure his turning the waste in, such as a deposit paid on the new article refundable upon turn-in. The latter does not appear practical as the collection sites could be overwhelmed by these worn out articles and it does not provide an incentive to the site operator. On the contrary, it requires him to maintain a costly collection and storage area.

Another plan might be a statutory surcharge on the original commodity selling price to pay for later public collection and disposal costs. This should be studied very carefully as it not only creates an additional tax on the consumer but may also be misinterpreted as license for casual discarding of the article. No convenient method of collecting the remaining rubber waste has been suggested by this report and it is recommended this be a separate study. It is possible that the inclusion of this waste in municipal waste that is to be incinerated may be helpful to the incineration, providing a readily combustible material to overcome some of the less combustible wastes. This being particularly true when wet wastes are to be incinerated.

SHIPPING AND STORAGE

If automotive tires are considered indicative of rubber waste, considerable economies could result if they are crushed or chopped as locally as possible prior to shipment to use points. The average tire occupies 1.3 cubic feet of space but when chopped, only occupies 0.5 cubic feet. More weight may be shipped per vehicle load or stored in any storage area by a factor of approximately 2½ to 1.

The recommended waste chopping may be done in stationary choppers in high waste areas or on portable choppers, moved on schedule, to low waste areas which cannot justify permanent installations. It has been estimated that the cost of a portable chopper would be $100,000. (TABLE II-15)

TABLE II-15

ESTIMATED COST OF PORTABLE RUBBER WASTE CHOPPER

1.	Flatbed tractor trailer	$40,000
2.	Alligator shears	5,000
3.	Hammer mill – hogger	30,000
4.	Screener	5,000
5.	Fiber separator/magnets	15,000
6.	Miscellaneous items	5,000
	Total (1968 prices)	$100,000

Testing of this type portable chopper in both high and low waste areas could achieve significant results, with the chopped waste also being evaluated locally as land fill or incineration fuel (see Potential Uses). It should also be noted that the design of either the stationary or portable chopper may be such as to prove of value in shredding other types of waste such as glass, wood, paper etc. so as to facilitate disposal or reuse. This should be an area of additional investigation.

One serious drawback to public transportation of ground or chopped rubber waste is the Interstate Commerce Commis - sion designation of this type material. This regulation* prohibits the bulk transportation of ground rubber waste under certain conditions. This may restrict shipments in bulk via public carriers, handling and packing costs.

*49 CFR 170:15
49 CFR 173:22
Para 73.201

POTENTIAL REUSE WITH REPROCESSING

The largest potential outlet for scrap rubber is rubberized asphalt roads. This is a matter for serious study and all possible assistance should be given to this program. The use of rubber in roads was thought of, patented and tried well over 130 years ago. However, it was not until the 1920's that a serious set of laydowns took place in England on the Dartford-Gravesend Road, London, and Lombard St., Birmingham. In these trials, rubber was added to a pitch coated concrete road and rubber blocks served as the road itself. In the U.S. in 1925, Goodyear tried laying a road using solid rubber blocks but it was far too expensive and very slippery when wet. In the 1930's in Europe and England, the many institutes, laboratories and local rubber interests investigated the use of natural rubber, which was at a very low price, and of nitrile rubber. Many roads were laid and the most notable was the Bussum road in Holland laid in 1936 using rubberized asphalt which lasted through World War II even under heavy war-time tank traffic. The road laid in New Cross, London, by Dussek lasted into the 1960's. Much of the work which has been done in the past has been less than definitive and much has been based on the addition of new rubber or rubber latices, which may be useful but irrelevant to the problem of solid waste disposal. Some success was achieved in the work done prior to 1950 but the whole approach was empirical; there being no thorough understanding of how the rubber acted in modifying the properties of bituminous mixtures. From about 1950 onwards research was intensified. Many full scale experimental rubberized road surfaces were laid and from these trials many specifications were published by 1964. The specifications basically are for topping a road bed including recommended temperature ranges, aggregate and bituminum (asphalt) proportions and method of blending the recipe. In the English and European writings mention is often made on the use of latex, vulcanized and unvulcanized rubbers. A survey of selected articles on use of rubber in asphalt, indicates a high degree of potential for rubber scrap. However, there is no indication that raw ground waste could be used to enhance the road properties. Some degree of solubility is required and is not obtainable unless the rubber molecular weight is substantially reduced with a combination of heat, time and chemicals. Some of the properties inherent in scrap may be desirable in rubber for asphalt since it has been compounded, vulcanized to higher molecular weight, and has some residual antioxidant. It is estimated that at a 5% usage of rubber in all new asphalt paving, the national demand would be equivalent to the current generation of scrap rubber as tires. Studies in this important potential usage, restricted to ground cured rubber or reclaimed rubber, should incorporate:

a. Feasibility studies on the incorporation of rubber material in asphalts and in hot or cold mix plants.

b. Determination of optimum levels of rubber addition.

c. Initiation of long term studies of the service improvement value, if any, of such additions to pavings in actual installations.

d. The logistics of supplying the waste in usable form where needed. Grinding of waste at regional or local disposal sites may be beneficial.

e. The extension of the use of cured scrap or reclaimed rubber in asphalt to public play grounds, tracks, courts, parking areas, and curbing or other barriers.

f. Determination of the degree and means of subsidiza - tion required to ensure use of waste rubber in paving asphalts, or, alternatively the proper form of mandatory federal or state action to accomplish this purpose.

To date, the testing of waste rubber in roads has been mainly done by dealers in the commodity. While liaison has been established, between interested parties, a strictly organized program should be created and explored. Al - though a blanket endorsement cannot as yet be given, the following advantages have been noted several times by different laboratories giving justification for establishing and supporting this program. Rubber modifies the behavior of asphaltic binders in a number of ways: 1) The softening point is raised which results in less flow at high road temperatures; 2) the brittle point is lowered and therefore less cracking results at low temperatures; 3) elastic proper - ties are imparted to the asphalt. Road trials have shown the advantages obtained from using a rubberized asphalt in different types of surfacing. In surface dressing, for example, normal asphalt binders tend to "fat-up" under heavy traffic at high temperatures. The addition of rubber prevents this because of the reduced temperature suscepti - bility of the binder. Also, the rubberized binder holds the stones more tenaciously, resulting in a greater stone coverage. When mixed materials are used, one of the most important results obtained by adding rubber is the resis - tance to cracking. This is particularly evident when the surfacing is used on a weak base, or over concrete, when cracks occur over the joints due to the movement of adjoining slabs.

Aside from the use of rubber in roads, the following areas show promise as large outlets for waste rubber. Reservoir linings made of reclaimed rubber sheets retain water much like the plastic sheeting now being used. Jetty and sea wall coating, a blend of asphalt and reclaimed rubber may help to lower maintenance costs on these constructions. They may also help to check soil erosion. The same blend can be used in place of reclaim rubber sheets in reservoir linings, culverts, and drainage ditches. Rubber and asphalt with and without scrap tire fiber can also be used for roofing and siding applications. Fiber, the by-product from the fiber separation system of the reclaimers, can be used as insulation board for buildings and truck bodies, mulch for new grass plantings along highways, polymer recovery, fuel for incinerators, filler for adding to concrete foundation and roads, and as a low cost construction material when coated with asphalt. Worn tires, reclaimed rubber slabs or molded reclaim rubber can be used as highway guard rails and impact absorbers and crumb rubber can be used as the cushioning media.

The pyrolysis or destructive distillation of rubber has been successfully accomplished resulting in products ranging from fuel gas to oils to tars. A preliminary review of these. products suggest no present economic capability to compete with new products. Use of this distillate in competition with presently used oils for extending various new rubbers would necessitate a low cost of the magnitude of 2-3 cents per pound.

The possibility of the distillate being used as a starting material for synthesis in the chemical industry, is complicated by the multiplicity of products or components obtained with pyrolysis. It may be possible to exert more control over the formation of these products through the use of selected catalysts. However these catalysts will have to exhibit broad activity in order to function with the multiplicity of rubber types in service; including all the added chemicals, curing agents and oils.

Section VI

Conclusions and Recommendations for Further Action

Since nearly 41% of the solid rubber waste consists of worn-out tires, solution of this segment of the problem will greatly alleviate the overall disposal situation. The directions that further work on this part of the solid waste problem should take are incorporated in the recommendations below.

1. The *logistics* of rubber scrap collection with emphasis on scrap tires is the first essential. Tires are so widely distributed, so obvious, and so large in annual volume that the primary need is to gather them in sufficient concentration that economical facilities may be constructed for their management and to ensure that they substantially disappear from the general environment. Probably the best way of studying the logistics of collection would be through a study on the logistics of original distribution in cooperation with the tire industry. The tire manufacturers and distributors devised a system for getting tires to the point of use at a minimum cost within a profit oriented structure. There will be much to learn here as to the best system to use to return the scattered scrap tires to new points of concentration. Perhaps the identical or closely similar chain of operation could be used in reverse at minimum cost. That is retailer, jobber, distributor, and warehouser.

The logistics almost certainly require a local collection system, reduction of bulk by chopping, establishment of fair minimum rail and truck tariffs and regulations for transportation to collection centers and establishment of proper facilities at those centers.

2. *Facilities* need to be developed for efficient and controlled conversion of rubber waste. As with any waste, no conversion system can make rubber solid waste disappear but can only convert it to a less objectionable or possibly useful form. Proper and practical performance standards on any disposal method must be established promptly, on an interim basis if necessary, so that obsolescence by statutory action will not further complicate the problem. Incineration appears to offer the best present conversion method as it can result in major reduction of solid waste with the potential production of heat, steam and possibly power. It also has the vast technology of furnace and boiler design as a starting point. The high heat of combustion, the generation of noxious sulfur, nitrogen, and other gases, and the relatively high content of metal and ash will make this a difficult design problem which probably will require financial support at the beginning.

3. *Other conversion* means have been suggested such as the pyrolysis work of the Bureau of Mines with the Firestone Tire and Rubber Co. or chemical or biochemical processes. These do not offer as quick or as economically feasible solutions in the short run but they appear to be deserving of continuing supported research. Centralized facilities for collection and combustion of scrap would offer ideal support for pilot operations of advanced conversion studies.

4. *Densification* of tires and other rubber waste is essential whether they are to be disposed of in local land fill, burned in local incinerators, or shipped to centralized collection centers. This densification requires only cutting and chopping to less than one inch size and can be done with existing unit equipment. Supported efforts should be directed to the design of pilot systems, preferably portable, which will do this size reduction cheaply, with minimum investment, minimum labor input, and sufficiently rugged to operate outdoors in rugged terrain and with little or no special maintenance.

5. Waste rubber in roads is a matter which calls for serious study. Much of the work which has been done in the past has been less than definitive and much has been based on the addition of new rubber or rubber latices, which may be useful but is irrelevant to the problem of solid waste disposal. It is estimated that at a 5% usage of rubber waste in all new asphalt paving, the national demand would be equivalent to the current generation of waste rubber tires. Studies in this important potential usage, restricted to ground cured rubber or reclaimed rubber, should incorporate:

a. Feasibility studies on the incorporation of rubber materials in asphalts and in hot or cold mix plants.

b. Determination of optimum levels of waste rubber addition.

c. Initiation of long term studies of the service improvement value, if any, of such additions to pavings in actual installations.

d. The logistics of supplying the waste rubber in usable form where needed.

e. The extension of the use of cured waste or reclaimed rubber in asphalt to public play grounds, tracks, courts, parking areas, and curbing or other barriers.

6. The Bureau of Solid Waste Management could maintain continuing surveillance over federal, state, and local legislation, industry standards, consumer demands, and technological changes to ensure that such programs and regulations do not inadvertently and unnecessarily exaggerate the scrap rubber problem by limiting the service life of rubber products. This could comprise, among other things, tire safety standards, retreading standards, highway speed maximums, highway construction standards, axle-load standards, tire overload standards for original equipment, industrial safety standards involving belts, hose, cable and personal protective equipment. Although such action for the public is intended for beneficial purposes there is always the possibility that through over-enthusiasm or lack of information the actual service life of tires and other rubber products may be reduced to the extent that the solid waste problem is seriously aggravated. The Bureau of Solids Waste Management should be prepared to advise on such public actions before they are given final form.

7. Waste rubber, particularly tires, could possibly be used as protective barriers on the nation's motorways. Either in the form of whole tires or ground rubber in containers, they could be effective impact absorbers at underpasses, median barriers or land cuts.

Appendix I Glossary

Adjusted Tires
Tires that have passed initial manufacturers inspection but are revealed after use, to be unfit. They are returned to the dealer for compensation.

Clean Outs
Residual rubber left in machinery from prior runs which is removed and discarded.

Factory Wastes
Floor sweepings, polymer removed for testing and later discarded, etc.

Innerliner
An integral inside tire layer for improved air retention.

Mechanical Products Scrap
Products rejected by producer as being unfit for use due to manufacturing defects.

Nerve
A generic term used to denote the "springiness" of a polymer. Usually used when referring to the uncompounded polymer.

Off-the-road-tires
Tires which are larger than normal bus and trailer truck tires such as found on large earth moving equipment.

Other (as used in Table II-4)
Primarily selvage and portions of rubber polymer removed for testing.

Peelings, Fabric Free
Strips of tread which have been peeled off worn tires.

Polymer
A chemical compound formed by combining small molecules or atoms into long chains of essentially repeating structural units.

Raw Polymer
A polymer which has not been mixed with compounding ingredients such as curing agents and softeners.

Rejected Tires
Tires rejected by a producer as being unfit for use due to manufacturing defects.

Retread Buffings
The crumb rubber produced when a retreader grinds off the remaining tread from a worn tire before applying a new tread.

Rubber
A general term for polymer compound, and products.

Rubber Compounds
As used in this report, rubber compound refers to the polymer mixed with fillers, oils and curing agents.

Rubber Latex (latices)
A milky or tan colored solution consisting of rubber in water.

Safety Barriers
Separate liners placed inside tires to seal punctures and leaks which occur during road use. The liner may be a contaminant of reclaim or else it presents a manufacturing difficulty to the industry.

Scrap
Manufactured rubber articles or parts rejected or discarded and useful only as material for reprocessing.

Selvage
A border or edge trimmed off a molded part; also, that portion of a sheet of rubber which remains after parts are die-cut out.

Square Woven Duck
Fabric consisting of threads woven perpendicularly i.e. equal amounts of weft and warp.

Tire Parts
Tire selvage usually from the splitting industry.

Tire/Tire Products
Tires, innertubes, rubber curing bags and other products relating to tires or their manufacture, renovation or repair.

Waste
Rubber articles which through wear or contamination are disposed of as being of no further use.

Weftless Cord
A woven fabric in which the weft threads are replaced by a limited number of very thin threads.

Bibliography

This portion contains an alphabetical list of the oils and chemicals used or investigated by the reclaiming industry. Alongside each item, in italics, is the name of the person or organization that published data pertaining to the item. The periodical the data appears in will be listed under the person's name in the second section.

Accelerators *Khodevitch, L.*

Acid, abietic *Treves, A.*

Acid, Aliphatic, unsaturated derivatives *Tsvetaeva, E.M.*

Acid, benzoic *Amphlett, P.H., Hughes, A.J., Twiss, D.F.*

Acid, carboxylic *Wingfoot Corp.*

Acid, carboxylic, anhydrides *Drozdovskii, V.F., et al*

Acid, cresylic, petroleum, sulfide of *Smith, G.E.P., Jr.*

Acid, Dithiocarbamic *(1) Cech, C.J., Bata, A. -G. (2) Regie Nationale Des Usines Renault (3) Bata, A. -G. (4) Yaroslav, C.*

Acid, fatty *(1) Lebeau, D.S. (2) Tsveteava, E.M. (3) Rein-Chemie G.m. b.h.*

Acid, formic *Rubber Reclaiming Co.*

Acid, Hydrochloric *(1) Hudecek, J., Dlab, J. (2) Dasher, P.J.*

Acid, mineral *(1) Pearson, W.L., Schweller, H.E. (2) Dasher, P.J.*

Acid, napthenic *See Napthenic Acids*

Acid, organic *Kirby, W.G., Elliott, P.M.*

Acid, organic, polyglycol esters of *Saul, W., Wiggins, T.J.*

Acid, organic, zinc or aluminum salt of *Johnson, T.A.*

Acid, Phosphoric *Kelly, J.H., Jr.*

Acid, Phospheric, alkyl salt *Kelly, J.H., Jr.*

Acid, Phosphoric, alkyl *Kelly, J.H., Jr.*

Acid, sulfuric, conc. *Naftolen Gesellschaft*

Acid, sulfuric, dil. *Semperit Gummiwerk G.P.*

Acid, sylvic *Treves, A.*

Acid, tar, by-products *Metallgesellschaft, A. -G.*

Acid, thioglycoltic, B-napthalide of *Drozdovskii, V.F.*

Activator, surface *Sanyou, Yushi Kogyo Co.*

Activator, sulfur containing *Drozdovskii, V.F.*

Additives *Dufour, R., Leduc*

Agents, devulcanizing (list) *Oil, Paint and Drug Reptr., 141: p. 60 (May 25, 1942)*

Agents, non-stain *Keilen, J.J., Dougherty, W.K.*

Agents, softening, soling waste *Mishustin, I. U.*

Agents, swelling *Rivier, A., Dietzel, E.*

Agents, swelling, cracking aid *Reich, H.F.H.*

Agents, swelling, study *Rostler, K.S., White, R.M.*

Alcohols, aliphatic *Sartorelli, U.*

Alcohols, aliphatic, monhydric *Wingfoot Corp.*

Alcohol, ethyl *Moore, D. V., Thompson, H.H.*

Alcohol, n-butyl, w/steam *Bergmann, F., Dishon, B.R.*

Aldehyde *Mankowich, I.*

Alkali *Levin, M.*

Amide *Kirby, W.G., Elliott, P.M.*

Amine, aliphatic *Smith, G.E.P., Jr., Bennett, R.B.*

Amine, aliphatic, water insoluble *Kelly, J.H., Jr.*

Amine, alkylol *Dasher, P.J.*

Amine, hydroxyl– *Dasher, P.J.*

Amine, hydroxyl–, (or salt) *Dasher, P.J.*

Amine, mercapto– *Dasher, P.J.*

Amine, napthyl, phenyl-beta- *Johnson, T.A., Thompson, H.H.*

Amine, poly–, aliphatic *Dasher, P.J.*

Amine, secondary, polycyclic *DeWaele, A.*

Amine, Tri–, diethylene *VanValkenburgh, E.A.*

Ammonia *Joyce, W.T., Geyer, H.D.*

Ammonia, emulsions, w/reclaim *Radinger, E.J.*

Anhydride, maleic *Green, J.*

Anisates *Tsvetaeva, E.M.*

Aromatic, Hydrocarbons *Lambrino, V., et al*

Swellers (list) *Oil, Paint and Drug Reptr., 142: No. 16, p. 71, (October 19, 1942)*

Tarr, coal *Spocete, A.*

Tar, coal, distillate *Wingfoot Corp.*

Tars, gas *Krivunchenko, N.G., et al*

Tar, lignite *Kuznetson, V.I., et al*

Tar, pine *(1) Amphlett, P.H., Hughes, A.J., Twiss, D.F. (2) Berryman, G.C. (3) Solokov, S.A., et al*

Thiazole *(1) Bata, A.G. (2) Cech, C.J., Bata, A.G. (3) Yaroslav, C.*

Thiazole, mercaptobenzo- *(1) Amphlett, P.H., Hughes, A.J., Twiss, D.F. (2) Kawaoka, Y.*

Thiol, aromatic *Gumlich, W., Ecker, R.*

Thiophene (ring) *Sverdrup, E.F.*

Toluene, thiophene *Kimishima, T.*

Urea, phenylthio *Kawaoka, Y.*

Utanol *See Utanol*

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STUDY BY GAS CHROMATOGRAPHY OF THE PRO - DUCTS OF POLYMER PYROLYSIS
(French)
R. Audebert

Ann Chim (Paris), 3(1):49. January-February, 1968. 18 pages. The study by gas chromatography of the products of the pyrolysis of macromolecular compounds has undergone enormous development during the last 15 yr. After de - scribing the main types of apparatus employed and their uses, the characteristics parameters are shown which allow one to define the best conditions for pyrolysis and for chromatography. Typical examples are given to illustrate the applications of this technique. epg

THE INFLUENCE OF BROMINE COMPOUNDS ON THE COMBUSTION OF POLYOLEFINS
1. EFFECTS ON THE THERMAL DEGRADATION
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THERMAL DEGRADATION OF POLYSTYRENE
G J Knight (Royal Aircraft Establish., Farnborough, Hampshire, Engl.) J Polymer Sci, Part B, 5, #9, 855 (1967) September 3 pages Polystyrene will degrade entirely to monomer under flash pyrolysis conditions if small enough samples are taken and if the temperature is sufficiently high. With large samples secondary reactions take place due to diffusion effects. This would explain the dimer, trimer and tetramer observed in earlier experiments. At lower temperatures with small samples it seems probable that the time required to produce degradation and the lifetime of the styryl radicals are such that secondary reactions may occur.

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