SOLID WASTES IN THE AUTOMOTIVE INDUSTRY

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ABSTRACT

A 24-month study of solid waste and scrap generation, and related plant management practices, in the automotive industry was performed. The industry was categorized and defined in accordance with the United States Standard Industrial Classification (SIC) Codes 3711, 3712, 3713, and 3714. Special and custom vehicle and body manufacturers in SIC 3711, 3712, and 3713; and the parts and accessories suppliers in SIC 3714 were surveyed. The results of an in-house survey of Automobile Manufacturers Association (AMA) member plants covering all four SIC Codes is included in this report.

The information presented was derived from five principle sources: (1) industry-related publications and general references; (2) automotive industry trade associations; (3) questionnaires received from 43 different manufacturing plants within the four SIC Codes; (4) questionnaires from cities within 48 Standard Metropolitan Statistical Areas (SMSA) with automotive industry plants; and (5) field interviews and studies completed at a representative cross section of 74 manufacturing and assembly plants. The questionnaires were developed in cooperation with industry, the Bureau of Solid Waste Management, and other authorities.

A general description is given of the industry plant locations, minimum estimated plant values, vehicle production, employment, industry employee productivity, products, and manufacturing processes. Waste and scrap generation sources are identified; handling, collection, and disposal methods and their costs are presented; and the effects of automotive industry plant wastes on the environment and community are discussed. Stepwise multiple regression was applied to the investigation of plant parameters for predicting waste and scrap generation.

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DEFINITION OF KEY TERMS USED IN REPORT

Automotive industry--in this report refers to all of the companies and their plants defined by Standard Industrial Classification Codes 3711, 3712, 3713, and 3714. These plants manufacture automobiles, trucks, buses, and vehicle parts.

Average vehicle--denotes the vehicle derived by weighting the typical mean automobile and typical mean truck and bus by the proportion of each produced (see definition of "weight of an average vehicle").

Bin--a large enclosed stationary container structure or cubicle used for storage of a given material.

Composite automobile--a typical automobile which is formulated from the major components installed in new automobiles produced (see Table 6).

Composite truck and bus--see definition of "composite automobile."

Container--general term for any enclosure or receptacle that can contain something, as a box, bin, drum, barrel, bag, can, cubicle, etc.

Cubicle--a stationary materials storage structural container open at the top having three side walls with or without a door. The walls are commonly of wood or concrete. Large cubicles will be designated as bins.

Drums--those containers having a cylindrical shape, generally uncovered and open at one end. Commonly used in reference to 55 gal drums.

Salvage--waste materials that are not reclaimed as normal commercial-industrial scrap. Originates primarily in nonmanufacturing operations and is generally comprised of nonmetals.

Weight of an average automobile--a unit weight representing all automobiles produced in a given year, derived as follows:

$$\sum_{i=1}^{n} \frac{[(\text{curb wt of model } i) \times (\text{number of units of model } i \text{ produced in year})]}{\text{total automobile production}}$$

Weight of an average truck and bus--a unit weight representing all trucks and buses produced in a given year derived as follows:

$$\sum_{i=1}^{n} \frac{[(\text{curb wt of model } i) \times (\text{number of units of model } i \text{ (truck and bus) produced in year})]}{\text{total truck and bus production}}$$

Weight of an average vehicle (car, truck/bus)--a weighted average of cars and trucks/buses produced in a given year, derived as follows:

$$\frac{[(\text{wt of an average car}) \times (\text{total number of automobiles produced}) + (\text{wt of an average truck/bus}) \times (\text{total number of trucks/buses produced})]}{\text{total vehicle production}}$$

SUMMARY

History

In the early 1900's, the automotive industry consisted of many small vehicle manufacturers and parts suppliers. The trend toward consolidation of companies began in 1911 and in 1969 there were only four major automobile manufacturers. In addition, there were more than 2,000 manufacturers of parts and custom vehicles, some of whom supplied the major manufacturers.

The first mass production assembly line was installed at the Ford Motor Company in 1913. Since then, the line has been improved by the standardizing of parts, using computers to schedule assembly of several vehicle styles on one production line, and by introducing multistation transfer machines, which automatically perform several machining operations.

During World War II, materials shortages provided industry-wide impetus for improved management of scrap and solid waste. The large manufacturers began installing chip conveyors, crushers, balers, and machine oil recovery equipment.

In 1969, the industry comprised 2,638 plants with a minimum estimated plant valuation of approximately $1,695,000,000. Thirty-six percent of the industry plants were located in the Midwest, with Michigan and Ohio containing the greatest number of large plants. Michigan was the leading vehicle producing state with 34 percent of total automobile production in 1969.

The rate of increase in the industry's overall productivity, expressed in man-hours per vehicle produced, is declining. This trend is the basis of recent (1969) comments by industry management that costs per vehicle have risen because of the lower rate at which productivity is increasing.

In the peak production year of 1965, more than 9 million cars and 1.7 million trucks were manufactured. The average number of hours worked per week by each employee was 44.2. For the period 1970-1975, the industry's production is projected to be 13 to 15 million vehicles per year.

Study Objectives

The objectives of the study were the following:

1. To determine the character and quantity of solid waste and scrap materials generated by automotive plants

2. To identify the sources of solid waste and scrap generation

3. To determine handling, collection, storage, and disposal methods and costs

4. To determine the effects of plant waste and scrap on the environment and community

Procedures

The study was conducted in four parts as follows: (1) questionnaires were mailed to 1,700 automotive industry plants; (2) questionnaires were mailed to 235 municipalities in which automotive plants were located; (3) field visits were made to 74 plants and 11 municipalities; and (4) the Automobile Manufacturers Association (AMA) provided questionnaires from a survey of 217 of its member plants. The information sought from each plant included the following: types and quantities of product, solid waste and scrap; waste management practices and costs; plant layout and process schematics; and comments on anticipated changes in waste management practices. The municipal authorities were questioned on industry waste problems and plant-municipal solid waste management policies related to environmental quality.

Of 1,700 plant questionnaires mailed, 138 were returned, and 43 of these were sufficiently complete for quantitative data analysis and an additional 29 were useful in supplying qualitative data. Forty-eight responses were received from municipal authorities, and seven of these contained useful information.

Results

The types and relative quantities, by weight (wet),* of solid wastes generated in the automotive industry were estimated to be as follows (by percent): paper and cloth (3.7); cardboard (4.8); wood (3.4); rubber (0.4); plastics (0.4); oils, paints, and thinners (1.1); cans, bands, and wire (0.8); garbage (3.4); sludges and slurries (30.5); and inert solids (51.6). Solid wastes amounted to 1,600 lb per 3,694 lb average vehicle (car, truck, bus) produced in 1969.

The sources of the plants' solid wastes determined by the field survey (excluding AMA member plants) were the following (by percent): machine and foundry operations consisting of machining, forging, casting, drilling, and grinding (49.4); trimming and cutting operations (3.5); offices (3.3); cafeterias (2.3); packaging and shipping (26.3); and general plant operations (15.2).

The types and relative quantities, by weight, of scrap generated in plants

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* All solid waste and scrap weights are described as received, i.e., wet weight.

sampled* by the project engineer were the following (in percent): ferrous (97); aluminum (1.65); bronze (0.6); and mixed copper, brass, and zinc (0.75). The weight of scrap generated during the manufacture of a composite vehicle was 1,000 lb.

The major nonmetal waste materials salvaged+ were cardboard (26.7 percent) and slag (57.9 percent) by weight of salvaged materials. Salvage materials amounted to about 8 percent, by weight, of the solid wastes reported by AMA member plants.‡

Waste- and scrap-handling equipment was used in 77.1 percent (54) of the 70 plants visited that supplied information.§ Hand trucks, tow trucks, forklifts, industrial trucks, belt conveyors, and vacuum systems were used to transfer materials.

Containers for solid waste and scrap located at the generation source and for storage ranged from 2/3 to 80 cu yd capacity. Stationary storage bins located outside the plant buildings ranged from 71 to 272 cu yd capacity. The most frequently used containers were 55-gal drums, observed in 66 percent of the 70 plants. The 55-gal drums are widely used because they are salvaged packaging containers and thus cost nothing.

Magnets, shredders, shears, balers, crushers, centrifuges, and compactors were observed in plants with estimated minimum values exceeding $300,000. Compactors, the most widely used equipment, were observed in 23 percent of the 70 plants. The motivation for compactor use was the reduced collection costs for transporting the smaller solid waste volumes.

Solid waste segregation was practiced at the generation source in 20 percent of the 70 plants and at the waste storage area in 11 percent. Scrap was segregated at the source in 47 percent of the plants, and at the storage area in 13 percent. Segregation both at the source and in storage areas was practiced for waste in 9 percent and for scrap in 21 percent of these plants. Thirteen percent of the plants, all of which employed fewer than 100 workers, did not segregate materials. Paper, wood, cardboard, and plastic wastes were not segregated unless a salvage market existed for them. Of 158 AMA member plants, 42 percent reported they salvaged materials. Of the total 440,999 tons/yr of salvage, slag and cardboard comprised 58 and 27 percent, respectively.

The major alternatives for disposal of solid waste were processing at the plant and utilization of disposal areas outside the plant. At the plant, the methods for

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* For purposes of this report, "sampled" refers to the sum of plants which were visited by the project engineer's staff and responding to the engineer's questionnaire.

\+ For this report, "salvaged" refers to solid wastes sold for reuse.

‡ Of 217 questionnaires received from the AMA, 158 contained usable information.

§ Although 74 plants were visited, usable information was obtained from only 70.

waste processing and disposal were incineration and landfill. With the exception of foundries, where metal by-products were recycled for reuse, most plants sold their scrap to private dealers. Incinerators, found in 28 percent of the plants sampled by the project engineer, were the most widely used waste-processing equipment. Twenty-four of the 32 incinerators were installed in large plants with values greater than $1 million. Incineration was most prevalent on the East Coast and in the Midwest. Although air pollution regulations are becoming more stringent (1970), these large plants tended to view incineration favorably.

The major factors influencing a company's solid waste management policy were costs, air pollution regulations, and the quantities of waste generated. The greater the waste quantities, the more feasible incineration became as a method of volume reduction, despite the added expense of air pollution control equipment.

Of 271 plants (including AMA member plants), 37 percent hauled their own wastes, 76 percent used private collectors, 6.7 percent used public collectors, and 25.5 percent used more than one of the above collectors. Public collection was used primarily for cafeteria garbage and office trash. The least frequent collection schedule was twice a month. Combined costs of waste collection and disposal for the entire industry decreased from an average of $80 per ton for 1 ton per month to $1.3 per ton for 10,000 tons per month. Self collection at $24.48* per ton was the most expensive, private collection at $22.98* per ton was the next most expensive, and public collection was least expensive at $8.08* per ton, as reported by AMA member plants. Landfill disposal costs reported by AMA member plants averaged $4.94 per ton of waste. Thus collection costs comprised the bulk of solid waste handling expenses. Plants using waste processing equipment had lower waste collection and disposal costs. Scrap was handled as a resource and sold.

Waste disposal records were kept at 60 percent of the 70 plants visited that supplied usable information. Sixty-six percent kept scrap records. The higher monetary value of scrap provided the incentive for keeping records.

Municipal authorities generally lacked dependable information on industrial solid waste management. There was little record keeping, especially regarding the quantities and types of solid waste from the automotive industry, although communities that charged for the use of their disposal facilities did have limited records. Private contractors rarely maintained detailed records of solid waste sources, composition, or quantities.

The automotive industry and the municipalities viewed each other's performance in handling solid waste as satisfactory. The major problem, as cited by 23 percent of the plants sampled, concerned lack of disposal sites. Of 18 municipalities that replied

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* Average cost.

to the question, only two reported air pollution to be a problem. The municipal authorities did not indicate they planned to control air pollution. Even in Michigan, where new (1969) State air pollution regulations are in force, plant personnel were being encouraged by municipal officials to incinerate.

Most waste and scrap storage areas, and plant noise were not detectable from access roads and the surrounding neighborhood. Seventy-seven percent of the plants visited were located in industrial areas, 9 percent in commercial areas, and 14 percent near residential areas. All the sampled communities that responded stated that industry was responsible for managing their own wastes.

INTRODUCTION

There is rising public awareness of the importance of protecting the environment from man-made air, water, and land pollution. Increasing population growth, industrialization, and farm mechanization have made it necessary to identify the sources and ascertain the levels of environmental contamination, pollution, and nuisances. Even animal and plant life have been endangered by man's onslaught against the natural environment. Solid wastes at present are a major concern throughout the United States. Of the total solid waste products generated in the United States from various sources, industry contributes approximately 30 percent.[1] In the future, increased solid waste generation will cause even more critical problems that can be solved only by government's and industry's working together to provide appropriate management systems.

The automotive industry is probably the largest business in the world and is considered to be the major source of consumer spending. There is extensive published information available from authoritative sources concerning technical, general production, and employment trends. The automotive industry has developed standard manufacturing processes, components, and materials in order to achieve efficient production. This standardization is particularly relevant in studying the possible waste and scrap sources and materials. The industry is geographically dispersed and includes major parts and assembly plants with advanced manufacturing methodology and materials. In addition, there are a large number of smaller specialty parts plants whose basic processes are similar to those of the major plants, but whose management tends to be less sophisticated.

The major objective of this study was to determine the character of solid waste and scrap materials generated by automotive plants in the United States in order to provide a valid base for predicting the waste quantities. To accomplish this objective, the following tasks were performed:

1. The capacities and capabilities of the automotive industrial plants in the United States were determined.

2. The industry's production trends were analyzed.

3. Sources of solid waste generation in the plants were surveyed.

4. The locations of industry plants and their effects on surrounding communities were identified.

5. Scrap and waste generation and disposal were classified by quantity and type.

6. Scrap and waste production were related to plant characteristics.

7. Waste storage, collection, and disposal practices were identified.

8. The costs of scrap and waste management in the industry were determined.

9. Future waste and scrap management trends in the automotive industry were analyzed.

The industry surveyed for this report consisted of the automotive parts and accessories manufacturers, and custom truck and bus manufacturers. The major automobile manufacturers who are members of the Automobile Manufacturers Association (AMA) were surveyed by the AMA. The automotive parts and accessories manufacturers were diverse and had large variations in many of their management practices; however, because of strong competition, the basic manufacturing processes tended to be standardized for the industry as a whole.

The study was performed in several chronological steps. The initial procedure was to contact trade associations in the industry and conduct a literature search. This was followed by a questionnaire survey to appropriate industrial plants and local municipalities. The final step was a field study of the industry on a national basis. The contacts with the trade associations and the literature search pointed out the lack of accurate data on solid waste, not only for the automotive industry but also for industry in general. Trade associations such as the AMA and the Automotive Service Industry Association were cooperative in supplying available information. Trade sources had, however, little specific data on waste management. The literature search covered areas such as automotive industry scrap, wastes, and manufacturing processes, with cross referencing between each area. There was a wealth of general information on the functioning of the industry, its products, and the types of plants. However, specific data relating to production, employees, and types and quantities of scrap and waste for individual plants was not available. The questionnaire survey attempted to ascertain the quantity and types of wastes. The results indicated that industry could not supply accurate records on many items. The follow-up plant visits confirmed the original questionnaire results. Plant waste quantities were often estimated by management because accurate information did not exist. Data was subsequently analyzed to evaluate the compiled field information and investigate relationships between a general plant variable and plant wastes and scrap.

Contacts with municipal authorities followed steps similar to the plant visits. Questionnaires seeking information on local automotive plants were mailed to appropriate municipal authorities; they revealed the same lack of specific solid waste data. Follow-up field visits to responsible municipal personnel were made in communities in which automotive plants were studied. Again the results indicated a lack of specific information since most municipalities did not directly collect automotive plant wastes.

Visual observations of the plants were made to detect air pollution, assess general property appearance and litter, and to determine if waste and scrap storage areas were visible from the access streets.

The field interviewers were equipped with cameras, tape recorders, tape measures, and questionnaires. Weights were obtained with in-plant scales. The questionnaires and interviews were summarized in written form at the end of each day.

THE AUTOMOTIVE INDUSTRY

Definition of the Industry

This study consisted of a nationwide survey of automotive industry plant solid waste management. The automotive industry is defined by Standard Industrial Classification (SIC) Codes 3711, 3712, 3713, and 3714.[2] For general reference, the Bureau of the Census has recently combined SIC Codes 3711, 3712, and 3714 into a single Code 3717 for summarizing data in their 1963 Census of Manufactures. The following industry definitions are, however, applicable in this report:

SIC 3711: Motor Vehicles

Establishments primarily engaged in manufacturing or assembling complete passenger automobiles, trucks, commercial cars, and buses; and special purpose motor vehicles such as campers, hearses, refuse trucks, and fire engines, etc. These establishments may also manufacture motor vehicle parts; however, plants manufacturing parts but not manufacturing complete vehicles are classified in SIC 3714.

SIC 3712: Passenger Car Bodies

Establishments primarily engaged in manufacturing passenger car bodies but not engaged in manufacturing complete passenger automobiles.

SIC 3713: Truck and Bus Bodies

Establishments primarily engaged in manufacturing truck and bus bodies, for sale separately or for assembly on purchased chassis.

SIC 3714: Motor Vehicle Parts and Accessories

Establishments primarily engaged in manufacturing motor vehicle parts and accessories but not in manufacturing or assembling complete motor vehicles.

These definitions do not include establishments manufacturing tires and tubes, storage batteries, sheet metal stampings, motorcycles, automotive glass, vehicular lighting equipment, or off-highway vehicles, since these are classified under other SIC Codes.

Industry Structure

Historical Background. During its infancy in the early 1900's, the automotive industry consisted of many small vehicle manufacturers and parts suppliers. The structure of the whole industry was similar to the structure of what is now labeled as custom vehicle and parts manufacturers. The trend toward consolidation of companies began in 1911. The installation of the first mass production assembly line at Ford Motor Company in 1913 complemented the consolidation trend as management realized the greater benefits realized by large (volume) production.[3] In 1910, by conservative estimates, the number of vehicle-manufacturing firms was put at 52. General opinion, however, estimated the number of companies as being closer to 1,000.[4] The industry as it is structured today presents a blend of the old and the new. There now exist only four major automobile manufacturing firms since the most recent merger, which occurred in 1969 between Kaiser-Willy Jeep Corporation and American Motors Corporation. In addition, there are more than 2,000 parts and custom vehicle manufacturers, some of whom supply the major manufacturers.

Competition among the manufacturers has led to the development of large mass production facilities. The mass production assembly line was improved by the standardization of parts for several vehicle models and colors, which allowed several vehicle styles to be assembled sequentially on one production line. Additional developments have occurred in the machine tools used to manufacture the vehicle parts. Large automotive multistation transfer machines were initially installed at the end of

World War II. These machines can automatically perform several simultaneous machining operations and transfer the part to a new station for additional machining.

The history of solid wastes and scrap in the industry is not well known for the period preceding World War II. The story of Henry Ford's requiring his suppliers to ship their goods in wood containers made of boards of a specified size and quality and then using the wood for floor boards in Ford cars is perhaps the first incidence of planned reclamation of waste materials. During World War II, materials shortages provided impetus for improved scrap and waste management. The large manufacturers began installing chip conveyors, crushers, balers, and machine oil recovery equipment. After the War, emphasis on reuse of manufacturing waste was reduced, and the industry's concentration was shifted to production in order to satisfy consumer demand. The period from the end of World War II to 1948 saw great changes in the industry that led to the establishment of large-scale standardized-assembly manufacturing methodologies that have been improved but are basically similar to those of today (1970).

Period of Study. The industry data presented in this report cover the period from 1948 to 1969. These years were relatively stable for the industry because no major economic and military upheavals occurred. Of more importance for this study has been the industry's stability, in terms of the number of major firms, and the utilization of technologic advances developed after World War II. Large assembly lines for producing automobiles have been uniformly installed at all assembly plants of the four major firms. Transfer machines have been operated by the major parts manufacturers. These manufacturing methodologies have been improved by the application of computers to control the assembly line operations and to program the machining operations of the transfer machines.

Five automobile manufacturers have dropped out of the market during the last 20-year period. However, they had essentially no effect on the industry structure, because their share of yearly vehicle production was less than 10 percent.[5]

Industry Distribution According to SIC Codes. The basic structure of the industry has changed little since 1958. The total number of plants, for the past 10 years, in the four SIC Codes studied is presented in the following list:[6]

SIC Code	1958	1963	1968-1969	
3713	562	610	855	
3711, 3712, 3714	1,560	1,958	1,783	142 / 44 / 1,597
Total	2,122	2,568	2,638	

The figures for 1958 are lower, partly because of a revision in SIC 3714, to which ignition systems were added in 1963. Figures 1 through 4 show the number of plants in each state by SIC Code and give the minimum estimated total tangible assets of the industry in each state.

The minimum total tangible assets for each SIC Code are as follows:

SIC Codes:	3711	3712	3713	3714	Total
Minimum tangible assets (millions of dollars)	112	20	369	1,194	1,695

The greater value of plants in SIC 3714 reflects the fact that 60 percent of all plants are classified in this SIC Code. These values are low (and therefore termed "minimum") because many plants are not valued individually in the Thomas Register source, and large plants are listed only as "over one million dollars." These figures have been adjusted upward to include plant values greater than $1 million using field survey data.

Geographic Location. Thirty-six percent of the industry plants are located in the Midwest with Michigan and Ohio containing the greatest number of large plants (see Figures 1 through 4). The locations of the 48 major automobile assembly plants, which produced 100 percent of the automobiles in 1969, are shown in Figure 5 with production percentages for each state. In addition, trucks are manufactured in 47 plants,[7] 23 of them being automobile assembly plants, but on separate production lines. Michigan is the leading vehicle-producing state, with 34.94 percent of total production, and Missouri is second with 10.76 percent. The maximum geographic change in production since 1963 has been in Wisconsin which has experienced a 4 percent decline in percentage of total automobiles assembled. The lower Wisconsin production reflects American Motors Corporation's decreased market position. Minor changes reflecting local market conditions have occurred in other states.

The total industry production of automobiles, trucks, and buses during the post-1948 period is given in Table 1. Bus manufacturing is quite low representing less than one percent of total annual vehicle production.

Employment Trends. The post-1948 period may be divided into two eras: 1948 to 1959, and 1960 to the present. This division reflects the impact of computer control of the manufacturing and assembly operations, which is indicated by the productivity trend change in 1960. Figures 6 and 7 and Table 2 indicate this change in trend in the man-hours required to produce a vehicle and supporting replacement parts. The productivity is based on the average weekly hours worked listed in Table 2, which have remained relatively constant. A linear least squares fit of the log transformed parabolic curve* was used for projecting worker productivity. The fitted parabolic curve in Figure 6 shows that the rate of increase of worker productivity over the long-term is decreasing. The indicated trend is the basis of recent comments by industry management in various news media that costs per vehicle produced have risen because of the lower rate at which productivity is increasing. These productivity curves are also heavily weighted in favor of the major manufacturers, who employ more than three-fourths of the workers.

Two additional significant points are the following: (1) the productivity increased during years when industry production was highest; and (2) productivity decreased during the years of military demand in 1951 and 1952, and in 1966 and 1967. The first item indicates that the industry does not operate at maximum plant capacity and can accommodate higher production levels without an additional number of plants. The second point illustrates the influence of military production and related market conditions on worker productivity.

Production Capabilities of the Industry. The peak production year was 1965, more than nine million cars and 1.7 million trucks were manufactured. The average number of weekly hours worked was 44.2, which was reduced to 42.8 in 1966, when more workers were hired. The present industry capacity may be estimated at 13 to 15 million vehicles. Estimates of vehicle production for 1975 from industry news sources predict about 13.5 million vehicles.[8] Because the four manufacturers have not indicated plans for major new automobile assembly facilities before 1975, their present production capability should be sufficient to satisfy this expected demand. New-car sales estimates by the industry are based on a second- or third-car market for a family, the number of scrapped vehicles, and the increase in cars required to accommodate population growth.[9] However, general economic indicators of buying power provide a direct estimate of persons per car, which can be used with population predictions to estimate vehicle production. A correlation coefficient of .98 was obtained between the number of cars in operation and the Gross National Product. Figure 8 reflects this buying capability of the public in persons per car, which was used to predict the number of cars in operation through 1990.

New Plant Locations. The major criteria for determining the geographic

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* The parabolic $y = ax^b$ was log transformed to fit by minimizing $\sum_{i=1}^{n} [\log y - \log a - b \log x]^2$. For total employment R^2 equaled 0.67, and for production workers R^2 was 0.72.

location of new plants vary according to the sector of the industry characterized by the plant. The major location criteria for assembly plants are market proximity and transportation costs. All the major new assembly plants since 1948 have been built in California, the South, and Missouri. The costs of transporting body sections have been reduced by locating body fabricating plants in proximity to assembly plants. The criterion for locating major parts plants has been proximity to raw materials and customers. The manufacturers of engines, transmissions, chassis components, and frames are largely located in the Midwest, where raw steel is readily available from steel mills. A secondary consideration is the scrap market, which supplies these same steel mills.[10]

Manufacturers of smaller vehicle parts are more widespread. The secondary replacement parts manufacturers are not closely tied to the vehicle manufacturers and are located in the major vehicle market areas.

Thus, most parts plants are concentrated, as listed in Table 3 and as shown in Figures 9 through 12, in major cities and in the Northeast-Central region of the United States.

PRODUCTS AND PROCESSES

Industry Plant Types

The primary manufacturing operations used by plants in various SIC Codes may be divided into major plant type subgroups. The primary products and plant types for each SIC Code were defined previously (pages 7 and 8).

There are two types of plants in SIC 3711--assembly plants and integrated plants that both assemble motor vehicles and manufacture parts. Most assembly plants of SIC 3711 are large-volume, mass production plants of the major automobile and truck manufacturer members of the AMA. These plants account for more than 99 percent of all complete motor vehicles produced in the United States.

The integrated plants of SIC 3711 are of two types. The first type consists of an assembly area and a manufacturing area, not necessarily in the same building. The other type is comprised of custom vehicle assembly and component manufacturing areas, in the same building. Vehicle bodies, parts, and some accessories may be manufactured on the same production line in the latter type.

The body plants, SIC 3712 and 3713, are basically of two types--mass production and custom assembly. They differ largely in their production rates. The primary processes are sheet metal and structural fabrication.

The parts and accessories plants, SIC 3714, differ markedly in products, production rate, and processes. These plants utilize a wide variety of machining, casting, forging, drilling, grinding, cutting, and trimming operations.

The differences between automobile, bus, and truck plants are primarily of product size and product numbers rather than of basic plant operation or waste management practices.

Automotive Industry Products

Automobiles. The highly competitive nature of automobile manufacturing results in great emphasis on production costs. In turn, this emphasis leads each firm to use the least expensive materials and fabrication processes available. Thus, the materials utilized for major vehicle components tend to be standard for the four major firms. The major variations among automobiles are size, equipment options, and luxury (price) class.

Models. The term "models" refers to the number of different sizes, price classes, and optional equipment combinations available. Table 4 lists the total number of automobile models offered each year from 1948 to 1970. The number of models offered in 1970 was 75 percent greater than in 1948, and yet the number of automobile firms in 1970 was less than half the number in 1948. The number of models has remained relatively constant since 1965 which indicates that consumer taste differences and model costs have met at a mutually acceptable level of diversity.

Optional Equipment. The term "option" refers to the manufactured components added to, or subtracted from, the basic model. The "basic" model varies for different automotive price classes. For example, the least costly model in a given product line might include automatic transmissions as optional equipment, even though the number of installations sold as a percent of the total transmissions installed is greater than 80 percent. Thus, the frequency of installation of components in assembled vehicles may not indicate that they are actually optional in usage. Table 5 indicates the increase in use of various components that might affect the type and quantity of solid waste or scrap generated. Some inconsistencies may develop in the future because certain luxury models may list some items as standard equipment. For example, air conditioners for less expensive models would be listed as optional, while expensive models would have them as standard equipment.

Air conditioners have shown a dramatic growth because they are relatively new to the automobile market. For example, in 1962, 11.3 percent of the vehicles manufactured had air conditioners, but in 1969, the figure rose to 54.4 percent. The increase in the use of air conditioners will generate additional copper and aluminum scrap.

Another option, vinyl tops, has gained in popularity. The percentage of vehicles manufactured that had vinyl tops increased from 11.9 percent in 1966 to 41.4 percent in 1969. Vinyl can be either salvaged or disposed of as solid waste.

The V-8 engine presents a slightly different example. Installations of V-8 engines increased from 55.3 percent in 1962 to 89.9 percent in 1969. The amount of scrap generated from the manufacture of engines has increased owing to the increased number of cylinders. The percent increase in scrap may be less than the percent increase in the number of cylinders, although the sizes of the engine block and head were greater for the V-8 engines than for the older type of engines. In addition, there were two more cylinders to be machined and four more valves and other parts to be manufactured. "Optional" equipment thus affects both the quantities and types of waste and scrap generated.

Trucks. Three basic truck types produced since 1960 are the following (by percent): pickup (58), tractor cab (5), and special vehicle/van (37).

These basic truck models vary over a wide range of sizes and models and have from 3,500- to 20,000-lb body weights. Truck tractors, for over-the-highway trailer hauling, range up to 16,000 lb net weight and are generally manufactured in the integrated plants of SIC 3711, (see page 12). All truck models are classified into eight standard sizes based on gross vehicle weight (GVW).[11] The smaller 5,000-lb GVW pickup trucks are generally mass produced in assembly plants of SIC 3711, (see page 12). GVW classes above 40,000-lb, 3-axle combinations include the trailer weights and load, and thus GVW model designations are descriptive of the relative truck tractor sizes available. Different sizes and models of truck tractors are fabricated with similar parts and materials. The bodies are usually fabricated of steel or aluminum sheet, although a small percentage has Fiberglas cabs.

The remaining truck models are termed "special vehicles" owing to the relatively low production quantities and specialized uses of each type. "Special vehicles" include utility, recreation, food delivery and refrigeration, tank, refuse, food vending, panel delivery, van, and stake van trucks. These truck models vary widely in their body materials, structure, and major accessories installations. Common body materials used are Fiberglas, steel sheet, aluminum, wood, and canvas. The accessories installed according to the vehicle's function include refrigeration units and hydraulic loading and compacting equipment. Some of these accessories units are made with stainless steel, copper, brass, bronze, or other metals.

The seats, cab paneling, and instrument panel constructions are similar for all types of trucks and are not likely to vary greatly with truck size.

Buses. There is little difference among various bus models in terms of body structure and materials used. Bus bodies are manufactured from sheet steel or aluminum and have standard equipment installations. Interior paneling is usually plastic sheet over fiberboard or wood backing material. The seat covers are generally plastic filled with foam or cotton padding. The size of a bus is probably the most significant variable that influences scrap and waste generation.

Bus sizes are classified two ways as follows: (1) by the GVW classes used for trucks and (2) by the number of seats. Eighty-seven percent of the buses produced since 1965 were in the 16,000- to 19,500- and 19,500- to 26,000-lb GVW classes.[11] Buses in these two GVW classes have seating capacities ranging from 32 to 66.[12] Thus, a 34-seat, i.e., 106 percent, increase in seating capacity would cause a corresponding increase in seat and interior panel waste material quantities per bus produced.

Vehicle Components. Components refer to parts and accessories (see Glossary, Appendix A) commonly used in motor vehicles. Table 6 lists the vehicle parts common to all automobiles, trucks, and buses. Other components that serve special functions are: wrecker booms, fifth wheels, hydraulic hoists and lifts, fire vehicle equipment, and ambulance equipment. Fire and ambulance equipment, and hydraulic lifts are not, however, classified in the four SIC Codes studied. The components in the engine, transmission, differential, front end, and chassis groups are primarily manufactured from ferrous metals. Body and miscellaneous vehicle components may be metal, plastic, fiberboard, or cloth. The basic manufacturing processes and materials are described in detail in the section on methods and procedures.

Product Trends

Vehicle Size Trends. Two trends in vehicle size, based on weight, are evident, as shown in Figure 13. The short-term trend shows weight increasing since 1960, while the long term trend shows decreasing vehicle weight. Compact automobiles were introduced in 1961, which accounts for part of the indicated decrease in car weight. Other factors were the introduction of lighter weight aluminum for cast iron in some engine blocks, which increased the aluminum consumption per car, as shown in Figure 14; and increased plastic usage since 1960. The weight increase from 1961 to 1965 resulted from an increase in the size of compact cars as economic conditions improved. Several new compact cars were introduced in 1970, that were similar in size to small imported cars. Thus, the average vehicle weight should decrease in 1970. The long-term trend for the weight of an average truck/bus, as shown in Figure 13, exhibits the same general trend as the long-term trend for cars. The following two factors caused this: (1) an increase in production of lightweight pickup trucks used for recreation and (2) the introduction of Fiberglas-reinforced plastics for truck cabs. The short-term upward trend in truck/bus weight indicated from 1963 to 1967 results from increases in vehicle load capacity demanded by commercial trucking firms.[13] The combined weight of an average car/truck/bus trend is also shown in Figure 13. The effects of lighter vehicle weights and materials substitutions are indicated in Figure 14, which shows decreased ferrous metal consumption by the automotive industry.

Product Materials Trend. The major trend in materials is away from ferrous metals and towards plastic compounds, aluminum, and copper, as shown in Figure 14.

Fiberglas use in automotive vehicles was expected to rise 22 percent in 1969, from 134 million lb in 1968 to 164 million lb, and 55 percent in 1970 to 255 million lb. Sixty percent of Fiberglas consumption has been in cars, 15 percent in truck cabs, and 25 percent in commercial and recreation vehicles.[14] The growing recreation vehicle market is expected to contribute further to the use of Fiberglas by the industry. Fiberglas is used in vehicles primarily for: body sheet panels made of low-profile polyester resins; Fiberglas-reinforced thermoplastic body trim, grills, and instrument panel boards; and reinforced polyethylene fender liners. Among the newer plastic products are gas tanks, fasteners, and bumpers, which were introduced on a few 1970 model cars. In the past, major use of plastics has been in interior ceiling panels, insulation, seat covers, knobs, and handles. Plastics have displaced cast metals such as aluminum and zinc.[15] Electrodeposition processes can improve the surface appearance of thermosetting plastics so that they resemble metal, and thus impetus is provided to the use of plastic in vehicle trim and grills that are not structurally loaded.

Another recent innovation has been the use of rubber bumper guards and rubber bumpers as safety devices. Rubber may, however, be displaced by plastic foam bumpers owing to their greater nonelastic energy-absorbing properties.

Aluminum use has increased recently. Aluminum consumption by the automotive industry climbed dramatically from 514 million lb in 1960[16] to 791 million lb in 1969.[17] Most of the increased aluminum consumption has been for pistons and engine block castings, grill work and instrument panel extrusions, floor brackets, and trim. However, except for engine blocks and pistons, aluminum is in turn being displaced by plastics, and thus its use appears to have reached a plateau, as indicated by Figure 14.

Effects of Technology on Products. The major direct effects on products that technology causes are reflected in the capability of working with better, newer, and less costly materials. The plastics trend previously cited was made possible by advances in fabricating technology.

New technology has allowed printed electrical circuits to be substituted for wiring harnesses in instrument panels. Printed circuits reduce the amount of copper and wire insulation materials used while increasing fiberboard consumption.

Industry Cost Effects. The model stability previously discussed will be extended in the future by an increase in the time between model changes. Rising design and tooling costs, and competition from stable foreign car designs that maintain higher resale value are slowly affecting planned obsolescence, which was the basis for the industry's "three-year cycle" design timetable. The "three-year cycle" consists of the following: first year--an all-new car is produced; second year--a minor facelift is given by changing grills, light fixtures, etc; third year--a major facelift in the external sheet metal is made to give the car a new look. Then the process is repeated. This cycle has been extended to four years by some manufacturers and may reach six years for the newly (1970) introduced compact cars. The longer use of tools and dies will reduce the scrap and waste resulting from tooling setups that produce many rejected parts.

Government Regulations and Product Trends

Vehicle Safety Codes. The installation of seat belts on all new cars produced since 1966 is the major example of how government can directly influence industry's products. Other highway-safety-inspired product changes include padded instrument panels and seat headrests.

An air bag safety support system being tested by the National Highway Safety Bureau may be installed on some 1970 model cars and by 1973 may be universally installed.[18] These latter products are made of plastic materials.

Product Changes from Air Pollution Regulations. The initial regulations controlling vehicle emissions have resulted in new products such as crankcase vent systems and proposals for exhaust gas afterburners and filters. The major effects of air pollution regulations on vehicle products will, however, occur as a result of a program to develop new and better vehicle power sources, announced by the United States Department of Health, Education, and Welfare in December 1969. A five-year plan has been formulated to help replace the present internal combustion piston engine by sponsoring a $5 million product development program. A commercially feasible replacement is expected by 1976.[19] The new basic power sources to be investigated are electric motors, gas turbines, steam engines, and hybrid engines that combine two basic engine types. The introduction of any one or combination of these power sources would measurably affect the manufacturing processes and materials used by the industry. Electric motors are constructed of iron, copper, and plastic materials; gas turbines and steam engines require high-quality steels to withstand high temperatures and pressures, although some sections may be cast; and hybrid engines generally combine these two. Gas turbines require large air intakes, protection against dust ingestion, and exhaust heat deflectors. The basic processes and manufacturing waste types and quantities will all be affected. Most likely, in the future, an increase in metal sheet, tube, and plate scrap will occur together with a decrease in casting sand wastes.

Plant Operations

Identification of Plant Operations Generating Solid Waste and Scrap. Plant operations were categorized into the following five major groups: (1) office; (2) food services; (3) packaging and shipping, which includes receiving; (4) machine and foundry; and (5) trimming, cutting, forming, and assembly. Waste materials comprised 31.4 percent and scrap 68.6 percent of all materials discarded during plant operations. Combustible wastes comprised 51.4 percent of all waste materials. Plates 1 and 2 show the major types of scrap and solid waste observed in the plants that were visited.

Office Operations. Office wastes generally consisted of paper, light uncorrugated cardboard, floor sweepings, paper and plastic cups, and some lunch garbage. The variables tending to affect waste types and quantities were the number of employees; the use of computers, which generated data card wastes; and the proportion of office workers who ate lunches at their workplace. Office waste sources were bond paper and carbon paper from typing, discarded correspondence, supplies, wrapping, and discarded advertising literature. Office waste made up 3.34 percent by weight of all plant waste in the automotive plants sampled.*

Food Service Operations. Cafeterias, in-plant food- and drink-vending machines, and food-vending trucks were the three major food service operations. Employees who brought their own lunch produced wastes and garbage similar to the vending machine wastes, and these wastes will be discussed as such. There were cafeterias in 45 percent of the plants sampled by the project engineer and in 47 percent of the 217 AMA member plants. Cafeteria wastes were basically standard wet garbage (see Glossary, Appendix A) with some food container wastes. The food container wastes were, however, mixed with general plant wastes, and the garbage was usually handled separately. The quantity of cafeteria wastes varied greatly among plants and within plants on different days, depending on the proportion of employees eating there and on the weather. In the plants sampled by the project engineer, garbage wastes amounted to 2.3 percent by weight of total plant waste materials. In AMA member plants, garbage amounted to 4.1 percent of total plant wastes.

Packaging, Receiving, and Shipping Operations. Packaging wastes generally consisted of cardboard boxes, wood crates, wood pallets and skids, paper, plastic stuffing, tape, and metal banding. Packaging wastes averaged 26.3 percent of wastes in the plants sampled. This average was comprised mostly of wood and cardboard materials. Corrugated waste has been estimated to be about 50 lb for each automobile produced.[20]

The large mass production plants utilized reusable shipping containers with the following usable life schedules (average number of trips): cardboard (3), wood (6), rubber and plastic (10), and metal (60+).

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* For purposes of this report, "sampled" refers to the sum of 70 plants visited by the project engineer's staff and 43 that responded to the engineer's questionnaire.

Obviously, these containers will reduce the quantity of packaging wastes in proportion to their trip life. One major automobile manufacturer has utilized 23,000 reusable containers to ship parts to its 17 automobile assembly plants.[21]

Newer containers made of rigid wire mesh with disposable plastic trays combine the basic elements of reusable containers with disposable inserts. The packaging trend is towards reusable containers in the large plants with little change forecasted for the small plants employing fewer than 400 workers.

Processing Operations. The basic automotive plant manufacturing processes and their relative material losses are listed in Table 7. Machining produces the most material loss and welding/brazing/bonding produce the least. The results of the project engineer's sampling indicated that machine scrap made up 46.7 percent by weight of all plant waste and scrap and 66 percent of process scrap metals. The remaining 34 percent process scrap originated from the cutting, trimming, and forming operations. Foundry waste sand and dust comprised 49.4 percent and general plant wastes 15.2 percent of total waste materials. A detailed description of the processes that generate scrap and solid waste is given in Appendix D.

Casting molten metal and forging heated metals, when used, are the initial forming operations. Forging is illustrated in Figure 15. Then machining operations are performed to finish the product to proper dimensions. Figures 16 and 17 show the basic individual machining operations. A six-station transfer machine and its operational sequence is illustrated in Figure 18. Fabrication processes such as cutting, trimming, and forming are used primarily on sheet materials. The scrap generated by these basic processes is shown on Plate 1.

Process Trends. The trend to transfer machines has already been discussed. In addition, the basic process production rates have been increased substantially by the use of new machine tool metals and computers to control their operation. Table 8 gives examples of percentage increases in machine tool productivity and cost savings from 1950 to 1960. Increases in output ranged from 15 percent in broaching to 237 percent in sawing operations. Large, automatic sandcasting mold and core-forming machines have been developed which can produce 16 molds or cores in one cycle. The significance of these improvements is the increased parts production per sq ft of plant floor area and per employee.

Process Choice. Several processes may often be used to manufacture one part. The process choice may depend on the cost, severity of service, material, and complexity of the part shape. Forging, casting, and machining are often interchangeable as basic processes and are chosen for high-strength, low-strength, and intermediate-strength applications, respectively. Machining and die casting are required to form and finish complexly shaped parts. Some of the alternative manufacturing processes encountered in the survey are discussed next.

Product-Process Schematics

The process schematics in Figures 19 through 39 are arranged by the major plant type and process groups as follows: (1) automobile, bus, and truck assembly; (2) body fabrication; (3) machine, forging and foundry; and (4) miscellaneous parts fabrication. Scrap, solid waste, and salvage materials are identified at their source, and the basic raw materials and semimanufactured parts received at the plants are noted.

The percentages of scrap and waste generated in the plants sampled by the project engineer are given to exemplify differences among plants. When accurate data are available, the scrap generated per unit of product is given.

Mass Production--Automobile and Small Truck Assembly, SIC 3711. The processes illustrated in Figure 19 consisted of assembling manufacturing parts to form a vehicle. Occasionally, seat manufacturing and body section welding were completed in the plant. The major solid waste component came from packaging materials, which made up 93 percent by volume of the plant area wastes. The remaining 7 percent consisted of rejected and damaged parts. Rejected parts were returned to the supplier, and damaged parts were disposed of as scrap. All plant materials discarded were deposited in bins at the points of generation as noted.

Special-Purpose Truck and Bus Manufacturing, SIC 3711. Two examples of assembly plants for special-purpose vehicles are given in Figures 20 and 21. A custom bus- and fire vehicle-manufacturing plant (Figure 20) was set up on a shop basis, where each shop performed the functions as shown. The subassembly was then moved to another shop and mated to another subassembly. The volume of solid wastes generated was 94 percent of the volume of total material discarded, and the volume of metal scrap 6 percent. Steel and aluminum scrap represented 87 percent by weight of total disposed materials, with solid wastes comprising the remaining 13 percent. Waste and scrap bins were located in each shop near the process equipment. Wood and paper were mixed in the woodshop; masking paper and paint were mixed in the paint shop; metal scrap was segregated at the source.

Custom truck body and vehicle manufacture is illustrated in Figure 21. This plant was structured on an assembly line basis. The bodies were manufactured and assembled and parts added on a production line to form a complete vehicle in sequence. The scrap in this plant made up 72 percent by weight of the total discarded material, paper 6 percent, and paint sludge 22 percent. Metal scrap averaged 328 lb per vehicle produced. Waste and scrap bins were positioned next to the process equipment, and wastes were segregated as they were generated.

Body and Trim Fabrication, SIC 3712 and 3713. Body manufacturing is illustrated in Figure 21. The body parts include cowl tops, door panels, body pillars, trunk lids, rocker panels, roof sections, and floor sections--all requiring similar processing. This plant differed from the other body and vehicle plants discussed, in that conveyors were located under the fabricating equipment to remove scrap materials from the plant. Wastes amounted to less than 2.5 percent by weight of total material discarded; the remaining 97.5 percent consisted of ferrous sheet trim. The conveyor system handled about 3,000 lb of ferrous scrap per hr of operation.

A special-purpose truck body-manufacturing plant is shown in Figure 23. The wastes included Fiberglas and plastic body sheet trimmings, in addition to metal sheet, both of which were segregated at their source. Metal scrap made up 70 percent of the total discarded material weight; plastics and Fiberglas 18 percent; and wood, paper, etc, the remaining 12 percent.

The schematic for an exterior body trim plant is Figure 24. It includes fabricated exterior trim, wheel well covers, and door and window moulding. Eighty-three percent by weight of plant discards were scrap metal sheet trim and 17 percent paper and cardboard.

Parts Manufacturing: Machine and Foundry, SIC 3714.

Engine Manufacturing. The process sequence shown for casting engine blocks, heads, and camshafts (Figure 25) is applicable to cast iron and aluminum materials used in manufacturing gasoline and diesel engines. The major waste material from the plants sampled was burnt sand, which represented 90 to 99 percent by weight of all discarded materials. All metal scrap was recycled back to the furnace and reused. Sand losses averaged about 10 lb per engine in the plants sampled.

The schematic for crankshaft and camshaft bearings is Figure 26. Ninety-nine percent by weight of materials discarded were metals, of which 8 percent, consisting of babbitt dross, was sold as scrap. The remaining 1 percent was paper. Approximately 0.235 lb of ferrous and babbitt scrap were generated per bearing. The centrifugal casting process used here did not require sand. These bearing plants did not create significant waste problems.

The schematic for engine manufacturing and assembly is Figure 27.[22] The final steps in manufacturing a complete engine are illustrated. The cast engine blocks, heads, and camshafts were finish machined before assembly. These metal-cutting operations produced, on the average, approximately 100 lb of cast iron chips per engine. In plants of this type, approximately 5 percent of the metal wastes were aluminum chips from piston machining and the remaining 95 percent were cast iron chips and ferrous turnings.

The schematic for flywheels and ring gears is Figure 28. Ninety-eight percent by weight of the discarded materials were found to consist of steel chips, turnings, and metal sawing dust. The remaining 2 percent consisted of paper, wood, and cardboard.

Steel represented 91 percent by weight and cast iron 9 percent of the scrap metals in this plant. There were approximately 2.4 lb of steel scrap per ring gear, and 12 lb of cast iron scrap per flywheel.

Transmission and Parts. The schematic for transmissions is Figure 29. The plant had three production lines to manufacture the major transmission parts and two lines for various levers and brackets. Discarded materials consisted of 84 percent by weight iron and steel chips, and forge flashing; 1 percent aluminum and brass; and 15 percent waste paper, wood, and cardboard. The scrap generated per transmission in this plant was 344 lb.

The schematic for transmission and differential gear forging is Figure 30. This plant forged gear blanks by an alternative process to the straight gear-machining operations shown in Figure 29. In this plant, 16.2 percent by weight of discards were waste paper, cardboard, and wood; 68.3 percent steel flashing; and 15.5 percent steel scale.

The schematic for axles is Figure 31. It illustrates alternative processes for manufacturing the same product. The process choice depends on the two following criteria: (1) the expected stress loading on the axle and (2) the size and geometry of the axle shaft with respect to the raw bar material size. Forging scale wastes accounted for 13.5 percent by weight of discarded metal material with the remaining 86.5 percent consisting of steel machine chips (56.5 percent) and cut bar crops (30 percent). Metal scrap made up 97 percent of discarded materials, and paper and cardboard waste 3 percent. Scrap and scale loss, 9.2 percent by weight per axle, ranged from about 2.7 lb per car axle to 8 lb for a truck axle.

Front-End Assemblies. Front-end linkage and universal joints are illustrated in Figure 32, and idler arm, yokes, and tie rod ends, in Figure 33. These two schematics depict the major parts constituting front-end assemblies. Approximately 79 percent by weight of discarded materials consisted of forging flash, 11.6 percent forging scale, and 9.4 percent paper and wood wastes.

Chassis. Bumpers for cars and trucks are represented in Figure 34. This plant reclaimed plating metals for reuse in the bumper processing. Metal sheet scrap amounted to about 60 percent by weight of discarded materials, plating and buffing sludge 8 percent, and general wastes 32 percent. On the average, 5 lb of sheet metal scrap and 0.7 lb of sludge were generated per bumper.

Exhaust systems are represented in Figure 35. The plants sampled produced primarily tail pipes and mufflers. Discarded materials averaged 95 percent by weight metal trim and 5 percent waste paper, cardboard, and wood. Approximately 2.05 lb of scrap metal were generated per muffler.

Miscellaneous Vehicle Components.

Automotive Springs. See Figure 36 for process schematic. This plant manufactured springs for hood hinges, transmissions, clutches, doors, brakes, etc. Mixed metal scrap made up 76 percent by weight of discarded materials, and waste paper and cardboard 24 percent.

Seats. See Figure 37 for process schematic. Most of the burlap and wire were sold as salvage, which represented 20 percent by weight of discarded materials. Paper, cardboard, and wood wastes made up the remaining 80 percent. Approximately 0.1 lb of salvage was generated per seat cushion produced.

Air, Fuel, and Oil Filters/Cleaners. Figure 38 illustrates the processes. The filter manufacturing process generated scrap and waste materials. For the plants sampled, scrap averaged 54 percent, by weight, and wastes 46 percent of discarded materials. The waste generated per unit produced varied greatly, depending on the size of the unit.

Air Conditioner and Heater Units. See Figure 39 for illustration of the process. This plant manufactured the main unit body and purchased most parts. Scrap metal made up 77 percent by weight of discarded materials and paper and wood, 23 percent. Copper and brass scrap totaled 33 percent of the metals. Approximately 1.1 lb of metal scrap were generated per unit produced.

METHODS AND PROCEDURES

Industry Sample Structure

Four automobile-manufacturing companies assemble about 99 percent of the automobiles, trucks, and buses in the United States. These four major firms plus six other vehicle and component manufacturers are members of the major industry trade association, the Automobile Manufacturers Association (AMA). The remainder of the industry consists of parts and accessories manufacturers who supply the AMA member companies and the parts replacement market.

This study was conducted in the following three parts: (1) a questionnaire survey and visits by the project engineer's staff to plants manufacturing parts and accessories that were not members of the AMA; (2) a questionnaire survey of AMA member plants conducted by the AMA, who in turn made the questionnaire available for this study; and (3) a questionnaire and survey visits by the project engineer's staff to municipalities where automotive industry plants were located.

Sampling Methodology

Industry Visit Criteria. The plant information available from literature and trade association sources included plant products, the plant dollar categories, and, for a limited number of plants, the number of employees. The value of large plants given in the literature was listed as "over $1 million," and hence an accurate statistical distribution of plants by value was not available. The relationship between listed plant value and number of employees yielded a low correlation, and thus listed plant value was not presumed to indicate plant employment. In order to obtain representative industry data, a systematic procedure for selecting plants to be visited was developed based on the following four variables: (1) product, (2) size, (3) employment, and (4) location.

The automobile body and parts manufacturers included in SIC Codes 3711, 3712, 3713, and 3714 manufactured products that approximated 80 percent of the curb weight of an average car.[23] Plants selected for visits were chosen from these four SIC Codes. The plants were located in cities across the United States, as shown in Figure 40, and had a geographical distribution representative of that of the industry. The larger plants were emphasized in order to cover the greatest number of products and employees, though plants of all sizes were visited. The distribution with respect to the number of employees of all plants sampled is shown in Figure 41.

AMA member plants being excluded, the remainder of the industry varied widely in plant characteristics. Plants falling into SIC 3711, 3712, and 3713 used different materials but employed similar fabricating processes. Plants in SIC 3714 varied widely in accordance with the product, process, and materials used. The great variation in plant size and products of the portion of the industry studied was expected to result in large variations in waste-handling and management practices. Thus, a larger sample size was required to compensate for extensive differences in the smaller plants studied than would have been necessary for the large plants owned by AMA members with their greater product similarity. Plants in SIC 3711 were classified into automobile, truck, and bus plants. The major automobile and truck plants were not visited, because they were AMA members. Special-use truck manufacturers were grouped by truck type, and body manufacturers (SIC 3712 and 3713) were grouped by body type (dump, refrigerated, tank, etc). The parts and accessories manufacturers (SIC 3714) were grouped into eight major vehicle component groups (see Table 6) containing 78 vehicle components.

Statistical Methods. The plants not members of the AMA accounted for a disproportionately small amount of the total vehicle production being largely concerned with automotive parts and accessory manufacturing and custom truck and bus manufacturing. The sampling method used to determine which plants would be visited was structured to provide an estimate of scrap for a composite automobile/truck, and a representative sampling of the types of solid waste generated in the manufacture of major vehicle components (see Table 6).

The plants visited were chosen by stratified sampling from the population of plants that were not members of AMA. AMA member plants were not included in the sampled population because the AMA conducted a solid waste survey of its member plants and made the data available for use in this study. The characteristics used for stratification were plant product, size, and employment. The use of stratification by product made it possible to obtain a representative sampling of types of waste and of waste-handling practices and to derive estimates of scrap per component generated in the manufacture of components comprising 85 percent of the curb weight of an automobile/truck produced by the industry (SIC 3711-3714). These scrap estimates were then summarized to yield an estimate of scrap per automobile/truck. The use of a stratified sample also enabled concentration on larger plants which presumably account for more scrap and solid waste production in the industry's plants.

Although materials and processes used varied as did waste management practices, within a stratum the choice was arbitrary. All major waste management practices were represented in the portion of the industry visited. Twenty percent of the plants chosen by the sampling procedure were not accessible for visits; when this condition existed, an alternative plant representing the same product was chosen. The extrapolation of the estimates of solid waste for the portion of the automotive industry sampled to the entire industry should only be done for illustration purposes because of the existence of large integrated manufacturing and accessory plants with their large employment and production.

Plant Contact Procedure. The managers or presidents of plants selected for visits were initially contacted by telephone in order to obtain permission for a site visit. This approach resulted in cooperation from 80 percent of the plants thus contacted. The project engineer's staff reported that the plant personnel were cooperative in providing information for 90 percent of the plants visited.

Plant Data. The items sought at each plant included the following: (1) completion of the industry questionnaire which had previously been mailed to the plant; (2) product weights, weights of solid waste and scrap, contractor cost, recent or anticipated changes in management, etc; (3) plant layouts and process schematics noting solid waste generation and storage locations; (4) photographs of waste storage areas and containers and of the types of wastes, when permitted; and (5) evaluation of plant appearance with regard to litter, smoke and fumes, and degree of visibility of waste storage areas from outside the plant property. Copies of the Industry Questionnaire and Plant Visit Interview Information Sheet are included in Appendix B.

Most plants had scrap information available in terms of weights and dollar sales because records were regularly kept. In the few remaining instances it was also possible to acquire accurate scrap estimates because the plants called the collector when the scrap bins were filled. Thus, an accurate volume measure was obtainable and the consistency in scrap type provided accurate weight estimates.

Ninety percent of the plants visited maintained records of solid waste collection and disposal costs and cubic yards removed; however, many charges were flat monthly charges that may not always have been directly related to actual solid waste weights. The project engineer's staff made field estimates of the volume and weight of solid waste and this data was checked against the plant records. The composition and density of the waste in containers were measured when feasible, otherwise waste quantities were estimated. The procedure for estimating the wastes and training the field survey staff is briefly described in Appendix C.

Industry Coverage

Plant Visits. The portion of the automotive industry covered by on-site plant visits may be expressed in terms of the following descriptive parameters: (1) geographic location; (2) plant value; (3) employment; (4) products; and (5) production. As discussed previously, with the exception of plant production, these parameters were utilized to select plants for visiting. Since data on the total employment and production of parts and accessories by plants that are not AMA members is not available, the coverage will be presented in terms of the total industry.

Geography. The geographic distribution of plants visited is illustrated in Figure 40. Most visits were made in areas having the greatest concentration of automotive industry plants; additional visits were made in order to provide sufficient geographic distribution. A summary of the number of plants sampled in each HEW region and for the major product/SIC Codes is shown in Table 9.

Plant Value. The minimum valuations of the plants sampled are listed in Table 10. Approximately 24 percent of the minimum industry plant valuation, including AMA member plants, was covered. Minimum estimates for the AMA member plants were made; thus, the actual total industry valuation was much greater. The 217 AMA member plants that responded to the industry questionnaire probably comprised the bulk of the difference between the minimum estimated and actual valuations.

Employment. The number of employees sampled (AMA excluded) is listed in Table 11. The employees in plants sampled comprised 6.1 percent of 1969 industry employment. Employment data received from 158 of 217 AMA member plants listed 1969 employment at 673, 472, or 77.4 percent of total 1969 industry employment. Thus, waste data are available from plants employing 83.5 percent of the workers; hence, a reliable estimate of 1969 industry waste can be made when based on employment.

Product Type. The type of products manufactured in the 74 plants visited comprised 70 percent of the curb weight of an average automobile; they manufactured product types that comprised 85 percent of the types of products listed in SIC 3711 through 3714. The percentages of estimated 1969 industry production for most major products in the plants sampled are shown in Table 12. The visit coverage for special truck production was 14 percent, for bus bodies 20 percent, and for ambulances and hearses 13 percent.

Response to Questionnaire Survey. Plant visits were supplemented by mailed questionnaires (see Appendix B). The plants were listed on small tabs and randomly drawn from a box until approximately 50 percent or 1,200 of the plants were selected for the questionnaires. An additional 500 questionnaires were distributed separately by the Automotive Service Industry Association to its manufacturer members. Thus, a total of 1,700 questionnaires was distributed. Of these, 8.1 percent were returned.

The response to the questionnaire survey is presented in Tables 8 through 11. The responses, classified according to HEW regions, are listed in Table 9 in terms of plants responding. The replies to each question on the questionnaire are given in Table 13. Forty-three mailed questionnaires were completed in enough detail to be usable for technical quantitative and qualitative analyses. An additional 29 incomplete questionnaires were usable for qualitative analyses (Questions G through L).

A large number of questionnaires was returned without answers to any questions. The reasons for not answering are listed separately in Table 14. Of the 65 nonusable replies, the majority (68 percent) replied they were not presently manufacturing items in the four SIC groups being studied. These firms were not major producers according to industry sources and apparently supplied parts to automotive plants on a short-term contract basis.

AMA Survey Response. The AMA supplied 217 questionnaires from its survey of members' plants. The 217 plants responding comprised about 96 percent of the AMA member plants. Of this total, 158 were usable for investigating solid waste prediction parameters and 59 were useful only for waste-handling cost analysis. Plant employment with complete waste information was provided on 158 questionnaires and was the only parameter available for predicting waste quantities on an industry-wide basis. The AMA member plant employment coverage of the industry is illustrated in Figure 41. A summary of the AMA member plants' replies to questions on the questionnaire is given in Table 15. A sample questionnaire is included in Appendix B. The questionnaires did not identify the plant products or location. All responding AMA member plants supplied cost data for removal and disposal of their solid wastes. In addition, the quantity and type of solid waste were supplied by all but one plant.

Community Sample

Survey Procedure. The survey of municipalities presented few problems because the plants were situated in a relatively small number of communities. A total of 235 communities with automotive industry plants was located in 185 Standard Metropolitan Statistical Areas (SMSA) and 50 smaller towns spread across the United States (see Table 3 and Figures 9 through 12). All these communities were contacted by mailed questionnaires; additionally, in conjunction with the plant site visits, the responsible municipal authorities in 11 municipalities were personally contacted. Copies of the Municipal Questionnaire and Interview Forms are included in Appendix B.

Community Survey Response. Responses were received from communities in 48 of the SMSA's, or 26 percent of the SMSA's having communities with automotive industry plants. The total response, of which about 15 percent had useful data, was about 20 percent of the questionnaires mailed. Eleven municipalities were personally contacted by the project engineer's staff to follow up questionnaire responses and evaluate automotive plant solid waste management practices in relationship to municipal waste management policies. A summary of mailed responses from and personal contacts with these municipalities for each HEW Region is presented in Table 16. A breakdown of the types of answers from questionnaire responses shows one completed, six partially complete, and 41 incomplete questionnaires were received (Table 17). The limited data sample was useful for comparison with plant visit data.

Data Reliability

The plant data reliability was evaluated by three criteria as follows: (1) the percentage of the industry sampled based on the industry/plant parameters, (2) sampled plant representativeness for the whole industry, and (3) accuracy and completeness of the data sample acquired.

Industry Coverage. About 95 percent of the AMA member plants supplied information. Assembly and large integrated plants were both represented in the data. Some data was acquired for 85 percent of the major product categories, 83.5 percent of the total industry employment, and 13 percent of the total plant population.

Sample Representativeness. Since 20 percent of the parts and accessory plants contacted for visits were not accessible, the data may have been biased if these inaccessible plants had major waste management problems. Industry estimates based on the plant data were satisfactory since the industry coverage (including the AMA) is good. Thus, plant waste estimates may be low because of the possible bias.

Data Accuracy. The major problems in data accuracy were related to the accuracy and completeness of plant records, estimates by the field interview staff, and the questionnaires.

Plant records contained accurate data on the types of solid waste, the associated collection and disposal costs, and scrap sales by types and quantities. About 10 percent of the plants visited did not keep records for waste and scrap quantities; at these locations estimates based on measured volumes and listed costs were made by the field interviewers.

The independent data estimated by the field survey staff included weight and density (packing factor) for the solid waste and scrap. The volumes of scrap were accurately estimated because the small companies had their scrap removed on call when the containers of known volume were filled. Waste weight and composition estimates were probably less accurate owing to variations observed in different storage containers. The methods used to achieve uniform data accuracy are described in Appendix C. Special training in estimating waste densities was given to the field survey staff.

The plant value categories on the questionnaire (see Appendix B) may have required the large plants to declare less than their real value. This factor may account for some of the large variations observed in plant waste and scrap quantities for the greater than $10 million plant value category.

In summary, the reliability of the data cannot be defined in quantitative terms. Information obtained from company records is assumed to be accurate, particularly since money was involved. The reliability of AMA data cannot be proven but can be postulated as high because the large plants selected their waste haulers by competitive bidding based on expected large waste quantities and types.

DATA ANALYSIS

General Approach

Data analyses were designed with the following three objectives in mind: (1) estimation of industry solid waste; (2) estimation of total industry scrap and scrap per car produced; and (3) determination of general plant characteristics that would be useful in predicting plant waste and scrap quantities for individual plants, groups of similar plants, or regional areas. The analytical approaches used were developed to provide estimates of waste and scrap production based on available data.

The solid waste data contained in the AMA questionnaires was good, and when combined with the other study results, accounted for plants representing approximately 83.5 percent of total industry employment. Thus, a good estimate of total industry waste in 1969 was made by computing the average waste per employee for the plants responding and multiplying by the total 1969 industry employment.

The AMA members do not consider scrap a solid waste problem since it is presently being reused. Thus, salvage data was provided by the AMA survey, but specific scrap data was not included. Scrap estimates were, therefore, derived solely from the plants sampled by the project engineer, and from published sources. Scrap generation was obtained by estimating the scrap produced in the manufacture of a composite car/truck. The procedure was to obtain, from the plants sampled, estimates of the scrap generated in the manufacture of parts used to assemble an automobile, truck, and bus and to combine these estimates to yield an estimate of scrap produced in the manufacture of a vehicle composed of these parts. Although no direct measurement of the accuracy of this estimate could be made as a result of the small number of plants sampled for each product, a comparison with materials balance estimates for the automotive industry, derived from Figures 13 and 14, provided high corroboration.

Determination of general plant characteristics that would be useful in predicting plant scrap and waste quantities was not possible owing to the incompleteness of the available data. However, a study was conducted on the data from the plants sampled, using stepwise linear multiple regression. The preliminary study indicated that solid waste and scrap production could not be well predicted by the parameters of manufacturing process, employment, plant value, or the number of items made in an individual plant but that they might possibly be predicted for a group of plants with similar characteristics within an entire HEW region.

Automotive Industry Solid Waste and Scrap Prediction

Industry Waste Prediction. Initially, correlation studies were conducted to investigate the relation between cafeteria wastes and the number of employees. The results, based on 112 plants (including AMA) that supplied garbage information, showed zero correlation between number of employees and garbage produced.

Office waste studies were conducted on 27 plants surveyed* and visited by the project engineer. The correlation between office wastes and number of employees was 0.73. However, office wastes were not reported as such in the AMA members survey and thus were considered a secondary parameter.

A third investigation was made to relate total plant solid waste generation with employment for all products and processes combined on an industry basis. The results, based on 158 AMA member and 63 sampled plants, showed no correlation (0.00) for the industry as a whole. A plot of the plant wastes per employee is shown in Figure 42. The data points that fall outside the range of waste quantities represent foundries, which generate large quantities of waste sand and sludge.

* For the purposes of this report, "surveyed" refers to the plants that responded to the mailed questionnaire.

Automotive Industry Solid Waste Prediction. Industry data available from all sources provided detailed information on quantities and qualities of 1969 solid waste production in plants. In view of the high percentage (83.5) of total industry employment covered, estimates of the 1969 industry solid waste production and projections for 1975 were made on the basis of short-term trends as follows:

1. Waste estimates for 1969 were computed by summing the wastes, by type, for plants that supplied employment information and then multiplying by the following factor:

$$\frac{\text{Total 1969 industry employment (100 percent)}}{\text{1969 employment sampled (83.5 percent)}} = 1.2$$

2. Vehicle production for 1975 was projected as 13.7 million.

3. Productivity in man-hours per vehicle for total industry employment was projected from Figure 7.

4. The number of employees required to produce the vehicles in 1975 was derived from productivity by assuming a 52-week, 41.7-hour-per-week work schedule.

5. Wastes were then calculated for 1975 by using the ratio of derived 1975 industry employment to total 1969 industry employment.

Waste estimates for 1969 and 1975, by type, are presented in Table 18. Note that foundry sand comprised 83 percent of all inert solids generated and sludges from foundries accounted for 79 percent of the total sludges and slurries. The large amounts of sludge wastes are generated during the washing operation, where the cast part is cleaned with water and liquid cleaning compounds. The solid wastes per vehicle produced were 1,600 lb in 1969 and are projected at 1,480 lb in 1975. The decreased unit vehicle wastes in 1975 reflect technology advances related to plant production and operations.

Industry Scrap Estimates. The quantity of scrap generated by the automotive industry varies between plants manufacturing the same product. This is the result of the following: (1) the different sizes in which each product is available, (2) alternative manufacturing processes, and (3) differing process efficiencies. Scrap estimates were obtained by formulating a vehicle composed of parts manufactured in the plants sampled (see the parts list in Table 6). The scrap estimate for each item was obtained by dividing the amount of scrap produced per month in the manufacture of the item by the number of items produced per month.

Table 19 lists the parts commonly used in an automobile and the quantity of scrap generated during their manufacture. Table 20 contains estimates of the scrap generated from the manufacture of a truck and bus. A common undercarriage and parts composition was assumed for each truck type and for buses. Scrap projections for 1975 are based on the vehicle production projected for that year. The scrap estimates are for metals only. Approximately 97 percent of the scrap metals generated in the plants surveyed was ferrous material, 1.65 percent was aluminum, 0.6 percent bronze, and 0.75 percent mixed copper, brass, and zinc. This scrap materials composition is in close agreement with the materials composition of a typical automobile listed in Table 21.

Industry Materials Balance. A materials balance for consumption of metals by the automotive industry was completed to provide an alternative estimate of metal scrap. The materials balance was computed from the latest data available, 1966. Production, employment, and productivity in 1966 each differed by from 0.5 to 1.7 percent from 1969. Thus, these 2 years were assumed comparable for scrap estimation.

The computational steps were:

1. Metal materials consumption of 4,445 lb per vehicle produced (cars, trucks, and buses) in 1966 was taken from Figure 14 and is presented in Table 22.

2. The weight of the average vehicle produced in 1966 was 3,694 lb based on data calculations illustrated in Figure 13.

3. The metal materials in a composite vehicle described in Table 21 (89.5 percent) was used to estimate the quantity of metal (3,306 lb) in an average vehicle.

4. Scrap per vehicle and total industry scrap were calculated from 1969 vehicle production; it was assumed that the percent of material becoming scrap remained constant.

The scrap estimate by type of material is given in Table 22. The estimated scrap per average vehicle produced is 1,139 lb, which is slightly greater than the 1,000 lb per vehicle derived from Tables 19 and 20.

Prediction of Solid Wastes and Scrap for Individual Plants, Plant Groups, and Regional Area.

Model Formulation. Data from the plants surveyed and visited were studied to determine the usefulness of plant characteristics as predictors of plant waste and scrap quantities. The variables available as potential predictors in the study were product, processing operation, plant employment, plant value, and quantity of items produced. Owing to the large number and variety of products encountered, product groupings were used. Each plant was assigned a product group and a processing operation by determination of the major product manufactured by the plant and the predominant processing operation occurring in the plant. Thus, within any classification the possible predictive variables were plant employment, plant value, and quantity of items produced.

Since several plants did not give information on the quantity of items produced, two model formulations were used, one that included the quantity of items produced and one that did not. Four models were investigated, two for prediction of scrap and two for the prediction of solid wastes. The linear models were as follows:

$$(1)\quad Y_i = b_0 + b_1X_1 + b_2X_2 + \epsilon \qquad i = 1,2$$

$$(2)\quad Y_i = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \epsilon \qquad i = 1,2$$

where Y_1 = scrap produced (tons/month)

Y_2 = solid waste produced (tons/month)

X_1 = number of employees

X_2 = estimated plant value (in $10,000)

X_3 = quantity of product made

and ϵ is an error term with $E(\epsilon) \cong 0$

These models were first used for all the data available, without classification by process or product. This first run on waste prediction was similar to the study described above (see Industry Waste Prediction) and also showed no correlation (0.06) (see Tables 23 and 24, Any Plant Type). Then the models were used on data satisfying successively more restrictive classifications. This process of subclassification was limited by plant sample size considerations, and only those subclassifications that contained a large number of plants relative to the variance of the dependent variable were used.

Stepwise Linear Regression. In order to predict a variable Y_i in terms of X_1 and X_2 (and X_3) a "best fit" solution plane (hyperplane) was sought in three- (four-) dimensional space. The technique used to find this plane was stepwise linear regression, which introduces an independent variable into the linear model only if it will contribute significantly (as measured by an F-test) to the explanation of the variance of the dependent variable. This produces an approximate "best fit" solution, in the least squares sense, and has the advantage that variables not contributing to the explanation of the variance of the dependent variable are not used.

The general equations arrived at by this method are of the form:

$$(1)\ Y_i = B_0 + B_1X_1 + B_2X_2$$

$$(2)\ Y_i = B_0 + B_1X_1 + B_2X_2 + B_3X_3$$

where the B_i are estimates of b_i, unless $B_i = 0$, which was used to signify that X_i had not been brought into the equation.

The results of the stepwise regression analysis are shown in Tables 23 through 26. Presented along with the regression coefficients are the values of multiple R^2 which is a measure of the proportion of variance of the dependent variable accounted for by the prediction equation, and the standard error, which is the standard deviation of the residuals.

Discussion of the Model. In almost all cases, even when the amount of variance accounted for by the prediction equation was high, the standard error was too large to permit accurate predictions of individual plant scrap and waste.

This is most likely attributable to the wide range of plant products comprising one product group and to the fact that while a plant may have had an easily discernible major processing operation, it often also had a large number of secondary processing operations. A second source of error in these results was that the maximum figure allowed for plant value was $10 million which may have been too limiting.

Waste Management in the Automotive Industry Plants Sampled

Handling and Collection Methods at the Plant Source. Waste and scrap storage methods were essentially identical in the plants sampled. Solid waste and scrap were stored at the source in containers ranging in size from 55 gal drums up to 30 cu yd. Containers less than 4 cu yd were used in 85 percent of the 70 plants visited for source storage, of which 55 gal drums were the most common. Central storage areas located outside the plant buildings contained containers varying from 55 gal drums to 80 cu yd compactors. Large stationary storage bins that were built on the plant grounds varied in size from 70 to 272 cu yd. Presented in Table 27 is a tabulation of the container and bin sizes observed. Photographs of bins are presented in Plate 2c and d, and several common containers are shown in Plate 3. The distribution of container and bin sizes are presented graphically in Figure 43. The particular container size chosen depended upon the type and quantity of solid waste produced. In particular, large bulky wastes such as cardboard, sheet metal trim, wood, and large sheets of wrapping paper required the larger containers to allow longer periods between collection and to reduce spillover. Office waste, steel chips and turnings, and food vending waste (see Plate 3a) were stored in small containers such as 55 gal drums.

In-plant waste collection involved six pickup methods used either singly or in combination as follows: hand truck, towing vehicle, forklift truck, small industrial truck, belt conveyors, and vacuum system conveyors. Of the 70 plants visited that supplied information, 22.8 percent (16) used hand equipment only, 47.2 percent (33) used both hand and mechanical equipment, and 30.0 percent (21) used only mechanical equipment. Towing vehicles were used to tow wheeled containers, several of which were hooked together, to the storage area for processing and collection. Plants that used conveyors or vacuum systems to remove waste from process areas required little janitorial work in the process areas. Photographs of waste collection equipment are shown in Plates 4 and 5. There were basically two types of handling methods at the process waste generation source, as follows: (1) periodic removal, where collection from containers was scheduled periodically, and (2) continuous removal where conveyors or vacuum systems were used to remove wastes as they were generated to external storage containers. A summary of equipment use in the automotive plants visited is presented in Tables 28 and 29.

Vacuum systems were used for removing light sawdust or plastics from manufacturing areas where sawing or drilling occurred. They were present primarily in specialized custom truck body plants. Vacuum systems were also used to remove grinding dust in mass production operations and to remove paper from the vicinity of paper cutters. Another use was in the manufacture of arm and hand rests for the interior of vehicles. In these manufacturing areas, plastic and wood trim wastes were removed during the trimming operations.

Of the 70 plants supplying information on waste handling equipment, 21.4 percent (15) reported using conveyor systems. Conveyors were used primarily for the removal of scrap from the vicinity of machines. Although conveyors were used for all types of scrap, the bulk of the materials handled by the conveyors was made up of metal chips, turnings, and stamping scrap. One plant used a conveyor to remove sand from the casting shaking machines to an external storage area. Sometimes plants used conveyors to remove scrap from the processing area and to feed balers or shredders. However, most conveyors were part of complete scrap handling systems, which conveyed metal from the plant source into waiting railroad cars, gondolas, compactor vans, trailers, or stationary bins. They were used in mass production operations.

Overhead cranes were used less frequently than were compactors, conveyors, and vacuum systems. Next to incinerators, the most widely used item of equipment for solid waste volume reduction was the compactor.

The compactor solid waste storage container units in use in the 70 automotive industry plants visited varied in size from 16 to 80 cu yd. The number of plants with compactor containers of listed capacity is shown in the following list:

Container capacity (cu yd)	Number of plants
16	1
18	1
30	5
33	1
35	1
40	5
42	1
80	1

Except for two plants where compactors were used for scrap turnings, the compactors were used for normal solid waste, i.e. compacting paper and cardboard. Of two balers found, one was used to bale paper and corrugated packaging waste, and the other to bale scrap metal. At other locations, the shredder and shear were used to reduce sheet scrap to a smaller, denser, cleaner, and more easily handled size. One skip loader was used to load grinding paste sludge. Two overhead cranes were used primarily to load materials from the storage containers and bins into collection vehicles. One of the cranes was also used to remove sheet metal from within the plant process area to the outside storage area. Magnets were used to segregate ferrous from nonferrous scrap and waste and to load scrap from the external storage area into the collection trucks. In Michigan many of the private collectors utilized their own truck-mounted magnets for separating ferrous scrap at the plants when loading it into their trucks.

Equipment Use Factors. Several factors influenced the usage of handling or processing equipment in plants. Production volumes often influenced the choice of waste-handling equipment. In particular, large multistation transfer machines with high production rates generated large quantities of wastes per unit of operation time (Figure 18). These machines were set up in such a way that a conveyor automatically removed the metal chips, turnings, and grinding dust from beneath the machine and transported them to a storage bin or to scrap-processing equipment. These costly machines are used for high production rates and were encountered only in plants with plant capital values greater than $1 million.

In one large body plant the scrap was automatically removed from the shop area. The plant installed a conveyor unit capable of carrying 20 to 30 lb per lineal ft and of transporting 550,000 lb of metal daily. This conveyor system was located under shearing presses and fed a central conveyor that transported all scrap material to an outside processing and storage area. The plant also segregated its steel scrap into the following three categories at the outside processing area: (1) scrap suitable only for sale, which was directed to the conveyor for processing by a baler; (2) large flat pieces of irregular shapes suitable for reuse within the plant, which were separated for storage and reuse; and (3) small flat pieces, generally resulting from piercing operations, which were stored loose in freight cars, and subsequently sold to mills.

Other factors influencing equipment usage were safety and the need to prevent product damage. In areas where large amounts of dust were generated, which might have damaged products and machinery, or become a hazard for workers, vacuum removal systems were used. In areas where oil or water was employed as a lubricant or coolant the oily mixture was cycled through filters and settling tanks.

The volume reduction accomplished by the compactors resulted in reduced costs because collection and disposal costs were normally based on the volume of solid waste. Thus, the use of compactors in plants that generated large waste quantities resulted in significant cost reductions, even when the cost of the compactor equipment was considered.

Labor Aspects of Waste Management. In larger plants a regular maintenance department operated the equipment and collected the waste at regular intervals from containers located throughout the plant. In the smaller plants, the cleanup services were performed once or twice a day by one person who emptied the containers at the machines by hand or by forklift. This diversity in the methods of plant maintenance created a wide variation in labor costs. In plants with fewer than 50 employees, one or two persons spent a few hours per day cleaning up in the area of the process machines and then returned to other jobs. Cleanup costs were not separated. Larger plants that used highly automated waste-handling equipment employed labor to clean up spills. These labor costs again depended primarily on the particular efficiency of a system at a given plant.

Often the size of the containers located at a given station varied because replacements after collection were made from available empty containers. Occasionally large amounts of waste were generated at a station with a relatively small container. To remedy this situation, the containers were exchanged during in-plant collection.

Less than 10 percent of the plants visited contracted for private cleanup services, and most of these were restricted to office areas. Private janitorial services were commonly used to keep costs down. Cost and production records, however, could be safeguarded by using company-operated janitorial services at extra expense. This practice was followed in plants manufacturing prototype products, automobile bodies, and wheel drums.

Waste Storage Practices. The majority of plants stored waste and scrap in open metal containers or on open ground bins on the premises outside the building. Photographs of storage areas and containers are shown in Plate 6. The storage volume required depended on the quantity of waste generated and the frequency of collection and was commensurate with the space available. More than 90 percent of the plants visited maintained their waste storage areas satisfactorily and were given a fair to good rating for neatness and cleanliness. Two plants provided periodic exterminator services for the entire plant that included the waste storage area. Exterminator services were not used exclusively for waste storage areas in the plants visited.

Segregation of wastes and scrap of different types was completed in the plant or in the external storage area, or both, as shown in Table 30.

The major segregation occurred inside the plants at the production point, where it was easier to separate each type of waste and scrap by deposition in different storage containers. Twenty-one percent of the plants segregated metals both at the production source and in separate storage areas, and this finding suggests that source segregation was not complete. Primary segregation was made between metals and nonmetals. Twice as many plants segregated metal scrap as segregated nonmetal waste. A second level of segregation existed between ferrous and nonferrous metals. This was due to scrap collectors' requiring that ferrous and nonferrous metals be separated for sale because most nonferrous metals normally command higher scrap prices than ferrous metals do. A mixed metal scrap would often bring lower scrap prices.

The segregation of other solid wastes such as paper, wood, cardboard, and plastics was not done unless there was a specific salvage market for them. In plants where large quantities of wood and cardboard wastes were generated, compactors were employed to process the materials to reduce their volume and therefore the collection costs. This was also true for cardboard wastes and other uniform paper products that were salvageable for reprocessing in paper plants. Plants that combined cardboard, paper, rags, and general plant solid waste into one bin, had them removed from the premises by a collection agent as solid waste.

Office and cafeteria wastes were usually combined with general plant solid waste in the storage or disposal areas. Offices were usually cleaned once daily after regular working hours. In plants without cafeterias but with vending machines or vending trucks, the food service wastes were mixed with the general plant and office wastes at the employees' work area. The cafeteria or other food wastes were transported to the storage area after the last meal.

Fifty-one percent of the plants reported that they owned the equipment used inside the plant for handling, storing, and collecting wastes. The other companies rented or leased large containers, or trailers with compactor units, for waste storage outside the plant building. These large containers and compactor units were serviced by the collector, who periodically removed the filled containers and replaced them with empty ones.

Salvage Practices. Of the 158 AMA member plants that supplied information, 42.4 percent (67) reported they salvaged waste materials. The amounts salvaged, classified by type, are presented in Table 31. Of the total 440,999 tons/yr, slag and cardboard made up 57.9 percent and 26.7 percent, respectively. Of the 158 plants that supplied information, 23.4 percent (37) generated cardboard salvage, and 14.6

percent (23) generated paper salvage. Salvaged materials amounted to 8 percent of the waste generated in AMA member plants.

The distribution of the number of the 67 plants according to the number of salvage items generated is presented in the following tabulation:

No. of salvage items	No. of plants	Percent of plants supplying information
1	37	23.4
2	20	12.7
3	6	3.8
4	3	1.9
5	1	0.6

Waste and Scrap Management Methods. The major alternatives for management of solid waste were processing at the plant or using disposal areas outside the plant. The common methods for plant waste processing or disposal were incineration or the use of landfill on the site, or both. Plant scrap was sold to private collectors. At foundries, however, metal scrap was recycled for reuse. Foundry sand was recycled several times, but the sand on the mold surface was burned by the molten metal when cast and was finally disposed of as waste to landfills.

The major in-plant processing method was incineration; 28 percent (32) of the plants sampled burned some or all of their wastes. The total waste reported burned was 5,280 tons per year. Twenty-four of the 32 burners and incinerators were installed in plants with valuations greater than $1 million. A summary of burning in plants sampled is shown in Table 32. Conical burners and square fire boxes without APC equipment were used by small plants to burn small quantities of waste, usually records from offices. Photographs of small burners are shown in Plate 7. One plant of $1 million value burned in an open pit. Large capacity incinerators with APC equipment to meet air pollution requirements were reported in Michigan which recently (1969) enacted a strict air pollution code.

The geographic distribution of incineration in the plants sampled is presented in Table 33. The East Coast States of Pennsylvania, Massachusetts, and Virginia, and the State of Ohio had the highest percentages of incineration. For the East Coast, incineration was 41 percent and for Ohio 46 percent. In Michigan and Illinois, the incidence was one out of three plants. Plant interviews and mailed questionnaire responses indicated that incineration had been considered, or was being investigated for use by five additional plants.

Large plants visited indicated more interest in incineration than the small plants did. Although air pollution regulations by the State and local governments are becoming more stringent, plants still viewed incineration favorably. In Michigan several communities had encouraged large plants to incinerate their combustible waste. Larger plants can better afford to install incinerators with air pollution control equipment than can small plants. The reported costs of incineration at the plants sampled varied from $1.71 to $467 per ton of refuse, with an average cost of $83.40 per ton (based on 17 plants). This large variation in cost per ton was due to the variety of incinerators, type and quantity of waste incinerated, and variety of accounting practices. The small plants visited that used incineration were generally located in rural or outlying areas. California did not have plants with incinerators, because of its stringent air pollution requirements.

Field visits indicated that the major determinants influencing a company's solid waste management policy were costs, air pollution controls, and the quantities of waste generated. The larger the quantities of waste produced, the more desirable incineration became as a method of volume reduction, even with the added expense of air pollution control equipment and residue disposal.

Disposal cost data reported by the AMA survey for four combustion methods are presented in Table 34. Of the 158 AMA member plants supplying information, 8.2 percent (13) used incineration, and 5.1 percent (8) used an open burning dump. Of the methods listed, the conical waste burner had the lowest reported average cost, $0.93/ton, and incinerators had the highest average cost, $34.53/ton. Nineteen of the 20 AMA member plants with on-site incineration each employed more than 1,300 persons. One plant with an open burning dump employed 680 persons. Thus, most incinerators were located in the larger plants. The total quantity reported burned by AMA member plants was 43,762 tons per year (1969).

Additional in-plant processing and disposal methods as reported by AMA member plants included lagoon (3 plants); waste treatment plant processing (1 plant); and disposal of food waste in a garbage disposal unit (1 plant).

Information concerning the final disposal destination of solid waste was supplied by 39 plants visited. Of these, 33 used off-site landfills and 2 used on-site landfills. The small number of on-site landfills may be attributed to the high cost and the unavailability of land. The two plants utilizing landfills were located in rural areas in the Eastern United States, where inexpensive land was available.

Waste disposal off the plant premises was accomplished at public or private landfills, dumps, or incinerators. Incineration was used by 5.7 percent of the receiving communities. Privately operated incinerators were not reported, other than those located in plants. The final disposal destinations reported by the plants visited are tabulated in Table 35. Public facilities were generally open for public and private disposal.

The use of dumps was found in visits to plants in small towns in Michigan, Wisconsin, Ohio, and Pennsylvania. Rural landfill operations were less stringently controlled than urban landfills. Dump disposal was not reported by the plants visited in urban areas. In addition, landfill operating regulations were more stringent in the states where air pollution was regulated.

Waste Collection Practices. Of the 70 plants visited that supplied information concerning waste removal from the plant, 78.5 percent (55) used only outside collectors to remove the wastes from the premises; 11.4 percent (8) used both outside collectors and self haul; and 8.6 percent (6) used only self haul. Public collectors were used by 11.4 percent (8) of the plants. Of these, 7 also used private collectors. More than one removal agent was used by 21.4 percent (15) of the plants. Public removal was used primarily for cafeteria garbage and office trash.

Of the 217 AMA member plants supplying information on plant waste removal, 76 percent (163) used private collectors; 46 percent (100) self hauled; and 5.5 percent (12) used some public collection for cafeteria garbage and office trash. Twenty-seven percent (58 plants) reported more than one collector.

Plant solid waste and scrap removal schedules in plants visited depended on the following three factors: (1) the rate of waste generation; (2) the use or nonuse of mass production or custom (batch) production manufacturing; and (3) the bulkiness of the wastes. The removal schedules used in the 70 plants surveyed are summarized in Table 36.

All plants visited reported waste collection frequencies of twice a month or greater. Regular collection schedules were used for waste removal in 82.7 percent of the plants and for scrap in 58.7 percent. On call collection to remove wastes when storage containers were full, which occurred at least twice a month, was the practice in 17.3 percent of the plants. The two plants scheduling twice monthly waste removal did not have cafeterias and their wastes consisted of mixed waste and metal.

Most small parts and custom truck manufacturers had their scrap removed on call when their scrap storage capacity was full. The most frequent scrap removal schedules were found in large mass production plants that generated large scrap quantities and in plants with bulky sheet metal. The more frequent waste removal schedules were necessary to avoid health problems (vermin, rats, etc) from food service wastes and other organic materials. Scrap accumulation did not present health problems owing to its inert composition.

The Economics of Waste Management Systems. In-plant handling and storage equipment, capitalization base, and labor wages determined the costs at the plant. The collection and disposal portion of the costs were generally determined by private collectors. Scrap and waste are discussed separately because of their different disposal destinations and economic values.

Scrap was handled as a resource; i.e., it was sold for recycling to the basic metals industry. Scrap sales prices decreased as the distance of the plant from major scrap markets increased. Moreover, the scrap sales income reported by the plants was reduced by the haul costs. Manufacturers generating large quantities sold their scrap to collectors through monthly or yearly competitive bidding lists based on estimated scrap grades and tonnage. These plants tended to be consistent over the year in the type and quantity of scrap generated because of their mass production operation. Small producers and custom vehicle manufacturers were usually paid monthly for their scrap, the pay based on the weight disposed of by the private collector.

Waste removal costs included collection and disposal costs, that were combined in the fee plants pay to private collectors. Waste removal cost data for the entire industry including the AMA, in dollars per ton, are presented in Figure 44 as a function of the amount of solid waste generated in tons per month. Although there is considerable data scatter, the trend is clear: as the amount of solid waste generated increases, the removal cost per ton of waste decreases. The equation for the least squares parabolic curve through the data points was found to be

$$y = 80.05\, x^{-0.454}$$

where y = disposal and collection costs, dollars/ton

x = amount of solid waste generated, tons/month.

This equation is plotted in Figure 44.

To obtain a measure of the data scatter, the correlation coefficient r, defined by

$$r = \frac{\sum_{i=1}^{n} (\log x_i - \overline{\log x})(\log y_i - \overline{\log y})}{\left\{\left[\sum_{i=1}^{n} (\log x_i - \overline{\log x})^2\right]\left[\sum_{i=1}^{n} (\log y_i - \overline{\log y})^2\right]\right\}^{1/2}}$$

where n = number of data points

x_i, y_i are as defined above

$\bar{x}$ = mean value of x

$\bar{y}$ = mean value of y

was computed. A value of −0.82 was calculated for r (data with no scatter have a correlation coefficient with an absolute value of unity); hence there was good dependence of unit collection/disposal costs on waste quantity generated.

Collection costs reported by the AMA member plants are shown in Table 37.

The average reported costs for self hauling are greater than for public and private collectors. In addition, the maximum and minimum costs for self haul are much more extreme than for private collection. This indicates that factors other than cost were decisive in selecting the method of collection.

Landfill disposal costs reported by 44 AMA member plants averaged $4.94 per ton. Field studies indicate that this cost is considerably higher than the average landfill costs reported in a national study.[24]

The labor costs for janitorial services, pickup, and disposal, and equipment operation were or were not recorded separately, depending upon the plant sizes. In the plants visited, prices varied according to the geographic area, local waste practices, and the type of equipment. The effect of equipment type on costs is illustrated in the following tabulation.

Type of equipment	Average waste-handling cost ($/ton)	($/cu yd)
No special equipment	37.20 (12)	2.40 (21)
Conveyor	27.80 (6)	1.49 (5)
Compactor	28.90 (2)	2.06 (8)

Numbers in parentheses indicate the number of plants that supplied cost information. These figures indicate that the use of special equipment reduces waste removal costs.

The complex equipment required for processing and handling waste was expensive. For example, 1969 prices of balers for processing paper and corrugated waste ranged from $2,250 for 400-lb capacity to $3,850 for 900-lb capacity. For metal scrap processing, baler costs varied from $19,000 for a 125-lb bale capacity to $90,000 for a 750-lb bale capacity. Additional handling equipment such as conveyors, magnets, and cranes were obviously economically feasible only in large plants.

The costs of storage were primarily based on the assessed property valuation for the square footage used. Plants visited used less than 1 percent of their total plant land area for external storage of waste and scrap. Thus the storage costs, containers excluded, were relatively small and were usually not considered unless a large equipment installation was planned.

Special Problems in Waste Management. Information on special problems and procedures was supplied by 41 AMA member plants and 15 sampled plants. Fourteen plants reported that special handling was required for oils and sludges. Special problems noted were segregating of flammable liquid from disposable sludges and dewatering waste oils. Eight plants reported that chemical waste disposal required special handling and permission for landfill disposal because of toxicity or flammability. An additional 19 plants used special procedures to dispose of waste cardboard, paper, wood, plastics, rubber, liquids, and cast iron. Three of these 19 noted extra precautions were necessary to control smoke from their incinerators when wastes were burned. Future lack of landfill areas due to unavailability of close-in land was noted by 12 plants. The high cost of disposal was mentioned as a problem by two plants. Two foundries reported that special methods were used to dispose of inert solids and foundry sand. In addition, it was reported that the large quantities of disposed foundry sand were using up the available landfill sites. Two plants cited undependable waste collection pickup service schedules.

Efficiency of Waste Management Systems. An in-depth study on efficiency within the plant, concerning the handling and collection of waste from the generation areas was beyond the scope of this study. However, observations were made to identify obvious inefficiencies.

Cost per ton for waste collection and disposal is one indication of efficiency. These costs were discussed previously. The data indicated that large plants achieved economically efficient operation with large amounts of waste when waste-handling and processing equipment were used. The use of equipment such as conveyors, compactors, balers, shredders, and crushers reduced the labor required for waste management.

A subjective method of evaluating the overall efficiency of waste management is to request the plant personnel to rate their collection and disposal methods. Questionnaires employing a rating scale from 0 (poor) to 10 (good) were completed by plant personnel.

As shown in Figure 45, the results of the ratings indicated a curve slightly skewed towards the good side of the rating scale. Perhaps the good rating was influenced by limited knowledge and the attention commonly given to more important operating responsibilities. Nevertheless, most respondents indicated they were satisfied with their collection and disposal methods.

Aesthetics of Waste and Scrap Management Practices. The outside storage areas in plants visited were not visible in their entirety from public streets. The visible portions were the walls of stationary storage bins, and fully enclosed compactors which were located at the shipping dock. Where plants had open stationary bins, they were used exclusively for scrap storage. The heavy scrap was not wind blown and was little affected by the weather. Also, metal scrap did not attract vermin and thus could be stored uncovered.

Twenty percent of the plants had open solid waste storage (Plate 6). In one plant the solid waste was piled on the ground next to the scrap. When the plant representative conducting the plant tour noticed the piles, he immediately ordered the waste picked up and deposited in 55 gal drums situated within the storage area.

The frequency of solid waste and scrap pickup at plant storage areas affected their neatness and efficiency. Plants with a regular pickup schedule were cleaner than those with on-call pickup because spills occasionally occurred before the hauler was able to remove the solid waste and scrap. Of the plants sampled, only one complained of the time required for the hauler to remove the solid waste from the site. Another, similar situation noted was evident during a collectors' strike in one city, which caused the solid waste to pile up on the plant premises. The plant, in this case, did not have a truck available to remove the solid waste, and the overflow created an unsightly nuisance. However, the overall view of plant officials was that the collectors were responsive to the plant needs; this included haulers contracted for on-call collection. In fact, collectors required that scrap be segregated and solid waste be properly stored.

Industry Management Attitudes. Eighty percent of the plant officials interviewed were interested in solid waste and scrap control. They generally saw solid waste control as a management function requiring optimum economy to help keep an edge on their competition. Many of the plants with adverse opinions regarding effective solid waste management were probably eliminated from the survey during initial telephone contacts (about 20 percent). Therefore, the plant cross-section studied was, as previously noted, prejudiced towards the more efficient and cooperative plants, which rated themselves fair to good in the solid waste-handling and disposal methods. Companies with little waste tended to have less interest in the survey but were nevertheless cooperative. Mass production plant managers were very interested in solid waste and had studied, in depth, the best disposal and handling methods.

Of the 70 plants visited that supplied information concerning whether they kept records on solid waste disposal, 28 (40 percent) kept no records, and 42 (60 percent) did. Sixty-eight plants supplied information describing whether they kept records on scrap handling. Forty-five (66.3 percent) kept records and 23 (33.7 percent) kept none. The monetary value of scrap is the reason why more plants kept records on scrap.

Information on waste and scrap records were not provided by the AMA survey. Nonetheless, the detailed waste quantities and collection/disposal cost data provided in the AMA data indicates that reasonably complete records are kept by most plants.

Management in plants visited did not appear overly concerned with solid waste or scrap after it was removed from the plant site. Their main concern was getting it removed from their own premises, after which they had little contact with or knowledge of the disposal or reclamation operation. Exceptions to this were the plants that had self-haul setups and disposed of their own solid waste, and AMA officials who reported that member companies are "deeply concerned with ultimate solid waste disposal."

One plant official visited complained that his plant's waste hauler had a local monopoly and charged excessively high rates. This was verified in subsequent studies of the relation of costs to quantity of solid waste, which indicated that this plant's costs were two to three times higher in comparison with other areas where competition existed. Plants can become captive customers to collection monopolies if their capitalization is not sufficient for acquiring their own hauling vehicles. Well capitalized companies are less affected in this respect because they can usually afford to acquire their own vehicles for hauling.

Three plants volunteered questions concerning whether or not this study would lead to more Federal or other government regulation of their operations. It appeared that plants of $1 million or more in value responded to government regulations more than smaller plants, but tended to accept them with resignation. Plants under $1 million in value appeared more independent, perhaps because the Federal government has tended to ignore them in most surveys. Another reason for the independent attitude of smaller plants may be that the Federal government can regulate through government contracts, which were more commonly awarded to the larger plants than to the smaller plants.

Most plant personnel visited seemed aware of state and local government air and water pollution regulations but were not cognizant of government regulations concerning solid wastes. In general, management did not desire further government regulation of their operations, but they anticipated further pollution control.

Waste Management Trends. The automotive industry, especially AMA members plants, is becoming increasingly aware of internal waste handling costs. In the automobile assembly plants, this is exemplified by centralized monitoring of solid waste costs and scrap sales. Centralized and automated materials control was introduced to increase profits. The practices of separating scrap and waste costs and of studying the tradeoffs with respect to solid waste between alternative manufacturing processes have become common.

Reuse of process scrap and waste packaging material was also found to be increasing. The introduction of containerized shipping eliminated most disposable shipping crates and reduced the amount of packing required because of the stronger structure of the reusable containers. Much of the packing material was also reusable and significantly reduced packaging waste.

One major assembly plant published [25] information on experiments with a waste pyrolizer to reduce combustible waste materials to elemental charcoal and combustible gases.

Changes in waste management trends will have more effect on certain sizes and types of plants. Plants with large capital value, with their greater needs, are in a better capital position to use and benefit from the newer technologies. For example, major assembly plants may reduce their solid waste quantities in the near future. The overwhelming majority of their waste, estimated between 90 and 95 percent by volume, consists of reclaimable shipping and packaging materials. The use of metal containers, which have a long life, will tend to significantly reduce total solid wastes because the metal containers will be reused rather than become solid waste after each delivery. In addition, plants can increase their salvage of corrugated containers. One example was reported wherein a large plant spent $250,000 annually to dispose of its solid wastes, and then, by segregating its packaging and other wastes, obtained a new waste-scrap contract which resulted in a net yield of $100,000 annually.

The custom vehicle plants and the parts sector of the industry are not expected to experience large changes in their waste and scrap quantity because they tend to be limited by production rates and material requirements. Furthermore, the small producers do not have the capitalization base to invest in newer waste management equipment. Thus they will tend to remain relatively unaffected by technology changes in the near future. Custom body plants utilize a limited number of production processes and generally operate with efficient waste and finished product control because they can finish poorly trimmed body components by hand instead of rejecting them for salvage. Limitations on changes in process and product tolerances tend to constrain the amount of improvement which can be made in manufacturing to reduce the quantity of scrap and waste. It is assumed that most plants are operating at or near such an optimum for competitive reasons.

Packaging by the parts manufacturers is related to the ultimate destination of the product. Individual packaging is used for replacement markets, and bulk packaging for shipment to vehicle manufacturers. The replacement market tends to be relatively stable in its packaging requirements although there may be some trends away from cardboard and paper to plastic. Problems can arise because the plastics may be more difficult to handle in final disposal and they may not decompose in a landfill.

Community Relations

Discussion of Specific Problems. Several problems were encountered that arose from solid waste management practices and affected the communities in which the plants were located. Air pollution was caused by open burning dumps at two plants. Paint and grinding sludges from another plant were causing fires in the landfill when they were being disposed. Elsewhere, several authorities reported that automotive plant oils and greases required special handling when placed in landfills in order to prevent seepage into groundwater or the creation of fire hazards. One large automotive plant was disposing of waste vinyl sheets into a municipal landfill.

The landfill authorities reported that compaction of the vinyl was difficult. Vinyl sheets protruded from the earth cover, and the fill appeared somewhat more resilient than typical landfills.

Of the total of seven municipalities that responded to the project engineer's questionnaire and 11 municipalities interviewed by telephone, only two reported air pollution problems resulting from burning automotive solid wastes. The municipal authorities did not indicate any plans to control air pollution. Communities were aware that plant wastes were burned in the summer and that this caused smoke and other nuisances.

Municipal Disposal Costs. Two municipalities reported costs for public collection of industrial wastes of $1.43 and $10.26 per ton.

Municipal waste disposal costs reported by five communities varied from $0.72 to $5.00 per ton. The combined costs of municipal waste collection and disposal reported ranged from $2.15 to $11.44 per ton. A limited number of municipalities reported costs for industrial waste collection and disposal because most municipalities do not collect wastes from industrial establishments. As seen from Figure 44, these costs are within the range of costs reported by the plants.

Solid Waste Records. Municipal authorities contacted reported that they lacked dependable industrial waste information. The degree of availability of recorded data differed from community to community. There was little solid waste record keeping, especially regarding the quantities and types of solid waste from the automotive industry. Some municipal authorities estimated all the community industrial wastes. The reliability of these estimates, which were often based on personal observation by a landfill gateman, is open to question. Communities that charged for the use of their disposal facilities and those that had problems finding landfill areas had more complete records. Solid waste was seldom categorized separately for a particular industry.

The difficulty of obtaining accurate data is illustrated by the project engineer's experience with the waste-handling equipment manufacturers. Of ten manufacturers contacted, only two replied, and only one provided usable information. The manufacturer who provided the usable information supplied estimates of solid waste in two automotive plants. Estimates, not precise figures, were supplied because the automotive plants would not disclose their figures to the manufacturer even though the manufacturer had contracted to install waste-handling equipment for the plants in question.

Since the nature of the solid waste business is very competitive, private collectors were hesitant to release any information that might prove valuable to their competitors. Even those contractors who did provide some information had little accurate data because they had not maintained accurate type, weight, or volume summaries. Most collectors charged a fixed amount on a long-term or annual contract basis.

Genesee County, Michigan,[26] recently completed a solid waste survey; however, the automotive industry was not separately described. Three Michigan communities have conducted studies for solid waste master plans. The total solid waste contribution of the automotive plants was reported in the total for the region rather than separated by individual types and quantities. Thus automotive plant solid waste could not be separated from the total solid waste in a given community. In a recent study by the State of California Department of Public Health,[27] automotive industry solid waste was estimated to be approximately 0.6 percent of all manufacturing wastes generated in the State.

Community and Industry Views of Each Other Concerning Solid Waste Management. As a means of discerning the views of the community towards the industry and of the industry towards the community concerning solid waste management, plant and municipal authorities were asked to rate each other's effectiveness independently by mailed questionnaires. The results are presented in Figure 45. A comparison of the two ratings reveals very little difference in the number of responses for each rating value. Both private and public authorities responded with relatively high ratings, the combined mean rating being 3.5 on a scale ranging from 0 to 5. A rating of 4 had the highest number of responses from industry. The median rating was about 4. Municipal authorities rated industry at a mean of about 2.5. Thus, the automotive industry and the municipalities viewed each other's performance in handling solid waste as satisfactory. These ratings were based on limited industrial solid waste information and more than likely were influenced by the lack of specific automotive industry knowledge on the part of the municipal authorities.

Automotive Industry Views of Government Roles. One of the questions on the questionnaire mailed to the automotive industry asked whether adequate steps were being taken by municipal authorities to alleviate industrial solid waste disposal problems. Forty-nine percent of the 43 responses were in the negative, 19 percent were noncommittal, and 7 percent were not applicable or contained an unconcerned description of the role of municipal authorities. The affirmative responses represented 26 percent of the total responses.

The problems mentioned by industry were primarily concerned with lack of disposal sites; 23 percent of the plants responding to the question mentioned in the preceding paragraph noted the lack of readily accessible landfills, dumping areas, and available land within the city limits.

Most contact between plants and public officials occurred because of violations of pollution and health code regulations. For example, the State of Michigan recently enacted strict air pollution regulations to eliminate open burning and to increase solid waste incineration disposal. There appears to be a need for better communications between plant and public authorities in order to solve industrial solid waste problems as part of a regional program. If better solid waste management were provided, local conflicts might be prevented such as occurred when a Midwestern plant, using a landfill in a community, was subsequently prohibited by that community from that use and was thus forced to begin a search for another disposal site.

Pollution and Aesthetics. Automotive plants may cause land, air, water, or visual pollution. Air pollution is usually visible over a larger region than the other types of pollution are and thus is regarded as a community or regional problem. Air pollution problems at automotive industry plants were not noticed as being significant except when an incinerator or other combustion unit was installed (Plate 7). In a few small plants, open burning was observed. Open-pit incineration of waste oil was occasionally practiced by several plants, and this resulted in air pollution complaints. Open burning has, however, decreased in most areas. Several of the larger plants burned confidential office and production records; however, the incinerators were provided with their own air pollution control system.

In three of the Eastern States visited, the air pollution due to smoke from incineration was noticeable in the neighborhood, despite reported emphasis on strict regulation. Most small plants in the East that burned solid waste were in the rural or semirural areas and had few close neighbors. Most larger plants, especially in pollution-conscious States such as California, had stopped incineration or were investigating alternative means of disposal. Where incinerators have been installed, conformance to air pollution regulations has increased the operating expense.

There are problems even when incinerators do not contribute to pollution, because inert wastes and combusted residues must be disposed of. Fly ash tends to be easily wind blown and may create nuisances. Fortunately, rats and vermin are not normally found in ash storage areas and disposal sites.

Large firms located in small communities exert an economic influence on the area through the large number of residents employed. Thus, if they incinerated, and complaints were received, the complaints were seldom acted upon, being usually ignored by municipal officials in order not to disturb the economic base of the community.

Water disposal is an alternative to burning (air pollution). Waste-water pollution in the automotive industry is described in a recent study.[28] As a result of increased pressure to reduce water pollution, industrial solid wastes are being separated, and semisolid liquid concentrates are being disposed with solid wastes in landfills or even by incineration.

As a general rule, solid waste and scrap storage areas were located so as not to be visible from public roads. Those that were visible were kept clean. The larger corporations were well organized and used large, central containers and thus eliminated wind-blown wastes and overflow (Plates 6a, b, and c). The plants without storage containers and handling equipment tended to have ill-kept waste storage areas, and one on-site dump was poorly managed (Plates 6d, e, and f). Noise was not a problem outside of the plant areas. Most of the plants were located in noisy industrial areas. This tended to reduce the relative nuisance effect of local plant noise below what would exist if the plants were located near a quiet residential area. Of the 74 plants visited, 14 percent were located in residential neighborhoods, 9 percent in commercial neighborhoods, and 77 percent in industrial neighborhoods. Industrial trucks and other motorized equipment of course generate extensive background noise.

The Role of Government in Solid Waste Management. On a local or regional level, most government agencies reported little direct communication with the plants. The government agencies did tend to be responsible for seeing that various codes and regulations with respect to air and water pollution were met by the industry. Concerning the regulations for solid waste collection, all the communities responding stated that local industries were primarily responsible for handling their own waste material through private contractors who ultimately disposed to privately or publicly owned disposal facilities. Fifty percent of the private contractors used public facilities, and 50 percent used private facilities to dispose of their automotive industry wastes.

State governments have recently become involved as a result of the Federal solid waste program. They also traditionally are concerned when regional environmental problems develop. Federal and State regulations have recently produced stricter controls of air and water pollution. These recently enacted regulations and codes have prompted industry to consider alternative modes of solid waste disposal.

The AMA member plants were asked, on the AMA survey questionnaire, whether local government was concerned with their solid waste management activities. From the 85 replies received, it was found that local governments were largely concerned with disposal sites, collection, and disposal regulations. Disposal sites were provided by the city for 34 plants and by the county for 19. One plant provided its own site. The city provided collection service for 2 plants. Disposal procedures were regulated by the city for 14 plants, by the county for 9 plants, and by the State for 9 plants. Private contractors handled the collection and disposal for 12 plants.

In reply to the question whether local or State regulations affect solid waste management activities, 12 affirmative replies were received. The regulations noted concerned air pollution, littering, disposal sites, landfill procedures, and water quality for sewerage systems.

Geographic Trends in Waste Disposal. Incineration regulations serve as examples of variations in the local management of solid waste and in the local codes for controlling pollution, and in addition, illustrate National and regional differences. In Ohio 18.2 percent of the 11 plants visited that replied to the questionnaire were planning to incinerate in the near future. In Michigan, the corresponding figure was 6.2 percent, based on 32 plants studied. Conversely, in the Western States, incineration is gradually being reduced and phased out in all the plants surveyed. This indicated that State regulations have not yet completely affected incineration practices. This is particularly evident in Michigan, where the new State air pollution regulations may result in the proliferation of new plant incinerators.

Considerations of economic benefits resulting from the presence of industry have tended to made local officials minimize incineration regulations. In Michigan and California, however, there has been stronger enforcement. In these States, plant authorities definitely enforced new, strict air pollution regulations, even if increased expenses resulted. Tightened Federal regulations and additional State laws are envisioned by the industry and may be expected to reduce or eliminate many geographic differences by establishing uniform National standards in the area of land, air, and water pollution. Application of recently enacted Federal and proposed government air pollution control standards will eventually eliminate the geographic differences cited.

CONCLUSIONS

Industry Structure

Industry Plants. The number of major American automotive firms has stabilized at four. The existing automobile assembly capacity appears to be sufficient to meet the estimated vehicle demand through 197[illegible], when production is estimated to reach 13.7 million vehicles. Two new plants for truck production have been proposed by two major firms, one to be constructed in 1970 and one to begin full-scale production in 1970. Some of the production capacity in these plants will be filled by transferring operations from existing plants. The geographic distribution of vehicle assembly facilities is expected to follow market growth.

A 38 percent increase in plants classified in SIC 3713 from 1963 to 1968 was offset by a 9 percent decline in plants classified in SIC's 3711, 3712, and 3714. The increase in truck and bus body plants resulted from the increased demand for special types of vehicles.

Employment. The rate of improvement in employee productivity since 1960 appears to be approaching a limit. The large decrease in man-hours per vehicle from 1959 to 1960 appears to be due to technological improvements. As seen in Figure 6, the long-term productivity trend for total work force reached limiting values in the years 1950, 1955, and 1959, when a 220 man-hour-per-vehicle minimum occurred. A new minimum of about 174.5 man-hours per vehicle is indicated by 1965 and 1968 productivity (Figure 6 and Table 2). Thus, the long-term trend in productivity, while fitting a parabolic curve, actually occurs in incremental jumps. The yearly fluctuations reflect two factors as follows: (1) economic conditions and (2) war dislocations (1951-1953, and 1966-1969). The 1959-to-1960 jump and relative year-to-year stability since then appear to have resulted from the use of computers for production scheduling, machining control, and inventory control. Major productivity increases in the future are expected to result from new technologic improvements as indicated historically from 1959 to 1960.

Product Changes. The vehicle weight and materials trends discussed previously are the major product changes that will affect solid waste and scrap generation. As the weight of an average vehicle decreases, materials consumption decreases. On the assumption that a constant percentage of consumed metals will be generated as scrap, the amount of scrap will decrease.

The increasing use of plastics will reduce the discarded scrap and waste materials because plastics are primarily formed in molds or die cast. Die cast processing results in negligible material losses. The thermoplastics are recoverable for reuse; thermosetting plastics cannot be reused. Since thermoplastics are the most widely used there can be reclamation of waste plastics.

Solid Waste Estimation

Statistical Waste Prediction Parameters. Stepwise multiple linear regression analyses using process and product as categories, and employment, plant value, and number of units produced as independent predictor variables, were made for solid waste and scrap weight quantities. The results showed employment to be the dominant plant variable for both waste and scrap prediction when regression was done for individual categories (Tables 23 through 26). Note that regression without categorization showed no correlation (0.06) for waste prediction (see Tables 23 and 24, any product and any process) as did simple regression on employment without categorization (see Figure 42 and discussion on page 30). The variable "quantity of product made" was the least significant contributor to improvement in multiple regression R^2 as can be seen by comparing Table 23 with 24 and 25 with 26. The multiple-regression coefficient was most significant for waste prediction in plants machining engine systems, machining any products, and fabricating bodies. Scrap prediction showed the highest multiple regression for machining any product, and for fabricating body components. Thus, machining and body fabrication operations appeared to be the most consistent for predicting weight quantities of solid waste and scrap generated.

Waste Estimation. Estimates of total industry solid wastes for 1969 amounted to approximately 1,600 lb per vehicle produced. Of this total, 1,310 lb consisted of inert solids and sludges, 59.5 lb of paper, 76.5 lb of cardboard, 54 lb of wood, and 55 lb of cafeteria garbage. An independent source has estimated corrigated cardboard wastes at 50 lb per automobile produced, which is in close agreement with the survey results.

Scrap Estimation. The 13 percent difference between scrap estimates derived from the plants ampled (1,000 lb) and estimates based on materials balances (1,139 lb) may be attributed to one or a combination of the following two factors: (1) products listed in SIC Codes 3711, 3712, 3713, and 3714 that were not covered constituted 15 percent of the curb weight of an average vehicle; and (2) some of the materials consumed by the industry are used for fabricating in-plant facilities and equipment. Although employment was indicated to be a statistically significant predictor for scrap, a more realistic scrap breakdown for a separate composite car and truck/bus was achieved by a summation of scrap quantities generated during the manufacture of vehicle components. This approach provided a method of comparing scrap estimates derived from materials balances with plant sample estimates.

Waste Management

Salvage Operations. There is great potential for improvement in reclamation, i.e., salvaging operations. Salvage amounted to 104 lb per vehicle produced in 1969, or 6.5 percent by wet weight of the disposed wastes. For example, salvaged cardboard amounted to 30.3 percent by wet weight of waste cardboard, salvaged plastics amounted to 10.3 percent of waste plastics, and salvaged oils and paints amounted to 13.5 percent of wastes. Other materials were salvaged in smaller proportions (Tables 18 and 30). The major reclamation determinant for some plants is the availability of a salvage market. Small plants, with capital values of less than about $300,000, may not salvage waste materials, because they generate very small amounts or lack the capital base to install equipment required to process wastes for salvage. The industry management is oriented to production and therefore often overlooks opportunities for reclamation and salvage of materials.

Waste management practices vary widely in plants manufacturing the same product. For example, two foundries were visited, both located in the same city and therefore operating in the same economic and labor markets. These two foundries produced about the same weight of castings (engine parts, blocks, and heads), but sand (inert solid) wastes from one were 100 times greater than from the other. Thus, effective waste management in one foundry through reuse resulted in a 100-fold reduction in waste materials. Since foundries generated 54.5 percent of total industry waste in 1969 (Table 18), 78.6 percent of which was sand, significant reductions in automotive industry waste may be achieved by increasing reuse of sand. Foundry wastes varied from 0.45 ton to 620.7 tons per employee per year. Thus, it is apparent that many do not presently reuse or salvage their wastes. This variation in waste quantity existed for other types of plants (Figure 43), but the ranges were not as great.

If inert solids and sludges are excluded, cardboard and wood comprise 45 percent of the remaining 290 lb of waste per vehicle. Cardboard and wood are primarily generated from packaging materials; thus reusable containers can significantly reduce noninert waste materials. In fact, the inert materials, though generated in large quantities, do not affect the environment to the extent that noninert materials do. Thus, concentration on the reduction of waste cardboard, paper, wood, garbage, etc, will produce the greatest improvement in the environment. On an economic basis, the greatest socio-economic value in waste management would be achieved by concentrating on reducing noninert waste materials.

Scrap. All plants sampled sold their metal scrap or had it hauled away free of disposal cost. Thus, scrap disposal is not regarded as an industry problem.

Waste Management Efficiency. The salvage practices discussed in the previous paragraph are one indication of efficient waste management. Costs are the major factor associated with all measures of efficiency. The wide ranges of waste collection and disposal costs are attributable to differences in geography and management practice. The unit costs shown in Figure 44 vary by a factor of 10 for a given quantity of solid waste generated. Since labor rates and equipment costs do not vary geographically by this magnitude, the variation is attributed to differences in waste management practices. For example, waste collection and disposal costs for plants sampled that used compactors were below the unit cost curve shown in Figure 44. Thus, the use of waste-processing equipment improves the efficiency of waste management systems.

Automotive plants need to develop better information concerning solid waste quantities, types, and collection and disposal costs. It is apparent from the study data cited that there is a large range in plant costs per unit of waste removed and disposed. These differences are in part due to limited knowledge and cost control. Reduced costs for industrial waste removal and disposal will result if better data evaluations are made.

A definite relationship existed between plants with high capital values and the use of waste-handling and processing equipment. Larger plants will have the greatest variation in waste quantities resulting from the introduction of new methods of waste handling and disposal.

The smaller plants are not expected to experience large changes in the quantities of waste and scrap produced, because they are not in a financial position to utilize new equipment and receive the full benefit from technologic advances.

Environmental Aspects of Automotive Industry Wastes. More than 90 percent of the plants surveyed maintained their waste storage areas satisfactorily and were given a fair to good rating for environmental neatness and cleanliness.

Although quantitative noise level measurements were not made, observations by the field staff indicated noise was not an environmental problem outside of the plant boundaries.

In the Eastern and Midwestern United States, many plants used open-type burners or incinerators without air pollution controls. The stringent air pollution regulations and the large number of incinerators operating poorly indicate that there will be a need for further enforcement. Incineration practices have been affected more by State than by local regulation because local community regulations may not be enforced.

Solid wastes may affect groundwater quality primarily through disposal of toxic chemicals, oils, and sludges. Most plants and municipalities were aware of the potential problems; however, most private collectors refused to pick up and dispose of chemical wastes because of costs for special handling equipment or lack of disposal sites. Some of the plants affected reported that they dispose of these hazardous materials on their own property.

Municipal Industrial Waste Management Policies. The automotive industry and the municipalities viewed each other's performance in handling solid waste as satisfactory. Since many plants cited lack of available landfill sites as a major waste disposal problem the indicated community role is to develop long-range waste disposal plans. There is also a need to develop new methodologies for handling and disposing of solid wastes since part of the problem is that suitable close-in landfill property is becoming scarce. Communities can also assist industry in arranging for disposal of toxic wastes. At present, industry normally pays twice for collecting and disposing of its waste; once for private and self collection and again in taxes to support municipal collection and disposal.

TABLE 1

UNITED STATES AUTOMOTIVE INDUSTRY VEHICLE PRODUCTION

Year	Automobiles*	Trucks†	Bus‡ (factory sales)
1948	3,911,335	1,331,468	33,489
1949	5,118,293	1,111,934	19,761
1950	6,658,510	1,323,111	20,812
1951	5,330,594	1,287,233	29,149
1952	4,337,443	1,198,426	24,971
1953	6,134,823	1,190,254	19,540
1954	5,508,637	997,756	25,156
1955	7,942,125	1,215,236	30,558
1956	5,801,865	1,076,815	26,778
1957	6,115,454	1,056,076	27,574
1958	4,244,045	848,027	22,735
1959	5,599,471	1,096,335	27,398
1960	6,703,086	1,166,360	32,056
1961	5,522,004	1,099,620	28,658
1962	6,943,470	1,219,057	28,967
1963	7,644,359	1,428,240	35,706
1964	7,744,888	1,528,706	30,809
1965	9,335,208	1,747,628	35,184
1966	8,604,726	1,722,058	36,634
1967	7,412,610	1,548,014	35,866
1968	8,848,507	1,949,344	Not
1969	8,224,267	1,956,996	available

From: * Automotive News. 1970 Almanac, Detroit, Michigan, Slocum Publishing Co., 1970. p. 56.

† Automotive News. 1969 Almanac, Detroit, Michigan, Slocum Publishing Co., 1969. p. 56.

‡ Motor Truck Facts. Automobile Manufacturers Association, Detroit, Michigan. 1966 to 1968 issues.

TABLE 2

UNITED STATES AUTOMOTIVE INDUSTRY PRODUCTIVITY

Year	Total employees* (1,000)	Production employees* (1,000)	Average weekly hours*	Total vehicles produced† (1,000)	Productivity: Total man-hours per vehicle	Productivity: Production man-hours per vehicle
1948	780.7	631.9	39.2	5,276.3	301.60	241.30
1949	751.3	613.4	39.4	6,250.0	248.00	202.80
1950	816.2	677.1	42.1	8,002.4	223.08	185.12
1951	833.3	681.8	40.4	6,747.0	259.48	212.16
1952	777.5	618.7	41.4	5,560.8	301.08	239.72
1953	917.3	739.4	42.0	7,344.6	273.00	219.96
1954	765.7	601.5	41.5	6,531.5	253.24	198.64
1955	891.2	718.3	43.6	9,187.9	219.96	177.32
1956	792.5	619.5	41.2	6,905.5	245.96	192.40
1957	769.3	601.7	40.9	7,199.1	227.24	177.84
1958	606.5	452.5	39.7	5,118.1	244.40	182.52
1959	692.3	537.5	41.1	6,723.1	219.96	171.08
1960	724.1	563.3	41.0	7,901.5	195.52	152.36
1961	632.3	479.1	40.1	6,650.3	198.12	150.28
1962	691.7	534.0	42.7	8,191.5	187.72	144.56
1963	741.3	573.6	42.8	9,108.3	180.96	140.40
1964	752.9	579.2	43.0	9,304.4	180.96	139.36
1965	842.7	658.9	44.2	11,118.0	174.20	136.24
1966	859.2	668.4	42.8	10,363.4	184.60	143.52
1967	809.3	621.7	40.8	8,996.5	190.84	146.64
1968	843.2	727.7	43.1	10,797.9	175.01	151.04
1969	869.9	676.1	41.7	10,181.3	185.44	144.21

* Bureau of Labor Statistics.

† Automotive News, 1969 Almanac, Detroit, Michigan, Slocum Publishing Co., 1969. p. 226.

TABLE 3

MAJOR AUTOMOTIVE INDUSTRY PRODUCTION CENTERS

States	Index* No.	SMSA	1960 Population (1,000)	Number of plants	States	Index* No.	SMSA	1960 Population (1,000)	Number of plants
Ala.	1	Birmingham	721	10	Fla.		Jacksonville	455	1
	2	Montgomery	200	2			Miami	935	1
Ariz.		Phoenix	664	1		22	Tampa	772	4
		Tucson	266	1	Ga.	23	Atlanta	1,017	6
Ark.		Fort Smith	135	1		24	Columbus	218	3
	3	Little Rock	272	2			Macon	929	1
Calif.	4	Anaheim	704	5			Savannah	188	1
	5	Fresno	366	4	Ill.	25	Chicago	6,221	187
	6	Los Angeles	6,039	74			Champaign	132	1
		Oxnard	199	1		26	Davenport	319	8
	7	Sacramento	626	2		27	Decatur	118	7
	8	Salinas	198	2		28	Peoria	313	3
	9	San Bernardino	810	3		29	Rockford	230	11
	10	San Diego	1,033	4		30	Springfield	147	2
	11	San Francisco	2,649	26	Ind.	31	Anderson	126	3
	12	San Jose	642	2		32	Evansville	223	3
	13	Stockton	250	2		33	Fort Wayne	232	6
Colo.	14	Denver	929	21		34	Gary	574	8
		Pueblo	119	1		35	Indianapolis	944	24
Conn.	15	Bridgeport	338	18		36	Lafayette	89	3
	16	Hartford	549	12		37	Muncie	111	3
		Meriden	52	1		38	South Bend	271	10
	17	New Britain	129	6	Iowa	39	Cedar Rapids	137	3
	18	New Haven	321	5		40	Des Moines	266	4
		New London	171	1		41	Dubuque	80	5
	19	Stamford	174	7		42	Sioux City	120	3
	20	Waterbury	186	14		43	Waterloo	122	3
Del.	21	Wilmington	415	6	Kans.	44	Kansas City	1,092	7
						45	Topeka	141	2

TABLE 3 (Continued)

States	Index* No.	SMSA	1960 Population (1,000)	Number of plants
Kans.	46	Wichita	382	16
Ky.		Huntington-Ashland	255	1
		Lexington	132	1
	47	Louisville	725	7
La.	48	Baton Rouge	230	4
		Lafayette	85	1
	49	Lake Charles	145	2
		Monroe	102	1
	50	New Orleans	907	6
	51	Shreveport	281	5
Maine	52	Lewiston	70	2
	53	Portland	139	2
Md.	54	Baltimore	1,804	9
Mass.	55	Boston	2,595	28
		Fall River	138	1
	56	Fitchburg	81	2
	57	Lawrence	199	5
		New Bedford	143	1
		Pittsfield	77	1
	58	Springfield	494	8
	59	Worcester	329	7
Mich.	60	Ann Arbor	172	6
	61	Detroit	3,762	155
	62	Flint	416	4
	63	Grand Rapids	462	15
	64	Jackson	132	10
	65	Kalamazoo	170	7
	66	Lansing	299	12
	67	Muskegan	150	8
	68	Saginaw	191	9
Minn.	69	Duluth-Superior	277	2
		Fargo-Moorehead	106	0
	70	Minneapolis-St. Paul	1,482	45
Miss.	71	Jackson	221	3
Mo.	(44)	Kansas City	1,092	27
	72	St. Joseph	91	2
	73	St. Louis	2,105	48
	74	Springfield	126	9
Mont.		Billings	79	1
		Great Falls	73	0
Nebr.	75	Lincoln	155	2
	76	Omaha	458	5
N.J.		Atlantic City	161	1
	77	Jersey City	611	6
	78	Newark	1,689	47
	79	Paterson	1,187	21
	80	Trenton	266	6
N.Mex.	81	Albuquerque	262	2
N.Y.	82	Albany	658	5
	83	Binghamton	284	2
	84	Buffalo	1,307	32
	85	New York	10,694	93
	86	Rochester	733	13
	87	Syracuse	564	10
	88	Utica	331	2

TABLE 3 (Continued)

States	Index* No.	SMSA	1960 Population (1,000)	Number of plants
N. C.	89	Charlotte	317	7
		Fayetteville	148	1
	90	Greensboro	520	8
	91	Raleigh	169	2
N. Dak.	92	Fargo-Moorhead	106	4
Ohio	93	Akron	605	6
	94	Canton	340	2
	95	Cincinnati	1,268	13
	96	Cleveland	1,909	44
	97	Columbus	755	12
	98	Dayton	727	13
		Hamilton-Middletown	199	0
	99	Lima	161	7
	100	Lorain-Elyria	218	2
		Mansfield	118	1
	101	Springfield	131	4
		Steubenville-Weirton	168	0
	102	Toledo	631	14
	103	Youngstown-Warren	590	4
Okla.		Oklahoma City	512	1
	104	Tulsa	419	6
Oreg.	105	Eugene	163	2
	106	Portland	822	45
	107	Salem	147	4
Pa.	108	Allentown-Bethlehem-Easton	492	2
		Altoona	137	1
Pa.		Erie	251	1
	109	Harrisburg	372	3
	110	Johnstown	281	3
	111	Lancaster	278	2
	112	Philadelphia	4,343	35
	113	Pittsburgh	2,405	11
	114	Reading	275	7
		Scranton	235	1
	115	Wilkes-Barre	347	6
	116	York	290	3
R. I.	117	Providence	821	3
S. C.		Greensville	256	1
Tenn.	118	Chattanooga	283	2
	119	Knoxville	368	2
	120	Memphis	675	11
	121	Nashville	464	5
Tex.		Abilene	120	1
		Austin	212	1
		Beaumont-Port Arthur-Orange	306	1
	122	Brownsville-Harlingen San Benito	151	4
	123	Dallas	1,119	7
		El Paso	314	1
	124	Fort Worth	573	7
	125	Houston	1,418	10
	126	McAllen-Edinburg Pharr	181	2
	127	Odessa	91	2
	128	San Angelo	65	2
	129	San Antonio	716	9

TABLE 3 (Continued)

States	Index* No.	SMSA	1960 Population (1,000)	Number of plants
Tex.		Sherman-Denison	73	1
		Texarkana	92	1
	130	Waco	150	2
		Wichita Falls	130	1
Utah	131	Salt Lake City	448	5
Va.		Lynchburg	111	1
	132	Norfolk	579	4
	133	Richmond	436	5
Wash.	134	Seattle-Everett	1,107	14
	135	Spokane	278	7
		Tacoma	321	1
W. Va.	136	Charleston	253	6
	137	Huntington-Ashland	255	2
		Wheeling	190	1
Wis.	138	Green Bay	125	2
	139	Madison	222	3
	140	Milwaukee	1,278	54
	141	Racine	142	11

* Index number refers to locations on maps, Figures 9 through 12.

TABLE 4

MODELS OFFERED 1948-1969*

Year	Models offered	Year	Models offered
1948	201	1960	244
1949	205	1961	260
1950	243	1962	296
1951	243	1963	336
1952	224	1964	336
1953	210	1965	348
1954	240	1966	368
1955	216	1967	370
1956	232	1968	368
1957	245	1969	365
1958	263	1970	374
1959	239		

* Automotive News, 1969 and 1970 Almanacs, Detroit, Michigan, Slocum Publishing Co., 1969, p. 62, and 1970, p. 62.

TABLE 5

SELECTED "OPTIONAL" EQUIPMENT INSTALLATIONS

Component	Installations (% of vehicles produced) 1969*	1962†	1956‡	1950§
Automatic transmission	92.5	74.1	79.0	30.0
Air conditioners	54.4	11.3	3.0	1.0 ¶
Power brakes	54.6	25.7	33.0	3.0
Power seats	10.8	6.4	11.0	1.0
Power steering	85.6	42.7	30.0	2.0
Power windows	13.1	9.8	10.0	1.0
Vinyl tops	41.4	NA	0.0	0.0
V-8 Engines	89.9	55.3	79.5	42.6#
Safety Belts	100.0	NA**	6.0	1.0

* Automotive News, 1970 Almanac. Detroit, Michigan, Slocum Publishing Co., 1970. p. 64, 66, 68.

† Automobile facts and figures. Automobile Manufacturers Association, Inc., Detroit, Michigan, 1965. p. 14.

‡ Ibid. 1966. p. 13.

§ Ibid. 1958. p. 13.

¶ Ibid. 1962. p. 12

\# Automotive News, 1970 Almanac. p. 41.

** NA = Not available.

TABLE 6

AUTOMOTIVE VEHICLE PARTS GROUPINGS*

1 Vehicles (3711)	2 Body components	3 Engine system (mach. & forge)	4A & 4B Differential (rear end) & transmission	5 Suspension & linkage	6 Chassis & components	7 Misc vehicle components	8 Large cast components
Cars	Body w/top	Head	Gears	Drive shaft	Frame & motor supports	Air conditioners	Block, engine
Buses	Roof trim	Block	Shafts	Idler arms	Bumpers & supports	Air filters	Head, engine
Trucks	Front apron	Valves, springs & lifters	Housing	Supports	Muffler & tailpipe	Seat belts	Camshaft
	Front fenders	Rocker arm assembly	Panels, access cover	Shock absorbers	Front frame support	Ignition systems	Transmission housing
	Hood	Push rods	Rods & levers	Steering tie rods	Rims, wheel	Heater core	Diff. housing
	Grill	Oil pump	Ring gear	Steering gear	Gas tank	Radiator	Clutch housing
	Doors	Pistons w/rings & wrist pins	Banjo housing	Steering unit	"A" frames	Seats	Exhaust manifold
	Dashboard	Connecting rods	Ring gear carrier	"U" joint	Springs, front & rear	Oil filter	Intake manifold
	Trunk deck	Camshaft		Axles	Brake drums	Heater ducting	
		Crankshaft			Back plates	Floor insulation & padding	
		Flywheel			Oil pan	Roof insulation & padding	
		Clutch housing			Rocker box cover	Rear interior deck	
		Clutch plate				Brake shoes	
		Water pump				Clutch disk	
		Exhaust manifold					
		Intake manifold					
		Pulleys, fan & water pump					
		Fuel pump					

* U.S. Department of the Interior, Bureau of Mines memorandum, A dismantling time and motion study of a 1965 Ford Mustang two-door hardtop with a classification of metals and nonmetals.

TABLE 7

RELATIVE MATERIAL LOSS FOR MANUFACTURING PROCESSES*

Process	Relative material loss†	Form of waste
Sand cast	Mod	Foundry scrap/sand waste
Shell mold cast	Lo	Waste molding material
Permanent mold cast	Lo	Reusable scrap
Plastics casting	Lo	Reusable if thermoplastic
Investment casting	Lo	Reusable scrap
Die casting	Lo	Reusable scrap
Powder metallurgy	Lo	Practically nothing
Drop forging	Mod	Scrap, scale waste, depends on geometry
Press forging	Mod	Scrap, scale waste, depends on geometry
Upset forging	Med	Scrap, scale waste, depends on geometry
Cold headed parts	Lo	Very little scrap
Extrusions	Lo	End trim scrap
Impact forming	Lo	Blanking scrap only
Roll forming	Lo	Edge trim
Spinning	Mod	Edge trim scrap
Stamped and press	Lo	Blanks and trim
Formed parts	Mod	Blanks and trim
Electroforming	Lo	Very little
Machining	Hi	Chips and turnings scrap
Weld, braze, bond	Lo	Little
Painting: Spray	Mod	Overspray chips and sludge
Dip	Lo	Drippings
Electrostatic	Lo	Very little

* From Rusinoff, S. E. Manufacturing processes, materials and production. Chicago, American Technical Society, 1962.

† Key to relative ratings: Hi=high; Med=medium; Mod=moderate; Lo=low.

TABLE 8

EXAMPLES OF INCREASED EQUIPMENT PRODUCTIVITY*

Type of equipment	Avg % increases in output 1960 models vs 1950 models	Avg % savings on product production cost
Abrasive belt grinders	50	50
Automatic screw machines	20	15
Bandsaws	237	50
Bending brakes	28	25
Broaching machines	15	10
Cylindrical grinders	22	13
Drilling machines	34	28
Gear-cutting machines (bevel gear)	35	15
Horizontal boring machines	65	35
Hydraulic presses	25	10
Internal honing machines	55	50
Mechanical presses	52	18
Milling machines-vertical	28	23
Planers	20	10
Punching machines	25	
Shapers	53	
Shears	25	25

* From Weinert, A. Making production pay. Automotive Industries, 123(5): 74-78, Sept. 1960.

TABLE 9

AUTOMOTIVE INDUSTRY PLANTS: (VISITED/SURVEYED)/INDUSTRY TOTAL*

HEW region	Total HEW region	SIC Code 3711[1]	SIC Code 3712	SIC Code 3713	SIC Code 3714: 2†	3	4a	4b	5	6	7	8	Total
I	(4/1)/133	0/2	0/0	(1/0)/24		1/1		1/0			1/0		(3/1)/107
II	(6/5)/472	0/22	(1/0)/7	(2/2)/132					2/0	0/1	1/2		(3/3)/311
III	(0/1)/117	0/6	0/3	0/60	0/1								(0/1)/48
IV	(0/5)/164	(0/1)/7	0/3	(0/1)/91	0/1	0/1					0/1		(0/3)/63
V	(50/23)/955	(2/0)/49	0/19	(9/2)/217	4/4	7/7	2/0	4/0	3/2	12/2	5/6	2/0	(39/21)/670
VI	(0/3)/374	0/27	0/10	(0/1)/148						0/1	0/1		(0/2)/189
VII	(0/1)/130	0/3	0/0	(0/1)/81									0/46
VIII	(3/1)/54	0/3	0/1	(2/0)/8							1/1		(1/1)/42
IX	(11/3)/239	(1/0)/23	0/1	(2/0)/94	1/2	1/1			1/0	2/0	3/0		(8/3)/121
Total	(74/43)/2,638	(3/1)/142	(1/0)/44	(16/7)/855	5/8	9/10	2/0	5/0	6/2	14/4	11/11	2/0	(55/35)/1,597

* Total plants visited/surveyed excludes AMA member plants.

† Numbers 1 through 8 refer to product categories in Table 6.

TABLE 10

AUTOMOTIVE INDUSTRY PLANT VALUES IN MILLIONS OF DOLLARS:
(VISITED/SURVEYED)/INDUSTRY TOTAL*

HEW region	Total HEW region	SIC Code 3711[1]	3712	3713	3714
I	(22/10)/102.32	0/1.0	0/0	(1/0)/8.95	(21/10)/92.37
II	(23.5/4)/257.68	0/15.8	(10/0)/4.28	(11/1.5)/62.1	(2.5/2.5)/166.5
III	(0/0.3)/41.07	0/4.0	0/1.06	0/19.4	(0/0.3)/14.5
IV	(0/13.3)/43.63	(0/1)/5.4	0/5.18	(0/10)/15.04	(0/2.3)/18.15
V	(234.7/91.2)/989.91	(20/0)/46.4	0/6.01	(24.9/1.1)/149.5	(189.8/90.1)/788.0
VI	(0/0.61)/106.19	0/19.0	0/1.5	(0/0.3)/34.52	(0/0.31)/50.6
VII	(0/1)/61.60	0/2.9	0/0	(0/1)/42.0	0/16.6
VIII	(1.6/1)/12.5	0/0.5	0/0.78	(1.5/0)/4.62	(0.1/1)/6.5
IX	(5.2/1.85)/91.9	(1/0)/16.4	0/1.0	(0.6/0)/32.6	(3.6/0.85)/40.75
Total	(287/122.26)/1,693.9	(21/1)/111.4	(10/0)/19.81	(39/13.9)/368.7	(217/107.36)/1,194

TABLE 10 (Continued)

AUTOMOTIVE INDUSTRY PLANT VALUES IN MILLIONS OF DOLLARS:
(VISITED/SURVEYED)/INDUSTRY TOTAL*

HEW region	SIC Code 3714								
	2†	3	4a	4b	5	6	7	8	Total
I		10/10		10/0			1/0		21/10 92.37
II					2/0	0/1	.5/1.5		2.5/2.5 166.5
III	0/0.3								0/0.3 14.5
IV	0/0.3	0/1					0/1		0/2.3 18.15
V	2.3/11.1	55.5/42.5	11/0	17/0	14/11	66/1.5	4/24	20/0	189.8/90.1 788.0
VI						0/.3	0/.01		0/10.31 50.6
VII									0 16.6
VIII							0.1/1		0.1/1 6.5
IX	1/.35	.3/.5			.3/0	.5/0	1.5/0		3.6/0.85 40.75
Total	3.3/12.05	0 65.8/54	11/0	27/0	16.3/11	66.5/2.8	7.1/27.51	20/0	217/107.36 1,194

* Total plants visited/surveyed excludes AMA member plants.

† Numbers 1 through 8 refer to product categories in Table 6.

TABLE 11

AUTOMOTIVE INDUSTRY EMPLOYMENT: (VISITED/SURVEYED)/INDUSTRY TOTAL*

HEW region	Total HEW region	SIC Code[1]			
		3711	3712	3713	3714
I	5,720/1,045 17,370	0 3,950	0 0	70/0 9,440	5,650/1,045 3,980
II	4,315/665 91,850	0 39,950	3,500/0 6,930	431/216 4,570	384/449 40,400
III	0/12 30,387	0 13,600	0 2,600	0 2,137	0/12 12,050
IV	0/1,196 15,548	0 /338 4,870	0 978	0/350 3,110	0/508 6,590
V	28,099/13,027 625,180	925/0 281,000	0 48,000	3,071/105 13,180	24,103/12,922 283,000
VI	0/136 40,640	0 17,390	0 3,135	0/80 2,605	0/56 17,510
VII	0/110 10,325	0 4,490	0 0	0/110 1,305	0 4,530
VIII	111/1,000 2,234	0 470	0 79	81/0 210	30/1,000 1,475
IX	678/567 36,074	300/0 15,000	0 2,545	44/0 3,424	334/567 15,110
Total	38,923/17,758 869,613	1,225/338 380,900	3,500/0 64,400	3,697/861 40,000	30,501/16,559 384,600

TABLE 11 (Continued)

AUTOMOTIVE INDUSTRY EMPLOYMENT: (VISITED/SURVEYED)/INDUSTRY TOTAL*

HEW region	SIC Code 3714 2†	3	4a	4b	5	6	7	8	Total
I		5,000‡/1,045		250/0			400/0		5,650/1,045 3,980
II					375/0	0/165	9/284		384/449 40,400
III	0/12								0/12 12,050
IV	0/125	0/51					0/332		0/508 6,590
V	492/610	3,749/9,165	1,098/0	3,680/0	2,590/875	7,103/293	2,151/1,979	3,240/0	24,103/12,922 283,000
VI						0/12	0/44		0/56 17,510
VII									0 4,530
VIII							30/1,000		30/1,000 1,475
IX	45/26	35/40			34/0	42/0	178/501		334/567 15,110
Total	537/773	8,784/10,301	1,098/0	3,930/0	2,999/875	7,145/470	2,768/4,140	3,240/0	30,501/16,559 384,600

* Total plants visited/surveyed excludes AMA member plants.

† Numbers 1 through 8 refer to product categories in Table 6.

‡ Includes all employees in two plants where automotive product workers could not be separated from other production workers.

TABLE 12

AUTOMOTIVE INDUSTRY SURVEY--PRODUCTION COVERAGE
(EXCLUDING AMA SURVEY)

Product	Production covered*	Total production†	Covered (%)
Engines--gasoline			
(includes blocks)	1,119,000	6,690,000	16.7
Cylinder heads	1,112,400	14,910,000	7.5
Piston rings	15,000,000	788,900,000	1.9
Valves	74,036,000	193,400,000	38.3
Carburetors	372,000	16,300,000	2.2
Transmissions			
Total (car;automatic and standard, truck automatic)	16,501,000	9,135,000‡	--
Truck and bus, standard	150,000	1,481,000	9.6
Power transmission system			
Universal joints	5,120,000	39,100,000	13.1
Rear-axle shafts	1,024,000	19,340,000	5.3
Water pumps	1,750,000	4,700,000	37.2
Fuel pumps	108,000	15,090,000	0.7
Radiators	153,000	8,960,000	1.7
Oil filter elements	67,200,000	171,750,000	39.1
V-belts	12,000,000	49,500,000	24.2
Exhaust systems			
Mufflers	11,352,000	44,300,000	25.6
Tailpipes	8,748,000	67,600,000	12.9
Wheels	675,000	51,500,000	1.3
Bodies, truck			
Van	3,430	112,500	3.0
Utility	6,820	35,500	19.2
Tanks	78	1,320	5.9
Solid waste	3,590	6,090	59.0
Panel delivery and pickup	240	19,700	1.2
Other	3,621	28,900	12.5

TABLE 12 (Continued)

Product	Production covered*	Total production†	Covered (%)
Bus bodies			
Bodies--truck, bus, and other shipped to motor	3,120	17,240	18.1
vehicle manufacturers	19,100	89,500	21.3
Complete vehicles			
Ambulances			
Hearses	480	3,500	13.0
Passenger cars	6,000	8,349,438	0.1
Passenger car chassis	144,000	6,900,000	2.1

* Based on production figures in plants visited and questionnaires received.

† Figures for the entire industry, based on 1967 Census of Manufacturers production modified by ratio of 1969 to 1967 vehicle production.

‡ This figure includes only major industry companies but not others who manufacture in different industries.

TABLE 13

INDUSTRY QUESTIONNAIRE DATA REPLIES*

Question	Replies to questions: Answer: Yes	Answer: No	No answer	Comment given
A. Plant facilities:				
Product identified	42/25† over 74		1/4 over 0	
Production rate	40/22 over 65		3/7 over 9	
Number of employees	43/23 over 74		0/6 over 0	
B. Plant value	43/19 over 74		0/10 over 0	
C. Quantity of solid waste	43/22 over 73		0/7 over 1	
D. Solid waste disposal method	43/28 over 73		0/1 over 1	
E. Monthly cost for each method	37/11 over 67		6/18 over 7	
F. Monthly sales of salvage:				
Description of salvage	35/14 over 65		8/15 over 9	
Sales ($)	32/10 over 56		11/19 over 18	
G. Rated present handling and disposal method	42/20 over 72		1/9 over 2	

TABLE 13 (Continued)

Question	Replies to questions: Answer: Yes	Answer: No	No answer	Comment given
H. Provided schematic of plant	11/2 over 51		32/25 over 23	0/2 over 0
I. Do solid waste disposal problems exist?	2/0 over 2	33/29 over 59	0/0 over 0	10/0 over 13
J. Are municipal authorities taking adequate steps to help?	13/2 over 12	17/21 over 44	4/3 over 8	11/8 over 10
K. Does waste generation vary with production process changes?	12/0 over 3	26/29 over 57	1/0 over 1	4/0 over 13
L. Are changes in waste handling foreseen?	5/1 over 3	31/28 over 53	0/0 over 2	9/1 over 16

* See Sample Plant Questionnaire in Appendix B.

† a/b over c

a = number of plants from the total of 43 plants that returned complete questionnaires.

b = number of plants from the total of 29 plants that returned incomplete questionnaires.

c = number of plants from the total of 74 plants visited by the project engineer's staff.

TABLE 14

SUMMARY OF REASONS
FOR NOT ANSWERING MAILED PLANT QUESTIONNAIRE*

Reason for not supplying information	Number responding	Percent of 65 plants supplying reasons
Not presently manufacturing items listed under SIC 3711-3714	45	68.6
Closed; operations transferred	4	6.2
Information not available; no record	4	6.2
No solid waste generation	4	6.2
Unable to provide intelligent, factual answers	3	4.7
Not interested	2	3.2
No serious problems with solid waste	2	3.2
Information withheld for competitive reasons	1	1.7
Total	65	100

* Of 1,700 plants that received questionnaires, 65, or 3.8 percent, provided reasons for not supplying information.

TABLE 15

AMA QUESTIONNAIRE REPLIES

Question	Number of plants that answered question	Number of plants that did not answer question
A. Plant facilities:		
Type of plant identified	158*/59	0/0
Current production rate given	96/0	62/59
Total number of employees given	158/2	0/57
B. Costs of collection and disposal given	158/59	0/0
C. Attached schematic of plant	144/1	14/58
D. Solid waste sold externally by:		
Item identified	67/11	91/48
Quantity given	67/9	91/50
E. Special problems existing	47/3	111/56
F. Local governmental agency concerned with plant's waste management activities:		
Collection	9/3	149/56
Disposal	74/13	84/46

TABLE 15 (Continued)

Question	Number of plants that answered question	Number of plants that did not answer question
Explanation	85/16	73/43
G. Do local or State regulations affect solid waste management activities?	100/57	58/2
H. Quantities and classifications of solid waste listed	158/58	0/1

* The numerator refers to the 158 usable questionnaires. The denominotor refers to the 59 unusable questionnaires.

TABLE 16

SUMMARY OF MUNICIPAL SURVEY

HEW region	Number of communities* with plants	Number of replies / Number of usable replies	Number of field contacts†
I	23	7/0	0
II	31	1/0	4
III	14	3/1	0
IV	17	4/0	0
V	90	12/4	6
VI	21	5/0	0
VII	18	4/2	0
VIII	5	0/0	0
IX	16	5/0	1
Totals	235	41/7	11

* All 235 communities with automotive plants were sent questionnaires.
† All communities contacted personally provided usable information.

TABLE 17

SUMMARY OF MAILED MUNICIPAL QUESTIONNAIRE RESPONSES

	Number of municipalities*	Percent of 48 responses
County+ is conducting an industrial solid waste study	1	2.1
Industry solid waste collection and disposal is the responsibility of the individual plants	3	6.2
Do not keep records of industrial wastes	6	12.5
Not aware of automotive industry plants in city	27	56.3
Incomplete	4	8.3
Partially completed questionnaire	6	12.5
Completed questionnaire	1	2.1
Total mailed response	48	100

* Questionnaires were sent to 235 municipalities, and 48, or 20.4 percent responded.

\+ Macombe County Planning Commission, 115 S. Goesbeck Highway, Mount Clemens, Michigan 48043.

TABLE 18

AUTOMOTIVE INDUSTRY WASTE ESTIMATES*

	Waste quantity		
Type of waste	1969 (tons per year)	(%)	1975 (tons per year)
Paper, cloth	302,000	3.72	373,000
Cardboard	388,000	4.78	479,000
Wood	274,000	3.38	338,000
Rubber	29,000	0.36	36,000
Plastics	32,000	0.40	40,000
Oils, paints, thinners	88,000	1.08	109,000
Cans, bands, wire	61,000	0.75	75,000
Garbage	276,000	3.43	341,000
Sludges, slurries	2,478,000	30.50	3,059,000
Inert solids	4,188,000	51.60	5,171,000
Estimated total wastes for complete industry	8,116,000	100.00	10,021,000
Total tons per vehicle produced	0.8		0.74
Estimated total wastes excluding foundry waste	3,694,000		4,560,000

From: * Data includes project engineer's sample and AMA information.

TABLE 19

WEIGHT OF SCRAP PRODUCED
IN THE MANUFACTURE OF A COMPOSITE AUTOMOBILE*

Item	Scrap weight (lb)
Body components	
Locks	0.03
Body, with top	342
	342.03
Engine system	
Crankshaft and camshaft bearings	4.8
Engine block and head	100
Flywheel	12
Exhaust headers	1.28
Carburetor	0.38
Regulator	0.38
Valves	4
Springs	0.09
Mechanical controls (choke)	0.01
Governor	0.82
Piston rings	0.21
Cylinder sleeves	0.67
Rocker arms	0.67
Push rods	2
Retainers	0.67
Fan clutch plate	2.55
Water pump	0.61
	131.14
Transmission	344
Differential (rear end)	
Axle	16
Ring gear	2.4
No spin differential	4
	22.4
Front end	
Ball joints	3.56
Front-end linkage	1.78

TABLE 19 (Continued)

Item	Scrap weight (lb)
Power steering pump	1.78
Universal joints	1.10
	8.22
Chassis and components	
Hub caps	0.34
Grease caps	0.34
Frame	54
Bumpers	10
Muffler	2.05
Exhaust brackets	1.28
Exhaust pipe	2.37
	71.02
Miscellaneous vehicle components	
Air conditioner and heater unit	1.1
Air filter	0.23
Fuel filter	0.23
Oil filter	0.23
Radiator	4.85
	6.65
Total scrap weight, lb	926

* Compiled from plants sampled by the project engineer within the four SIC Codes.

TABLE 20

WEIGHT OF SCRAP PRODUCED
IN THE MANUFACTURE OF A COMPOSITE TRUCK AND BUS*

Item	Scrap weight (lb)
Body components	
Lock mechanism	0.03
Body	421
Fifth wheel	16
Door panels	1.5
	438.53
Engine system	
Crankshaft and camshaft bearings	4.8
Engine, block and head	150
Flywheel and ring gear	12
Exhaust headers	1.28
Carburetor	0.38
Regulator	0.38
Valves	6
Springs	0.05
Mechanical control (choke)	0.01
Governor	0.82
Piston rings	0.21
Diesel fuel injection pump	6.35
Diesel nozzle assembly	6.35
Diesel nozzle holders	6.35
Cylinder sleeves	0.67
Rocker arms	0.67
Fan clutch plate	2.55
Water pump	0.61
In-tank fuel pump	38.9
	238.38
Transmission	344
Differential (rear end)	
Ring gear	2.4
Axle	16
Universal joints	26
No spin differential	4
	48.40

TABLE 20 (Continued)

Item	Scrap weight (lb)
Front end	
Front-end linkage	1.78
Power steering pumps	1.78
Ball joints	7.12
Air brake system	31.5
	42.18
Chassis and components	
Bumper	20
Muffler	2.05
Exhaust brackets	1.28
Exhaust pipe	0.64
Hub caps	0.34
Grease caps	0.34
Tail pipe	1.73
Frame	76
	102.38
Miscellaneous vehicle components	
Air conditioner and heater unit	1.1
Hydraulic tailgate lifters	30
Pintle hooks and couplers	32
Tow eyes	32
Air filter	0.23
Fuel filter	0.23
Oil filter	0.23
Radiator	4.86
	100.65
Total scrap weight, lb	1,315

* Compiled from plants sampled by the project engineer within the four SIC Codes.

TABLE 21

COMPOSITION OF TYPICAL AUTOMOBILE*

Material	(lb)	Total automobile (%)	Total metal (%)	Total ferrous metal
Light steel	1,309.5	36.6	40.9	
Heavy steel	1,222.4	34.2	38.2	
No. 2 bundle steel	2,531.9	70.8	79.1	
Cast iron	511.4	14.3	16.0	95.1
Copper†	31.9	0.9	1.0	
Zinc‡	54.2	1.5	1.7	
Aluminum§	50.6	1.4	1.6	
Lead	20.4	0.6	0.6	
Rubber	145.0	4.1		
Glass	87.2	2.4		
Other combustibles¶	127.2	3.6		
Other noncombustibles#	14.8	0.4		
Total	3,574.6	100.0	100.0	95.1
Total metals	3,200.4			

Year	Make	Model	Year	Make	Model
1954	Chevrolet	4-door sedan	1956	Cadillac	Coupe
1956	Buick Special	4-door hardtop	1964	Plymouth	2-door convertible
1963	Dodge Polara	2-door hardtop	1965	Mustang	2-door hardtop
1957	Ford	4-door hardtop	1962	Falcon	2-door sedan
1958	Rambler	Station wagon	1958	Ford Fairlane	4-door sedan
1959	Pontiac	4-door hardtop	1961	Oldsmobile	4-door hardtop
1963	Chevrolet	4-door sedan	1964	Chevrolet	Carry-all
1962	Corvair Monza	2-door sedan			

* Dean, K.C., and Sterner, J.W. Dismantling a typical junk automobile to produce quality scrap. Washington, U.S. Department of the Interior, Bureau of Mines, 1969. p. 5, 7.

† Including zinc in brass but not copper in solid solution in steel.

‡ As zinc base die cast exclusively.

§ As scrap sheet and cast aluminum.

¶ Cardboard, textiles, padding, plastics, petroleum products, etc.

\# Dirt, glass wool insulation, body putty, and ceramics.

TABLE 22

AUTOMOTIVE INDUSTRY MATERIALS BALANCE SCRAP ESTIMATE

Material	Material consumed* (lb/vehicle)	Material in finished vehicle† (lb/vehicle)	Scrap (lb/vehicle)	Total scrap (lb x 10^{-6})
Steel	3,455.4	2,600.8	854.6	8,884.7
Cast iron	592.8	525.2	67.6	702.7
Cu	59.8	33.0	26.8	278.6
Zn	110.1	55.0	55.1	572.8
Al	97.5	70.0	27.5	285.8
Pb	129.4‡	22.1	107.3	1,115.5
Total	4,445.0	3,306.1	1,138.9	11,840.1

* Automobile Manufacturers Association, Inc. Automobile facts and figures. Detroit, Michigan, 1956-1968; and Automotive Industries, July 1, 1961.

† Dean, K.C., and Sterner, J.W. Dismantling a typical junk automobile to produce quality scrap. Washington, U.S. Department of the Interior, Bureau of Mines, 1969. p. 5, 7.

‡ Lead consumption includes paint pigment and products manufactured in other SIC groups.

TABLE 23

WASTE PREDICTION--STEPWISE REGRESSION

Plant type: Plant process	Plant type: Product*	Data sample size	Regression results†: B_0	B_1	B_2	Standard error (tons/month)	Multiple R^2
Any	Any	88	9.42	.05430	.14398	402.20	.06
Any except foundry and nonmetal	Any	74	−1.49	.07471	.01622	43.37	.70
Machining	Any	29	−6.97	.08590	.02235	57.34	.75
Fabrication	Any	40	1.41	.04210	.02163	22.43	.68
Nonmetal	Any	10	64.49	.24266	.02328	118.58	.36
Machinery	Engine system	15	−.36	.07290	.01884	48.18	.82
Fabrication	Body components	22	−.23	.03947	.02181	16.44	.85

* Product group refers to listings in Table 6.

† [Waste = B_0 + B_1 (employment) + B_2 (plant value)].

TABLE 24

WASTE PREDICTION--STEPWISE REGRESSION

Plant type: Process	Plant type: Product*	Data sample size	Regression results†: B_0	B_1	B_2	B_3	Standard error (tons/month)	Multiple R^2
Any	Any	80	5.89	.05208	.14759	.00001	405.21	.06
Any except foundry and nonmetal	Any	67	0.84	.07587	.01610	-.00001	43.19	.70
Machining	Any	26	-0.23	.08727	.02297	-.00002	55.66	.78
Fabrication	Any	37	-2.53	.04111	.02249	.00002	20.93	.73
Nonmetal	Any	9	77.86	.32946	-.04043	-.00002	115.47	.51
Machining	Engine system	15	25.37	.08330	0	-.00003	32.50	.91
Fabrication	Body components	17	.17	.03965	.02116	-.00001	17.07	.85

* Product group refers to listings in Table 6.

† [Waste = B_0 + B_1 (employment) + B_2 (plant value) + B_3 (quantity of items produced)].

TABLE 25

SCRAP PREDICTION--STEPWISE REGRESSION

Plant type: Process	Plant type: Product*	Data sample size	Regression results†: B_0	B_1	B_2	Standard error (tons/month)	Multiple R^2
Any	Any	77	.50	.29194	.14767	264.83	.53
Any except foundry and nonmetal	Any	71	11.09	.30581	.12761	268.10	.53
Machining	Any	27	7.64	.45893	0	223.25	.83
Fabrication	Any	39	12.48	.10056	.24473	215.13	.34
Machining	Engine system	14	76.97	.12853	.12705	164.63	.61
Fabrication	Body components	21	6.04	.12793	.02240	50.17	.83

* Product group refers to listings in Table 6.

† [Scrap = $B_0 + B_1$ (employment) + B_2 (plant value)].

TABLE 26

SCRAP PREDICTION--STEPWISE REGRESSION

Plant type			Regression results†					
Process	Product*	Data sample size	B_0	B_1	B_2	B_3	Standard error (tons/month)	Multiple R^2
Any	Any	72	5.32	.29497	.14273	-.00001	266.79	.54
Any except foundry and nonmetal	Any	65	5.79	.30322	.12788	.00002	270.16	.54
Machining	Any	25	32.08	.46431	0	-.00007	218.85	.84
Fabrication	Any	36	44.25	.08634	.25700	.00030	175.39	.58
Machining	Engine system	13	76.97	.12853	.12305	0	165.89	.61
Fabrication	Body components	16	9.49	.12951	.01676	-.00008	50.93	.84

* Product group refers to listings in Table 6.

† [Scrap = $B_0 + B_1$ (employment) + B_2 (plant value) + B_3 (quantity of items produced)].

TABLE 27

DISTRIBUTION OF CONTAINER SIZES
(VISITED-PLANT DATA)*

Container size (cu yd)	Number of plants	Plants (%)
0.67	1	1.5
1	1	1.5
2	6	9.2
2.25	1	1.5
3	4	6.2
4	4	6.2
4.5	1	1.5
5	7	10.8
5.5	1	1.5
6	2	3.1
7	1	1.5
8	7	10.8
9	1	1.5
10	11	16.9
12	7	10.8
13	1	1.5
13.5	1	1.5
15	1	1.5
16	2	3.1
18	2	3.1
20	9	13.8
30	6	9.2
32	2	3.1
40	3	4.6
42	1	1.5
56	1	1.5
65	1	1.5
71	1	1.5
111†	1	1.5
148†	1	1.5
210†	1	1.5
272†	1	1.5

* Total number of plants visited supplying information on container sizes: 65. Number of plants with 55-gal barrels: 20.

† Stationary three-walled bins.

TABLE 28

WASTE-HANDLING EQUIPMENT USE*

Plant value ($1,000)	Number of plants with listed item of equipment: Fork lift	Hand truck	Tow motor	Industrial truck	With equipment†	Total plants: Visited in plant value category	Within each plant value category with equipment (%)
10,000	17	6	5	1	22	23	95.7
5,000	2	0	0	0	2	2	100.0
1,000	17	4	1	2	21	28	75.0
500	5	1	1	0	5	9	55.6
300	1	2	0	0	3	6	50.0
100	1	0	0	0	1	2	50.0
50	0	0	0	0	0	0	0.0
10	0	0	0	0	0	0	0.0
Total equipment use	43	14	7	3	54	70	77.1
Percent plants visited using equipment	61.5	20.0	10.0	4.3			

* The above information was obtained from 70 plants visited by the project engineer's staff.

† Some plants use more than one item of equipment; thus there are fewer plants than equipment totals.

TABLE 29

EQUIPMENT USE BY PLANT VALUE*

Plant Value ($1,000)	Compactor	Conveyor	Vacuum	Crane	Magnet	Baler	Crusher	Shredder	Shear	Skip Loader	Centrifuge	Total plants with equipment	Total plants in plant value category	% plants within plant value category with equipment
10,000	9	7	1	1	1	2	1	1	1	0	1	17	23	74
5,000	1	1			1							2	2	100
1,000	5	3	2	3						1		11	28	39
500	1	1	1									1	9	11
300			2									2	6	33
100													2	0
Total, No.	16	12	6	4	2	2	1	1	1	1	1	33	70	
Plants using equipment,%	22.8	17.1	8.6	5.7	2.9	2.9	1.4	1.4	1.4	1.4	1.4			

* These data are based on information from 70 plants visited by the project engineer's staff.

TABLE 30

PLANT SCRAP AND WASTE SEGREGATION PRACTICES (70 PLANTS)

Segregation point*	Waste (nonmetals) Number of plants	(%)	Scrap (metals) Number of plants	(%)	Waste and scrap Number of plants	(%)	Total number of plants segregating	(%)
In plant at source	4	5.7	21	30.0	6	8.6	31	44.3
Outside storage area	1	1.4	7	10.0	1	1.4	9	12.9
Both in plant and storage area	1	1.4	8	11.5	6	8.6	15	21.4
Waste outside and scrap inside	NA†	NA	NA	NA	5	7.1	5	7.1
Waste inside and scrap outside	NA	NA	NA	NA	2	2.9	2	2.9
Total*	6	8.5	36	51.5	20	28.6	62	88.6

* Eight plants (11.4 percent) did not segregate any waste or scrap.
† NA = Not applicable.

TABLE 31

AMA SURVEY SALVAGE*

Item	Total salvaged (tons/yr)	Percent of total	Number of plants salvaging item	Percent of total†
Cardboard	117,677	26.7	37	23.4
Paper				
IBM cards	349	0.08	13	8.2
Tab cards	64	0.01	2	1.3
Loose cards	7,246	1.64	8	5.1
	7,659	1.73	23	14.6
Wood	14,749	3.34	17	10.8
Cloth	73	0.02	6	3.8
Thermoplastics				
Vinyl	2,547	0.58	4	2.5
Plastic	256	0.06	2	1.3
ABS film offal	500	0.11	1	0.06
	3,303	0.75	7	3.9
Slag	255,533	57.91	4	2.5
Rubber (including cured foam)	200	0.05	5	3.2
Oil (including sludge and slurge)	11,667	2.64	4	2.5
Glass	23,760	5.39	1	0.06
Combustible rubbish	3,917	0.89	1	0.06
Coke breeze	1,311	0.30	1	0.06
Zinc ash	918	0.21	1	0.06

TABLE 31 (Continued)

Item	Total salvaged (tons/yr)	Percent of total	Number of plants salvaging item	Percent of total†
Zinc pit cleanings	154	0.03	1	0.06
Grinding wheels	154	0.03	1	0.06
Cyanide salt	45	0.01	1	0.06
Nickel salt	14	0.003	1	0.06
Totals	440,999	100.0		

* Number of plants reporting salvage: 67.
† Based on 158 plants supplying information.

TABLE 32

INCINERATION USE IN AUTOMOTIVE PLANTS *

Plant value ($1,000)	Number of incinerators	Total number of plants sampled	Percent of plants with incinerators	Group (%)
10	1	3	33	25
50	0	1	0	
100	2	4	50	
300	3	11	27	22
500	2	17	12	
1,000	9	44	21	
5,000	1	2	50	31
10,000	14	32	44	
Total incinerator use	32	114	28	

* Information was obtained from 44 questionnaires that provided information, and 70 plants visited by the project engineer's staff.

TABLE 33

MAJOR GEOGRAPHIC REGIONS REPORTING INCINERATOR USE*

Area	Number of plants w/incinerators	Number of plants sampled	Sample with incinerators (%)
East Coast	7	17	41
Michigan	11	32	34
Ohio	5	11	46
Illinois	3	9	33
Indiana	2	11	18
Wisconsin/Minnesota	2	10	20
South	2	7	29
Total	32	97	33

* Data is grouped into the geographic regions having the greatest prevalence of automotive industry plants that use incinerators.

TABLE 34

AMA SURVEY OF IN-PLANT PROCESSING BY BURNING

Burning method	Number of plants	Plants* (%)	Cost ($/ton) Minimum	Maximum	Average
Incinerator	13	8.2	10.50	92.60	34.53
Open burning dump	8	5.1	2.02	4.44	2.86
Burned in boiler furnace	3	1.9	2.02	50.70	18.41
Conical burner	1	0.06	0.93	0.93	0.93
Combined†	5	0.32	9.23	20.75	13.01

* Based on 158 AMA plants supplying information; 20 of the 158 reported costs for at least one of the listed disposal methods.

† "Combined" lists the plants which reported using more than one of the four burning methods listed.

TABLE 35

PLANT SOLID WASTE FINAL DISPOSAL DESTINATION*

	Landfill		Dump		Incinerator	
	Number of plants	Plants (%)	Number of plants	Plants (%)	Number of plants	Plants (%)
Public	18	46.2	3	7.7	3	5.7
Private	17	43.6	5	12.8	0	0
Totals	35	89.8	8	20.5	3	7.7

* Based on 39 plants visited by the project engineer's staff that supplied information concerning plant solid waste final disposal destination; 6 plants sent their solid waste to more than one final destination.

TABLE 36

PLANT WASTE AND SCRAP REMOVAL SCHEDULES--PERCENT PLANTS

Item	On call	Twice a day	Daily	Twice a week	Weekly	Twice a month	Monthly
Wastes	17.3	5.8	42.3	15.4	15.4	3.8	0
Scrap	41.3	8.7	21.8	6.5	10.9	6.5	4.3

TABLE 37

COLLECTION COSTS REPORTED BY AMA MEMBER PLANTS

Collector	Number of reporting plants	Collection cost ($/ton)			
		Median	Average	Maximum	Minimum
Public	1	--	8.08	--	--
Private	44	6.71	22.98	250.50	0.92
Self	34	7.40	28.48	414.00	0.12

TABLE 38

LIST OF PROCESS SCHEMATIC SYMBOLS

The symbols used in Figures 19 through 39 are identified as follows:

◁ SW	= SOLID WASTE
(S)	= SCRAP
◇ SVG	= SALVAGE
▽ ST	= STORAGE
○	= LINE OPERATION, THE PRODUCT IS MOVED TO EACH PROCESS IN A CONTINUOUS LINE
□	= SHOP OR SECTION OPERATION WHERE SEVERAL FUNCTIONS ARE COMBINED, AND THEN THE PRODUCT IS MOVED TO ANOTHER BUILDING FOR THE NEXT PROCESS
⟶	= PROCESS SEQUENCE--PRODUCT FLOW DIRECTION

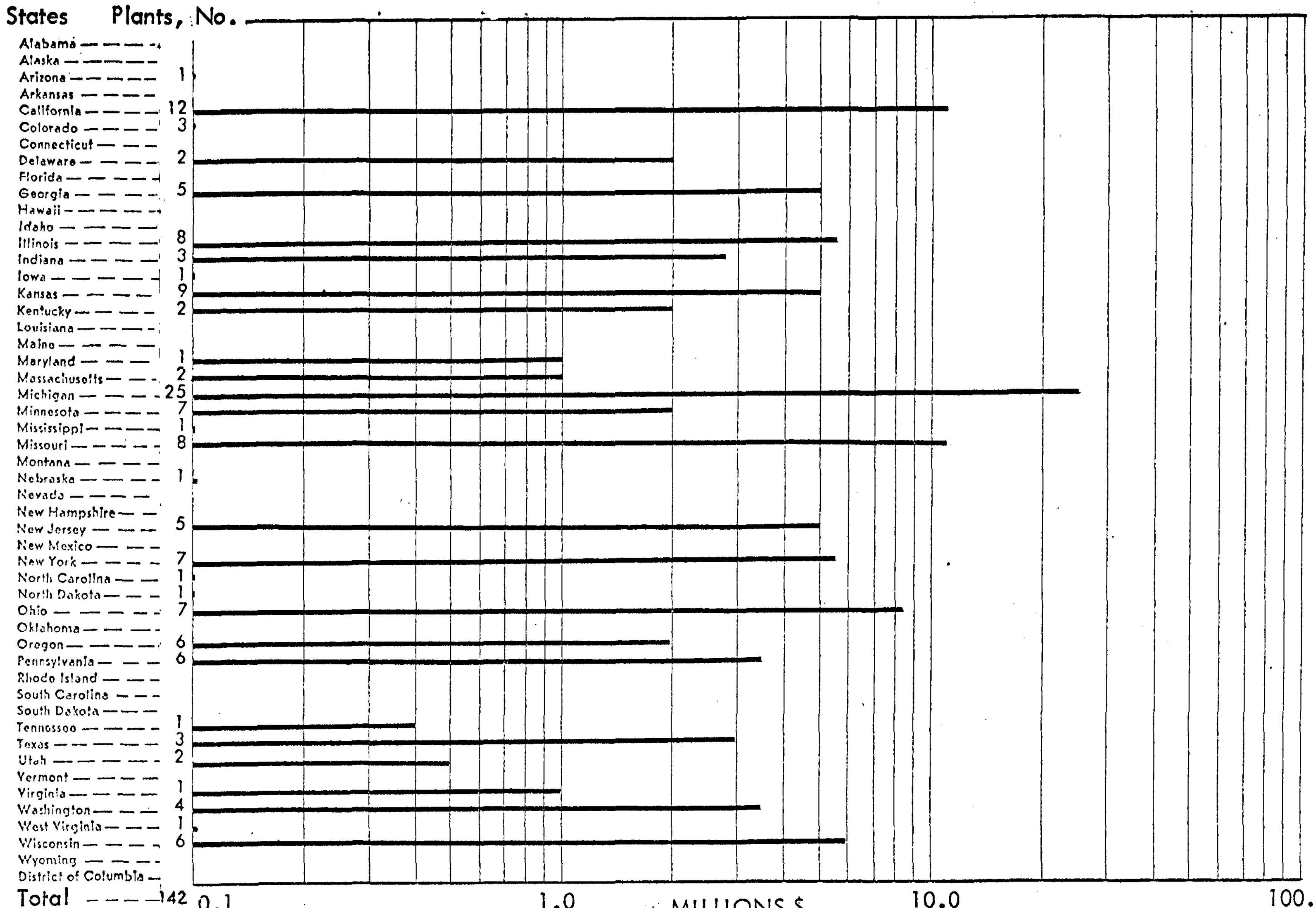


Figure 1. Minimum total tangible assets--SIC 3711. (From: Thomas Register, April 1968.)

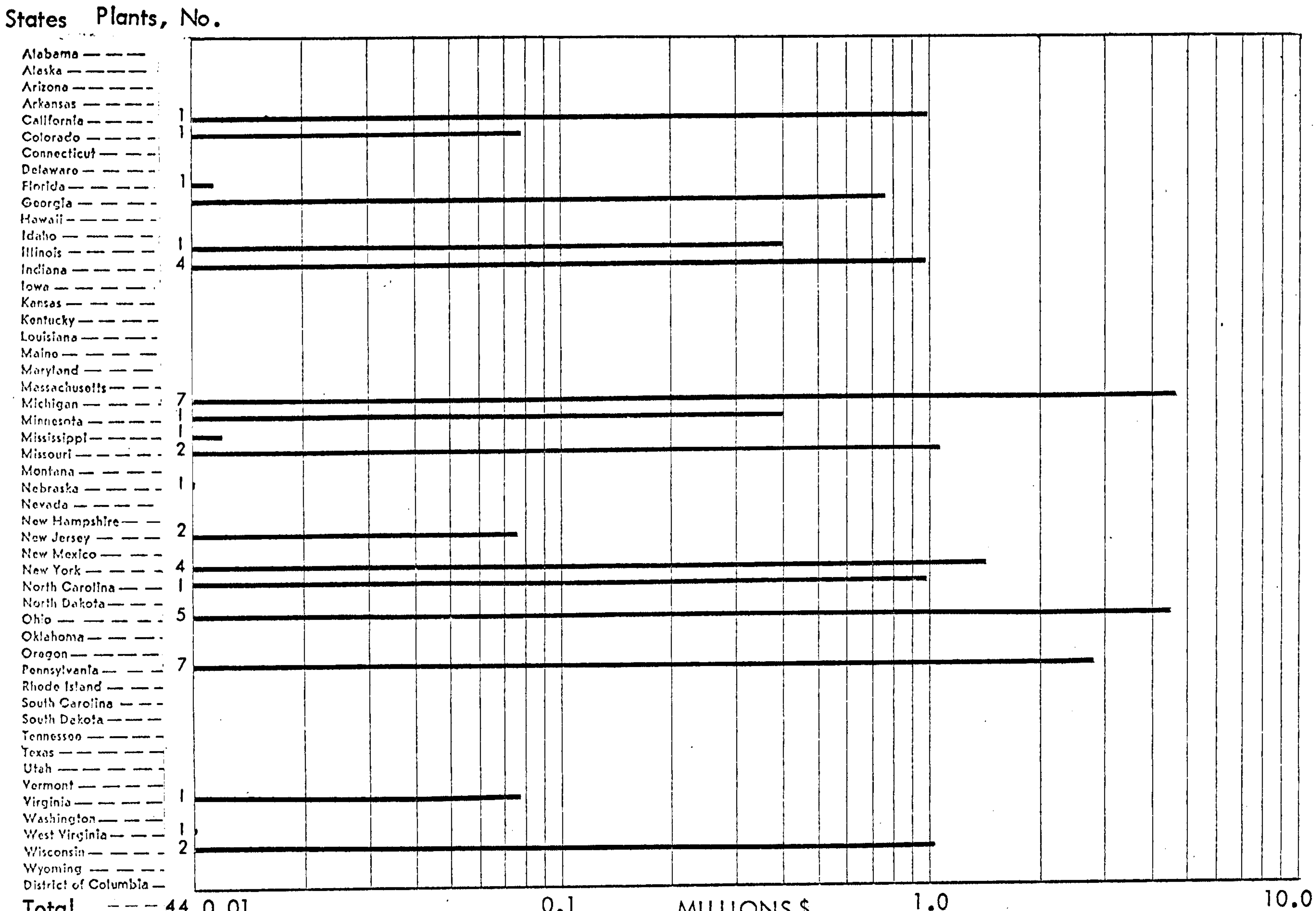


Figure 2. Minimum total tangible assets--SIC 3712. (From: Thomas Register, April 1968.)

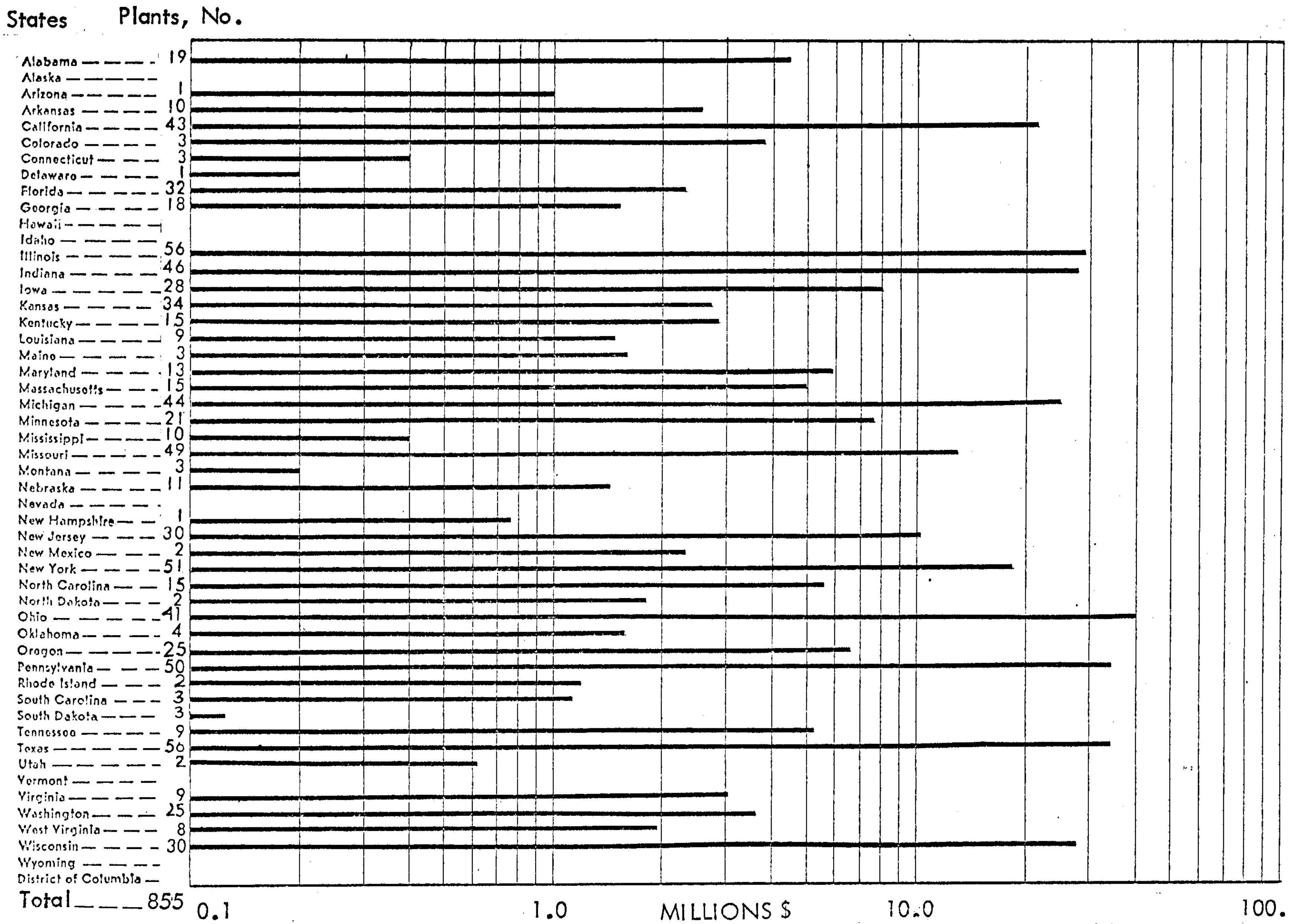


Figure 3. Minimum total tangible assets--SIC 3713. (From: Thomas Register, April 1968.)

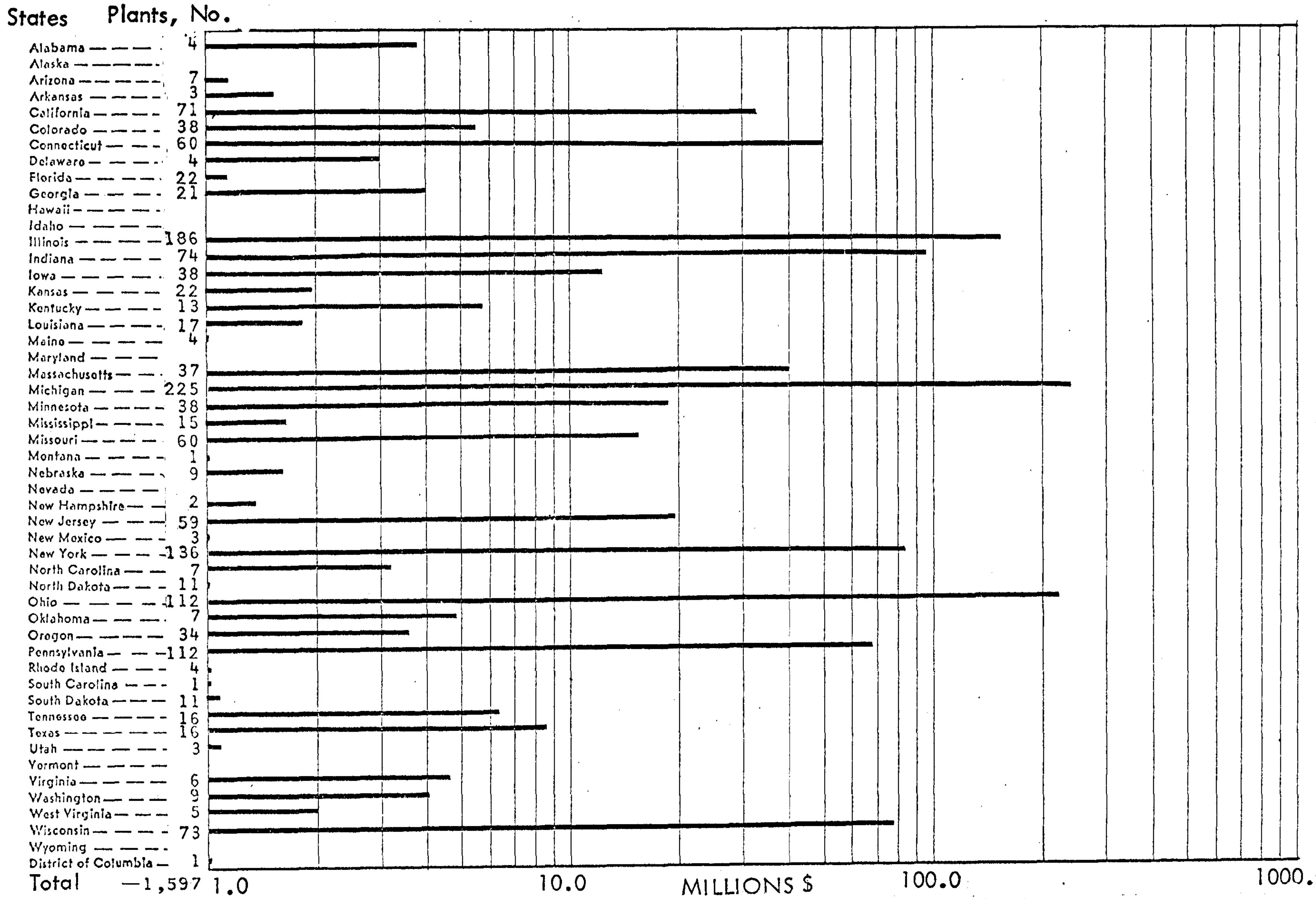


Figure 4. Minimum total tangible assets--SIC 3714. (From: Thomas Register, April 1968.)

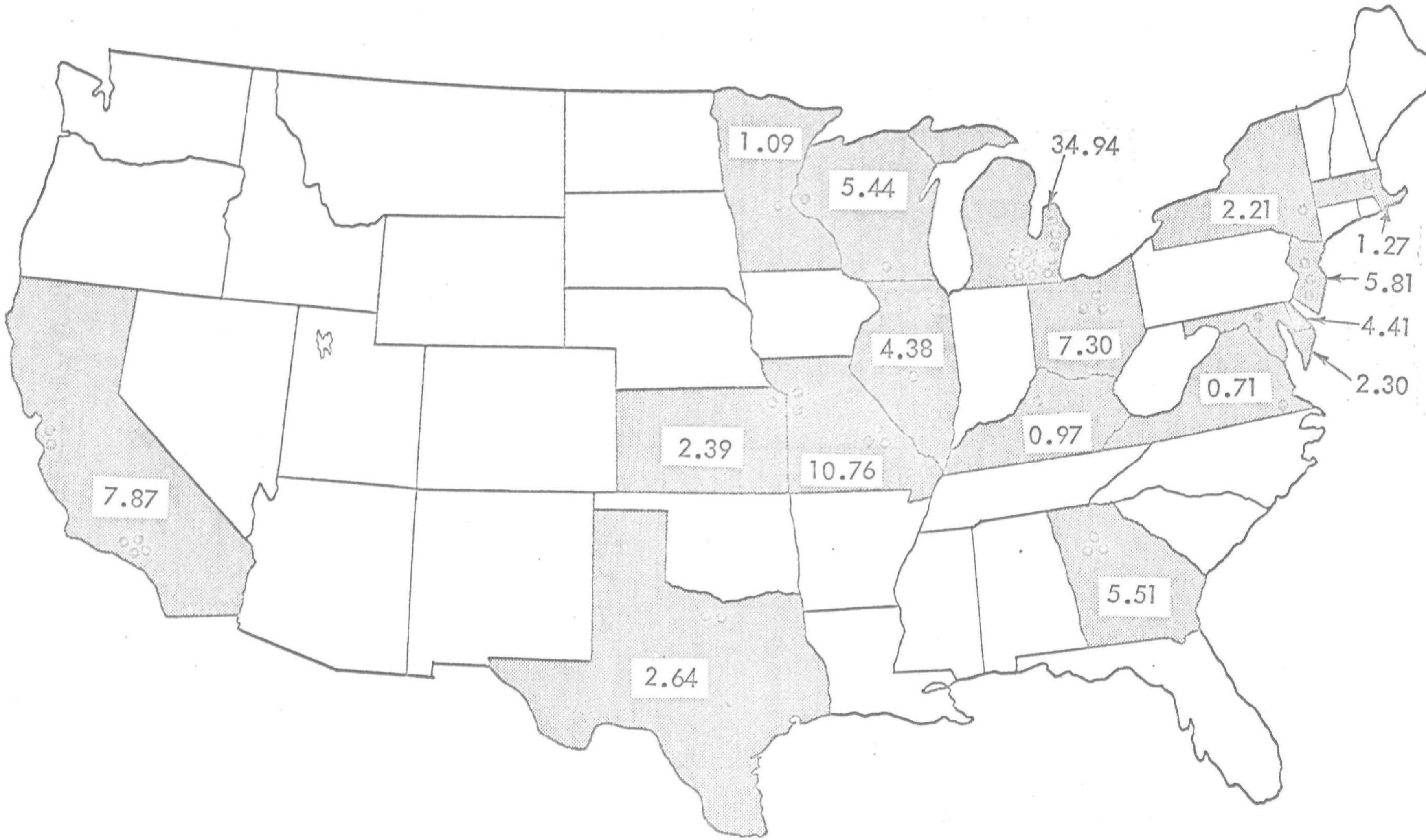


Figure 5. Major automobile assembly locations, 1969. (From: Automotive News, 1970 Almanac, Detroit, Michigan, Slocum Publishing Co., 1970, p. 58. Numbers represent State's percent of total.)

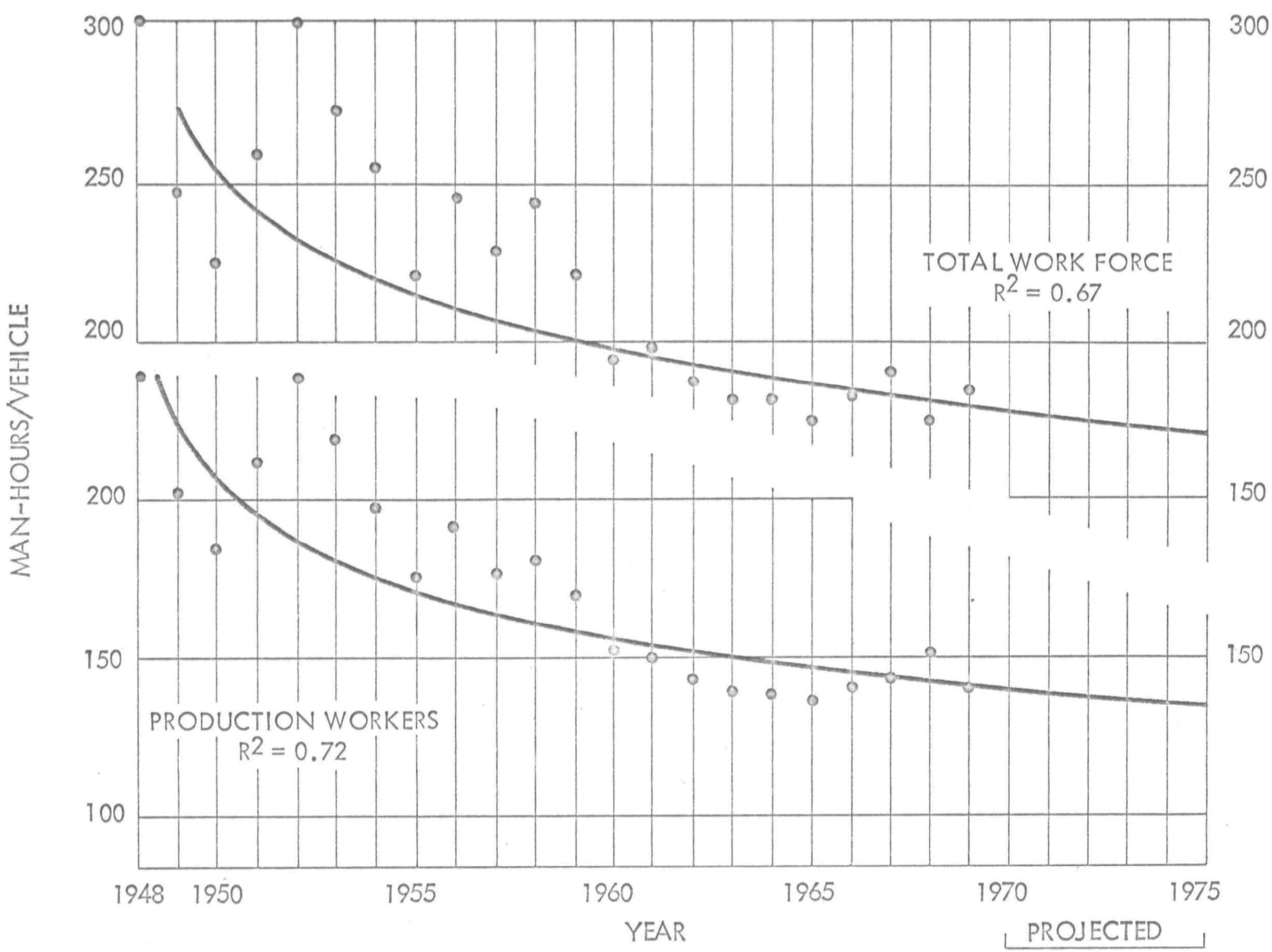


Figure 6. Employee productivity long-term trend. The curve represents a least squares fit of a log transformed parabolic curve ($y = ax^b$).

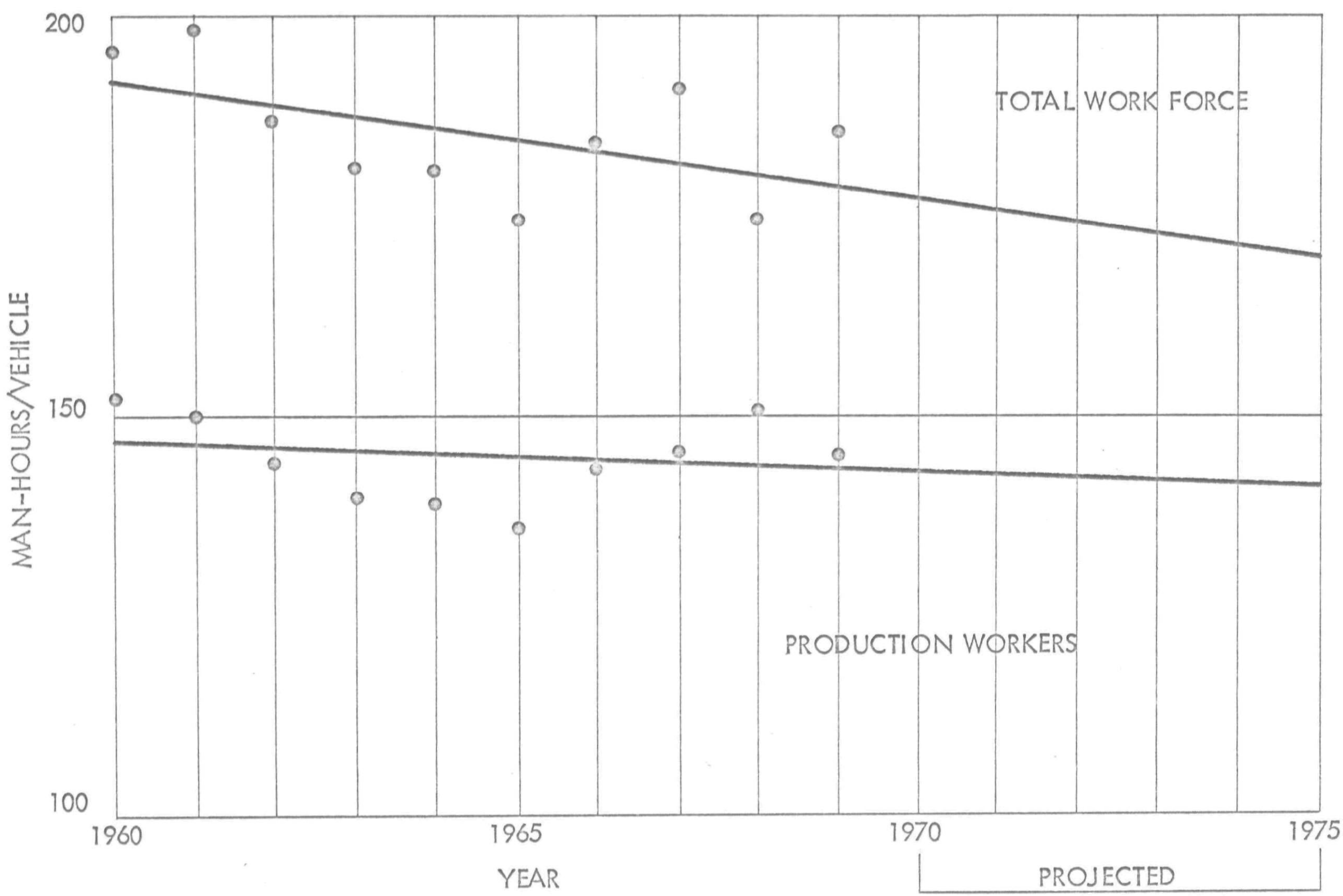


Figure 7. Employee productivity--fitted linear short-term trend.

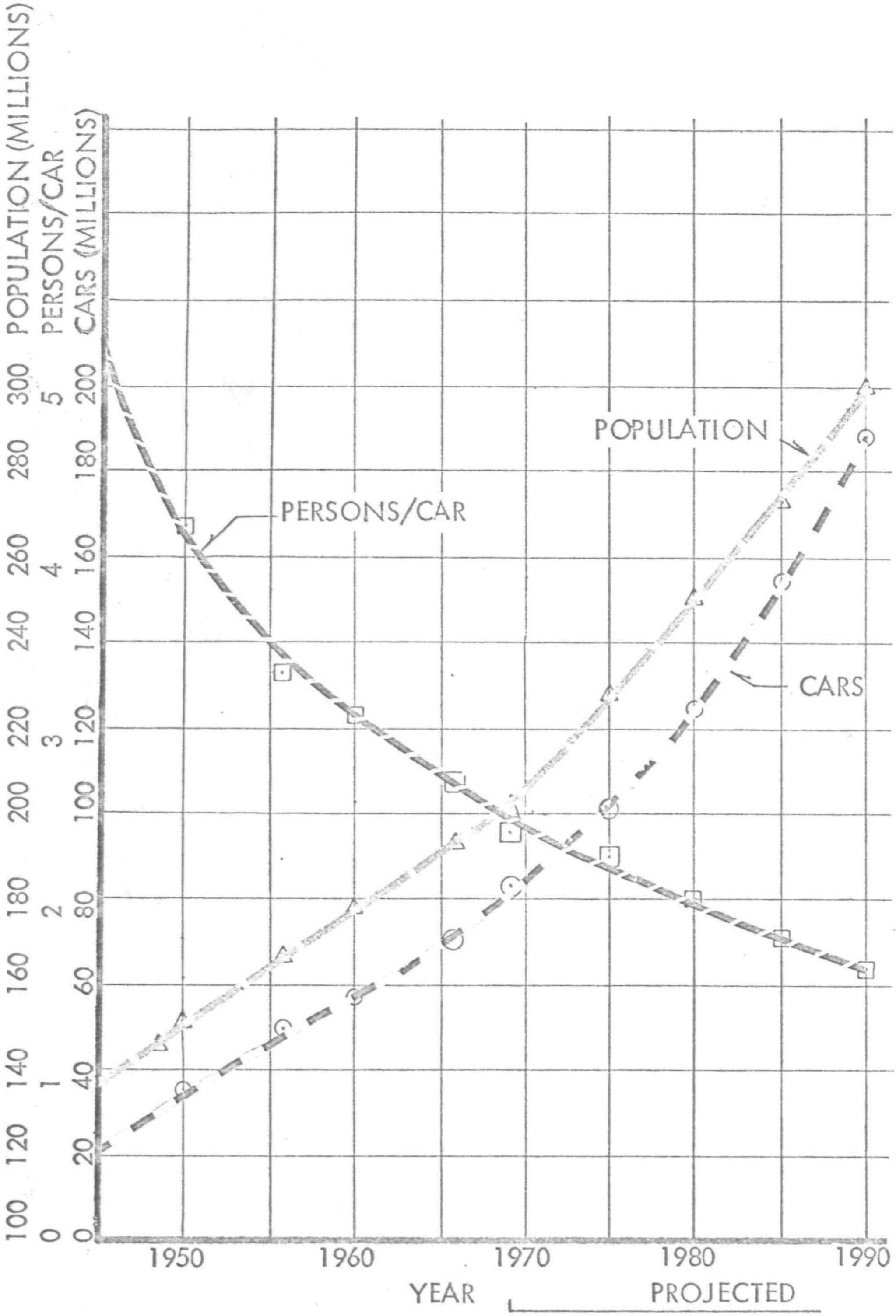


Figure 8. U. S. population/car use relationships.
(From: Automotive News. 1969 Almanac, Detroit, Michigan, Slocum Publishing Co., 1969, 226 p.)

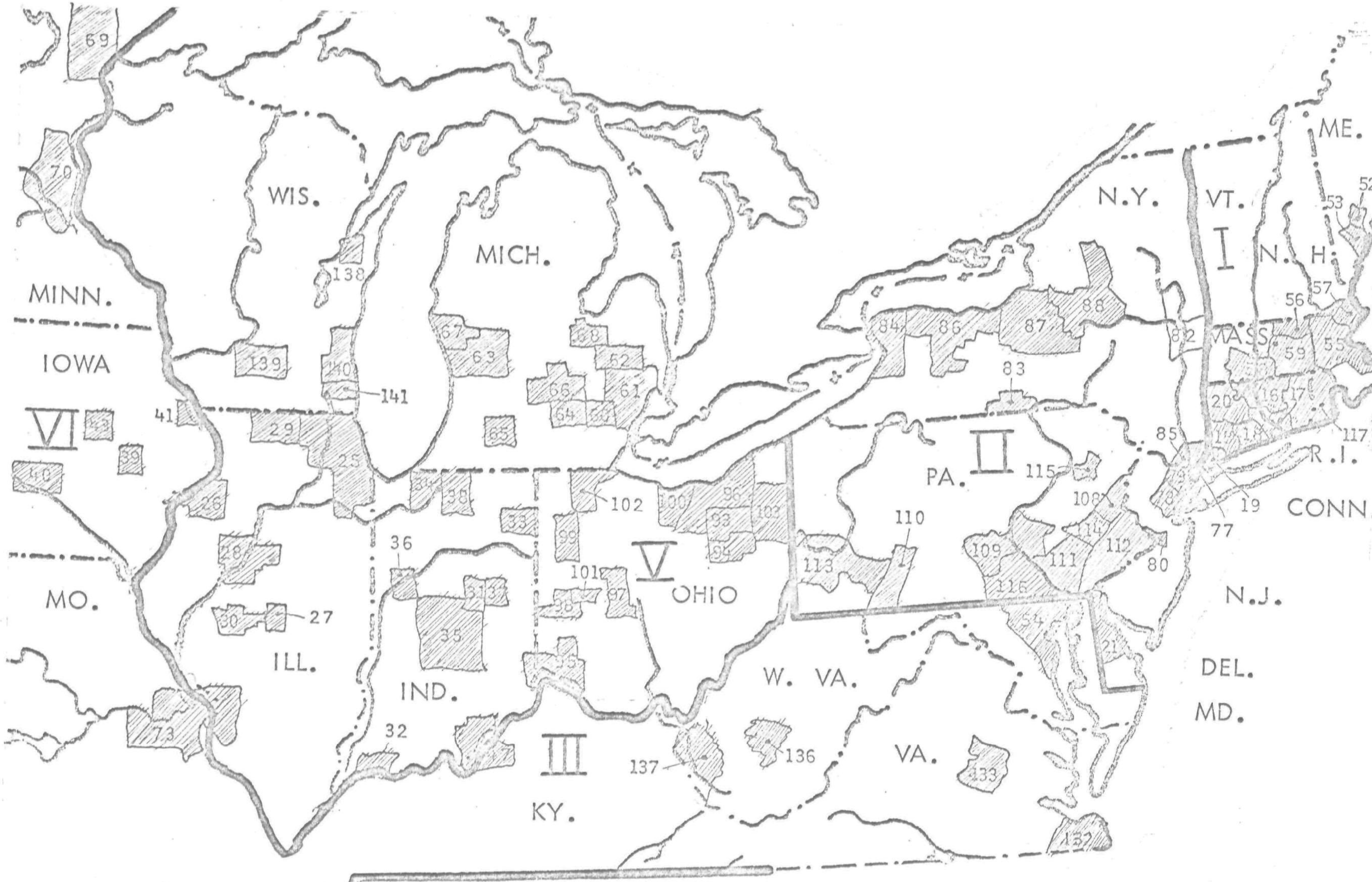


Figure 9. Major automotive production centers--Northeast and Central.
(Map numbers refer to index numbers in Table 3.)

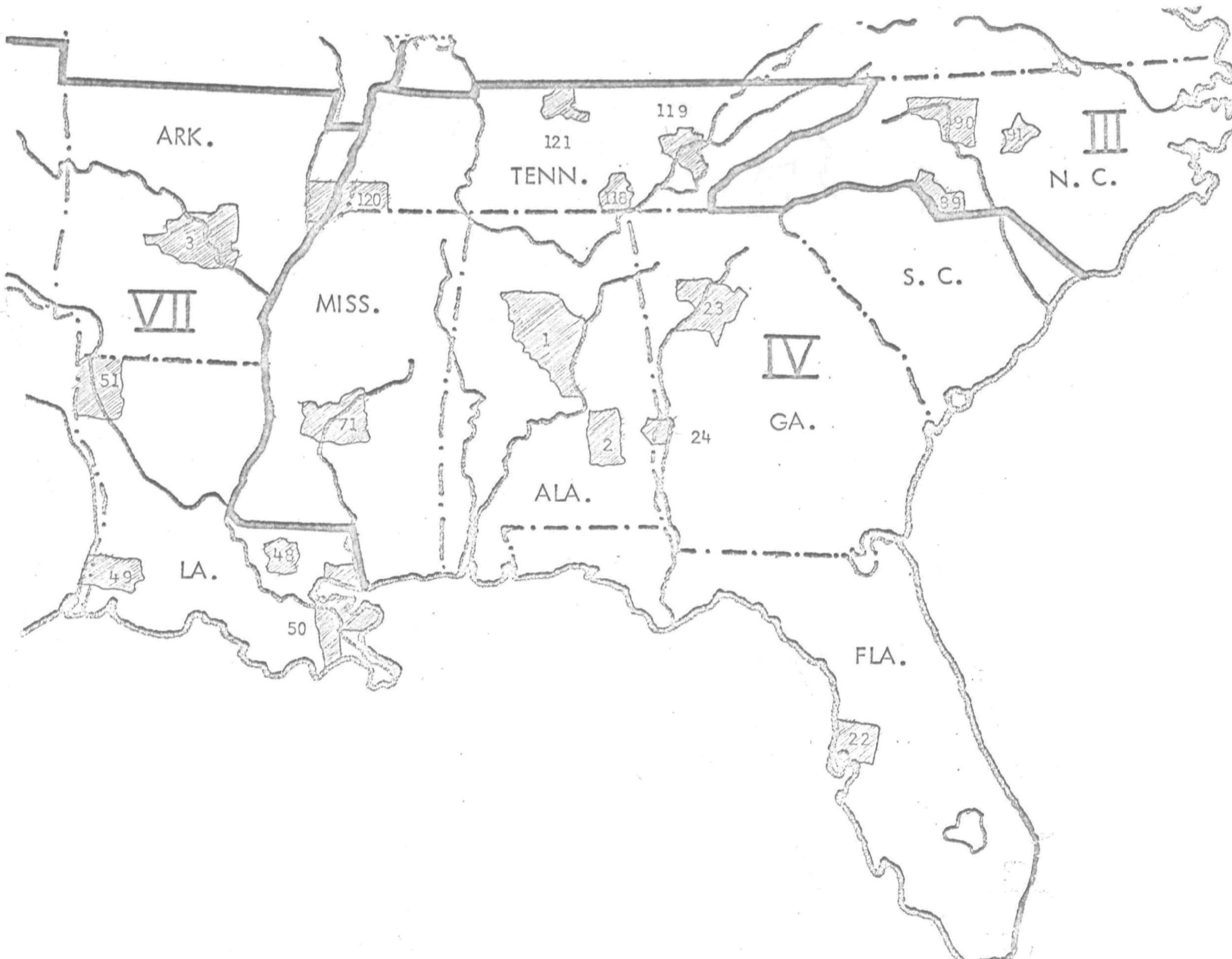


Figure 10. Major automotive production centers--Southeast.
(Map numbers refer to index numbers in Table 3.)

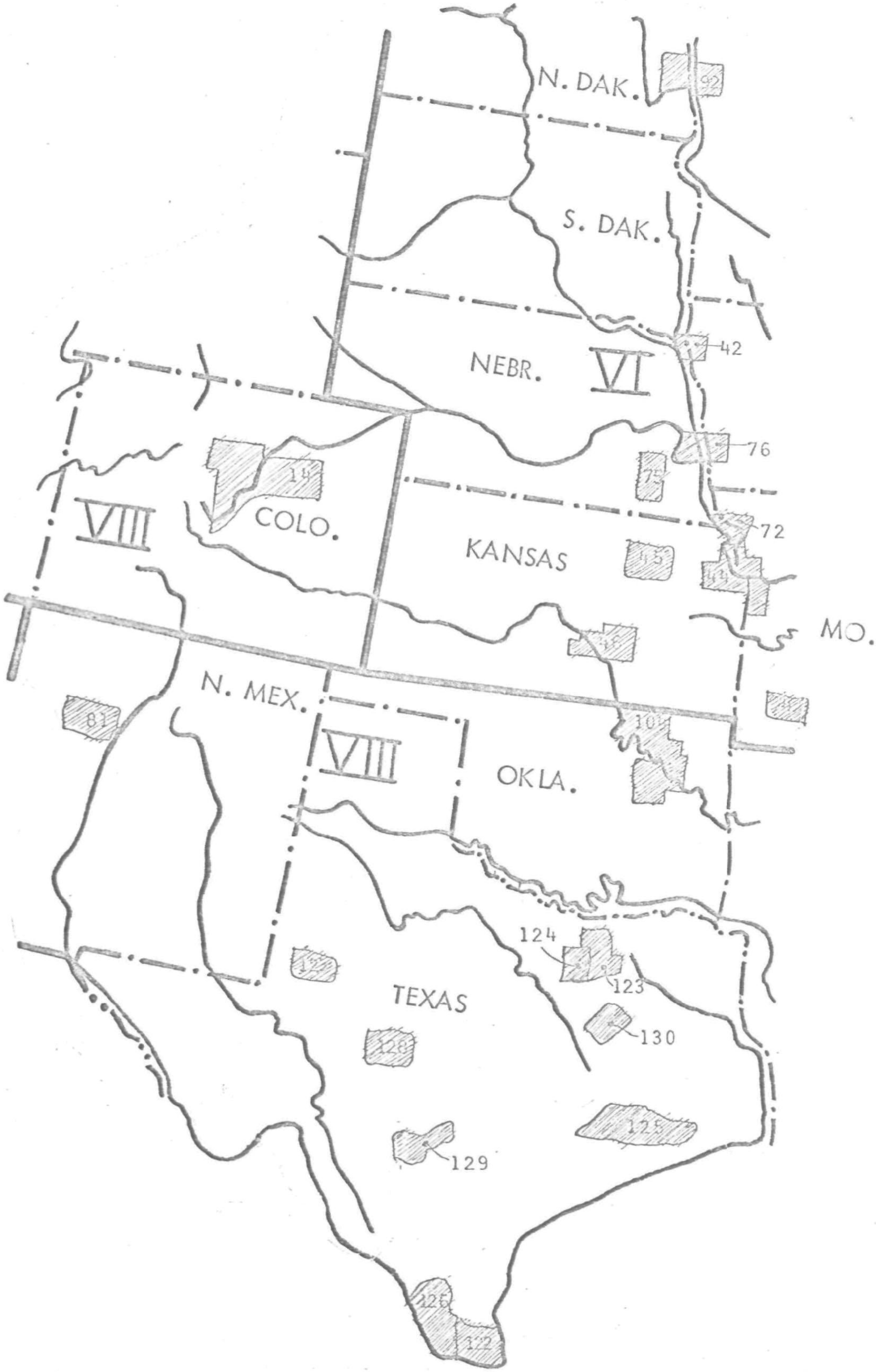


Figure 11. Major automotive production centers--Plains States.
(Map numbers refer to index numbers in Table 3.)

Figure 12. Major automotive production centers--West coast. (Map numbers refer to index numbers in Table 3.)

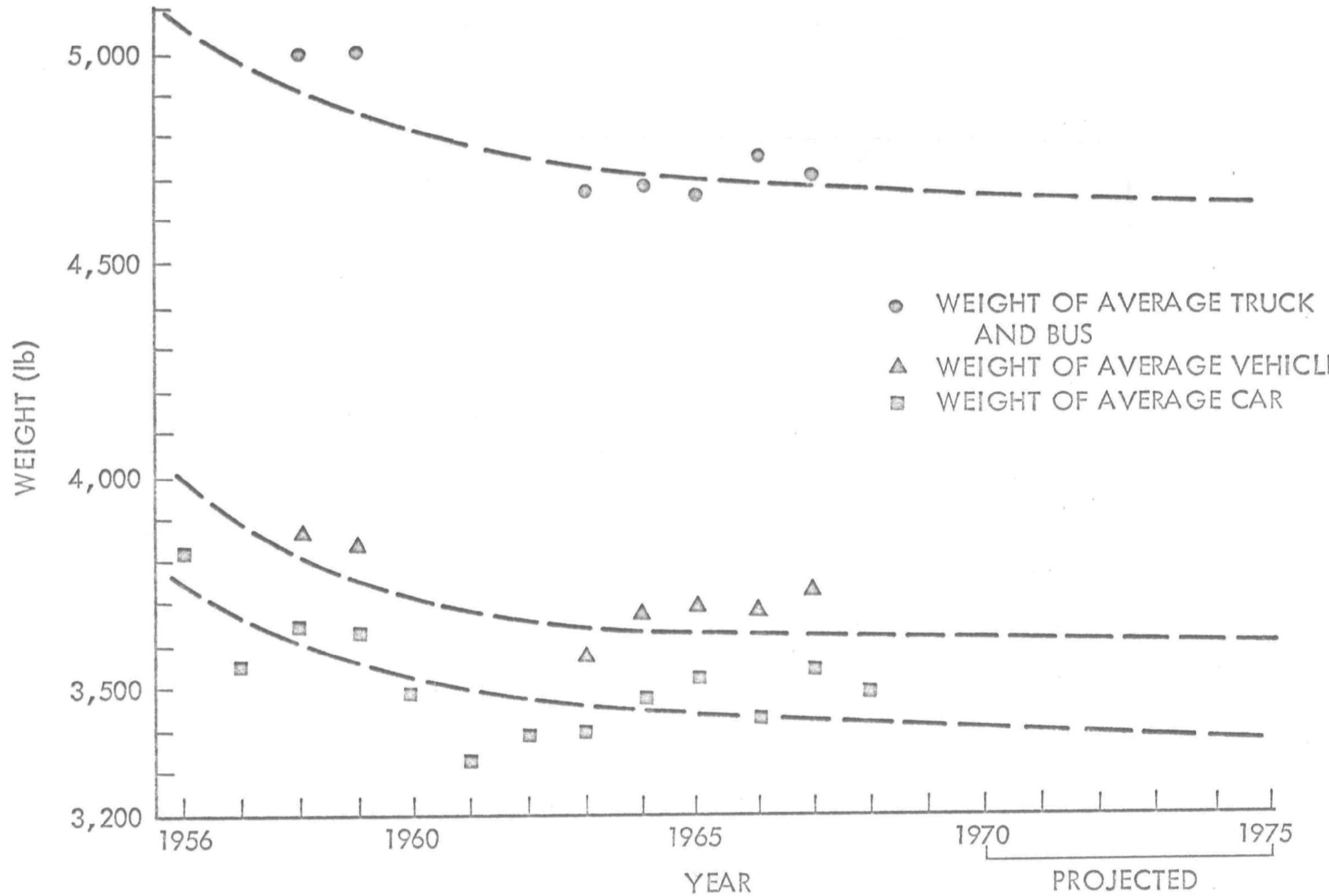


Figure 13. Weight of an average car and truck/bus.
(From: Automotive News Almanac, 1956-1969; Automobile Facts and Figures, 1956-1968; Motor Truck Facts, 1958-1967.)

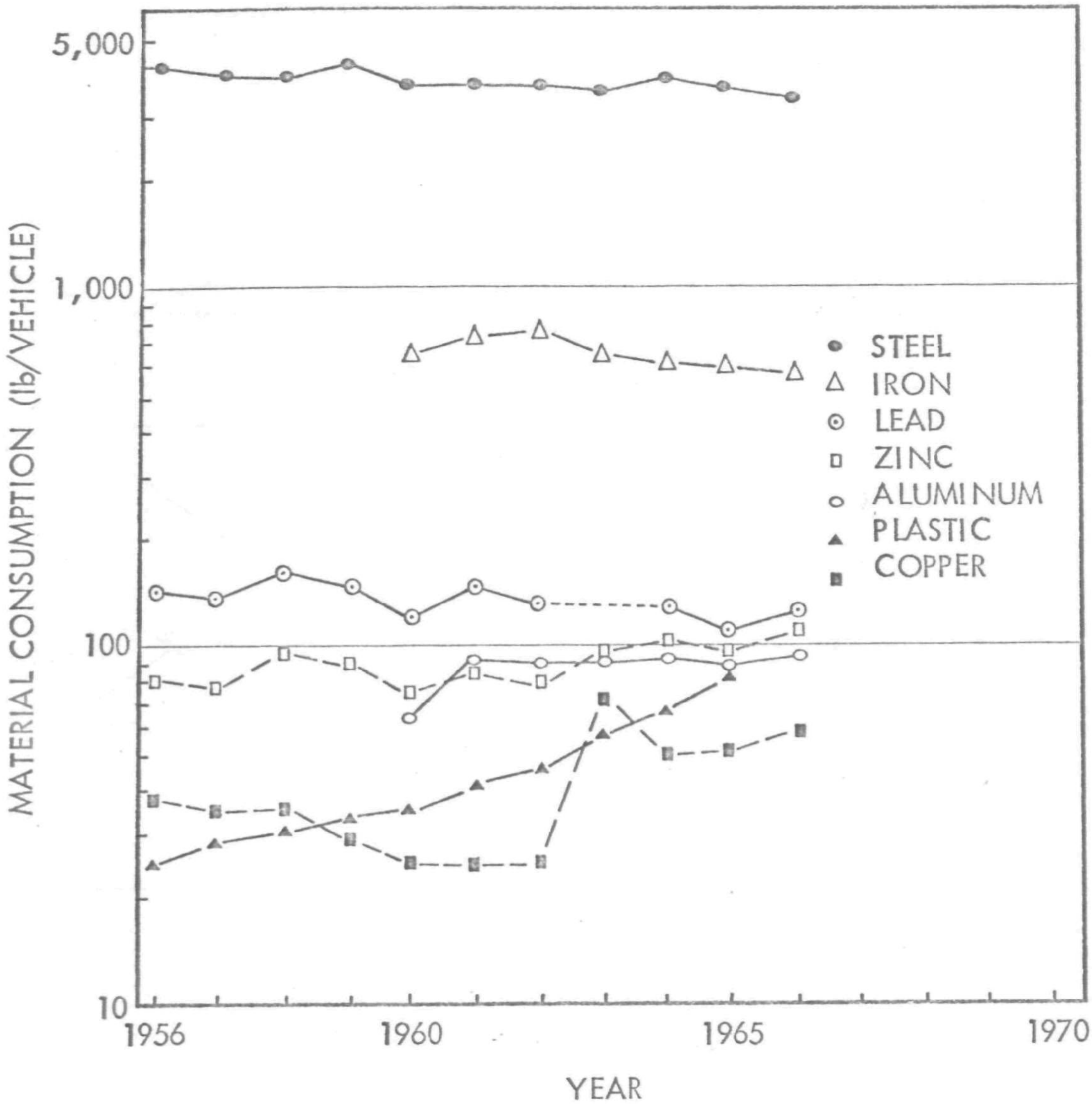


Figure 14. Material consumption. (From: Automobile Facts and Figures, 1956-1968; and Automotive Industries, July 1, 1961.)

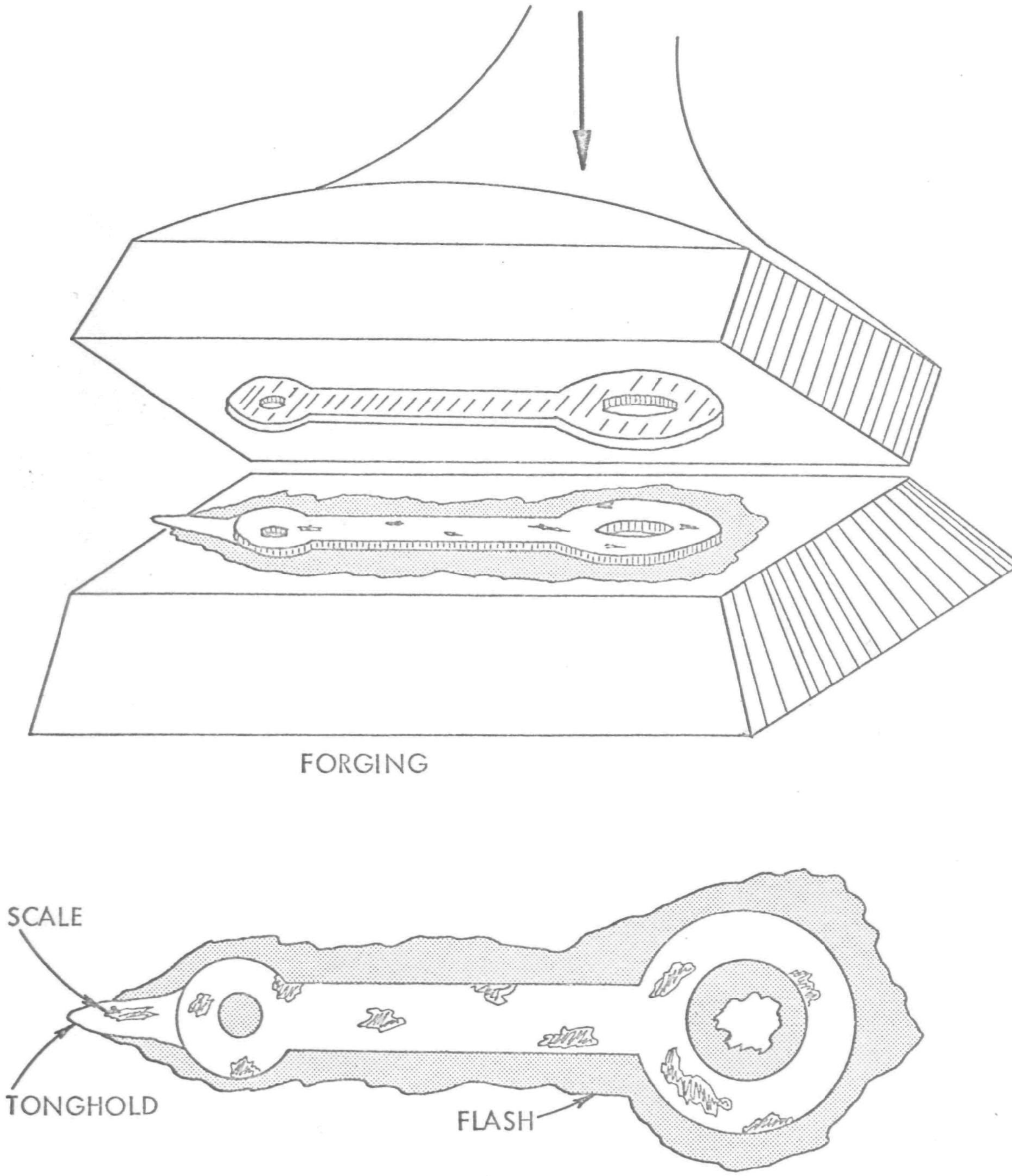


Figure 15. Forging a connecting rod.

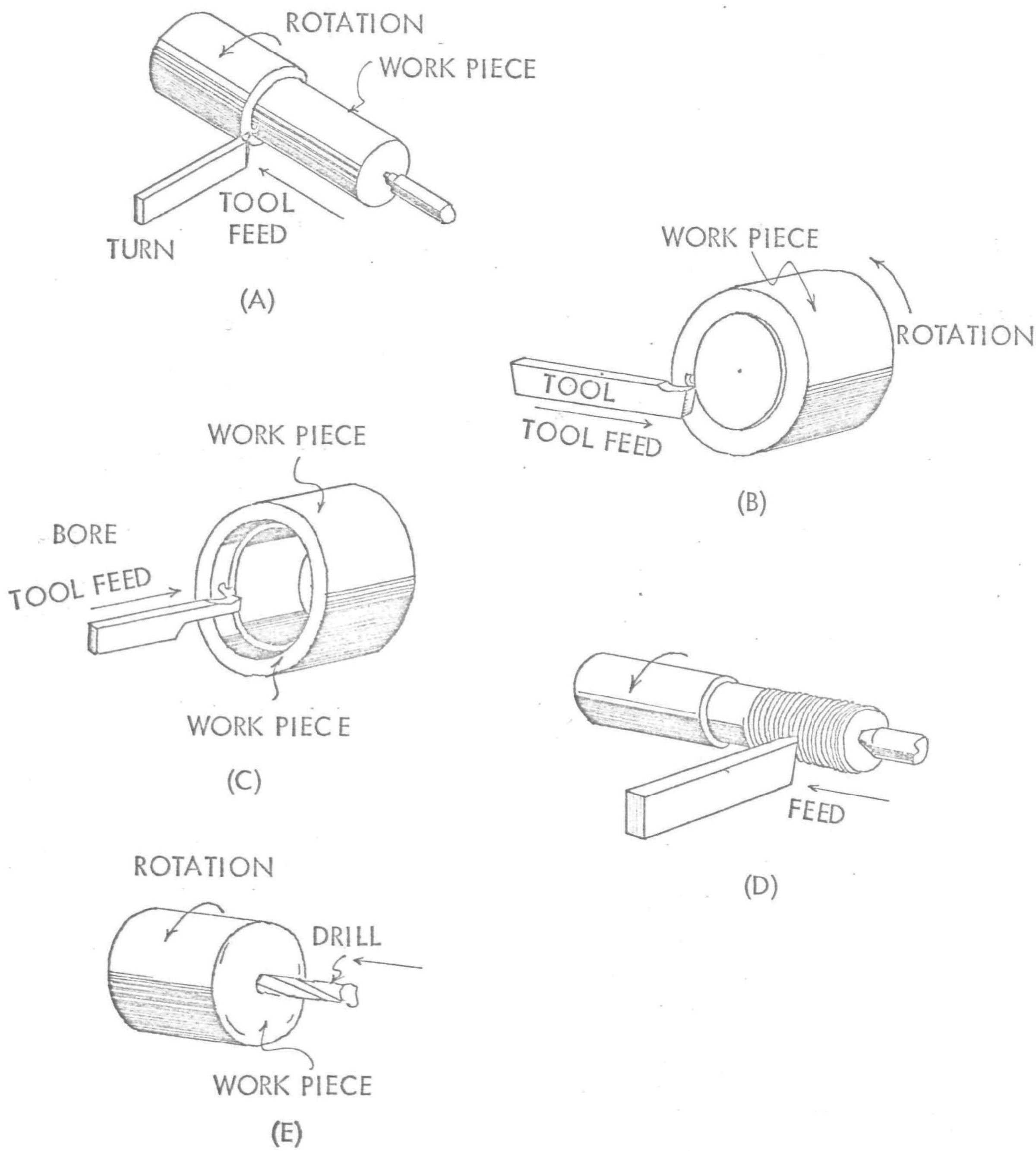


Figure 16. Turning operations. (From: Hall, H. D., and H. E. Linsley. Machine tools, New York, The Industrial Press, 1957. p. 151.) Principal operations performed on a lathe include the following: (A) turning an outside diameter, (B) facing the end or squaring the shoulders between different diameters, (C) boring or enlarging inside diameters, (D) cutting screw threads on the outside of the work, as shown, or inside a bored hole, (E) drilling a hole in the end of the work.

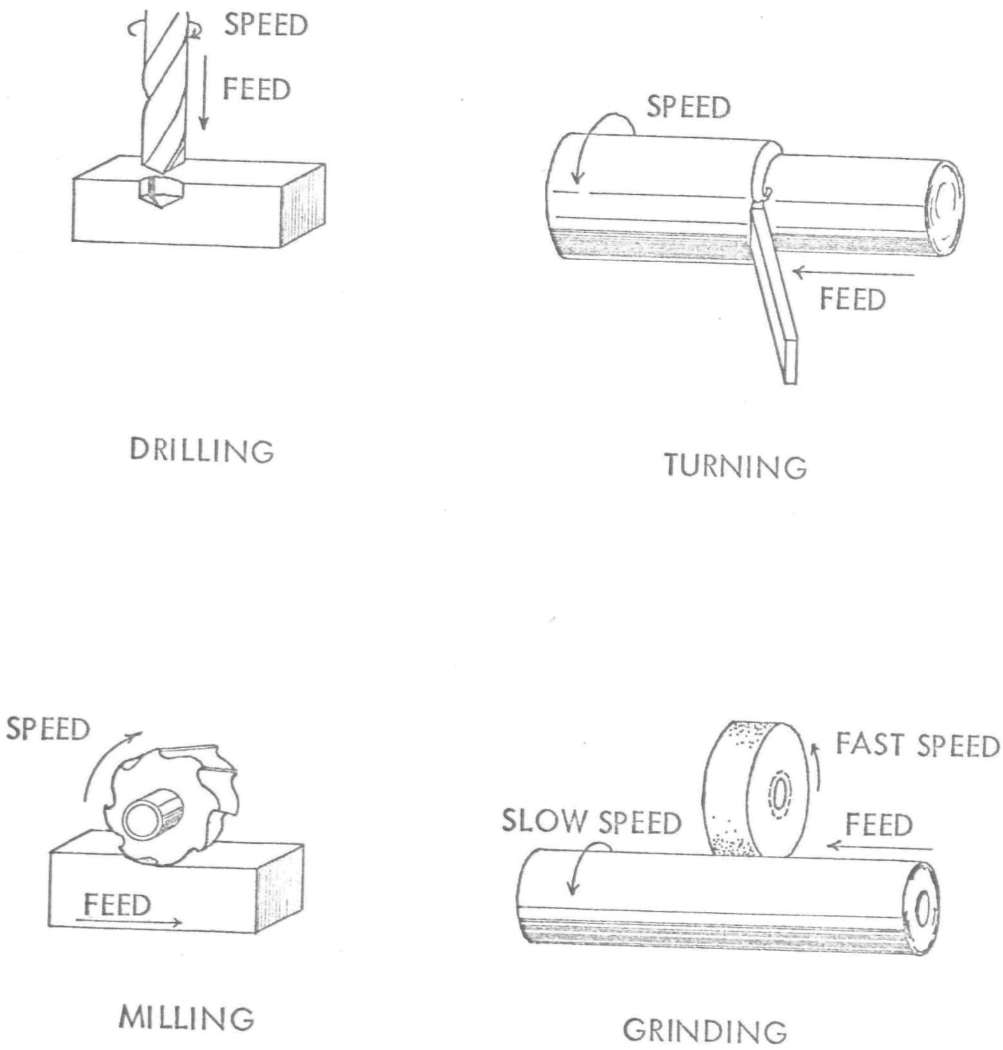


Figure 17. Basic machine tool operations. (From: Hall, H. D., and H. E. Linsley. Machine tools, New York, The Industrial Press, 1957. p. 151.)

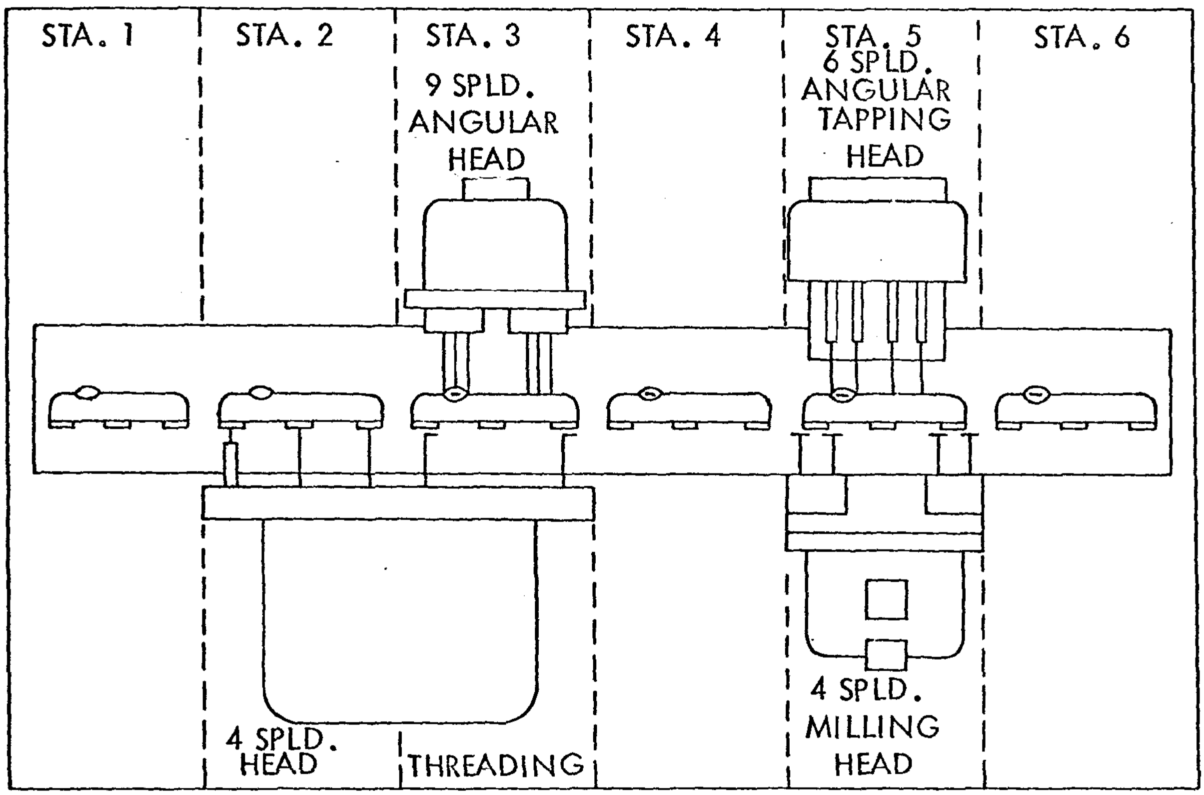


Figure 18. Six-station transfer machine for exhaust manifold machining. (From: Automotive Industries, January 15, 1950, p. 99.) Station 1-Load. Station 2-Drill (4) 13/32 in. dia. in center bosses, comb., drill and ream (4) 0.500 in. dia. in end flanges. Station 3-Bore (2) 1-15/16 in. dia., drill for (6) 3/8 in.-16 tap, drill 11/64 in. and 0.180 in. dia. (1) in top angular ports (l.h. head). Station 4-Idle. Station 5-Tap (6) 3/8 in.-16 in. angular flanges (l.h. head), mill (4) slots in end flanges (r.h. head). Station 6-Unload.

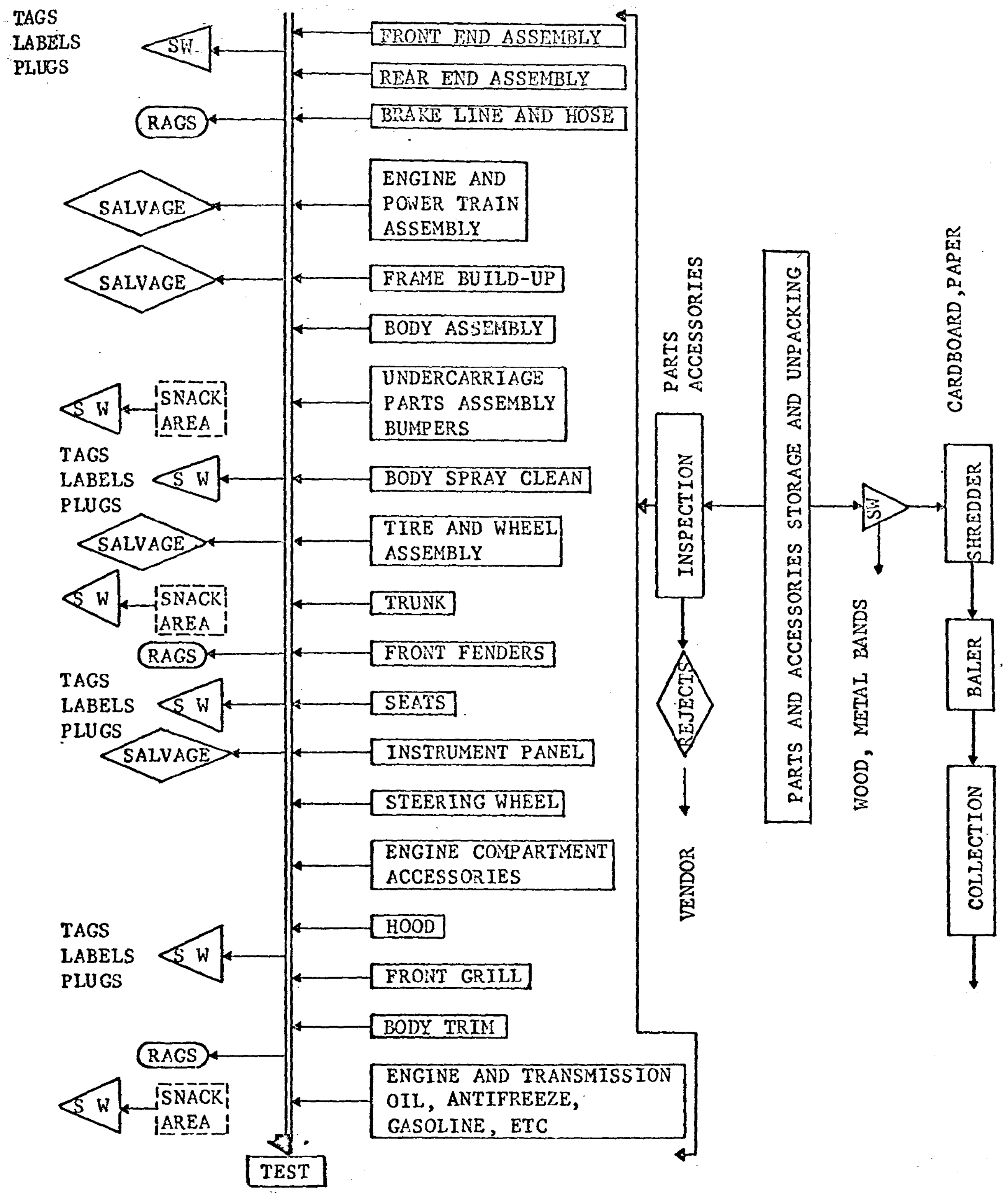


Figure 19, Automobile assembly schematic.

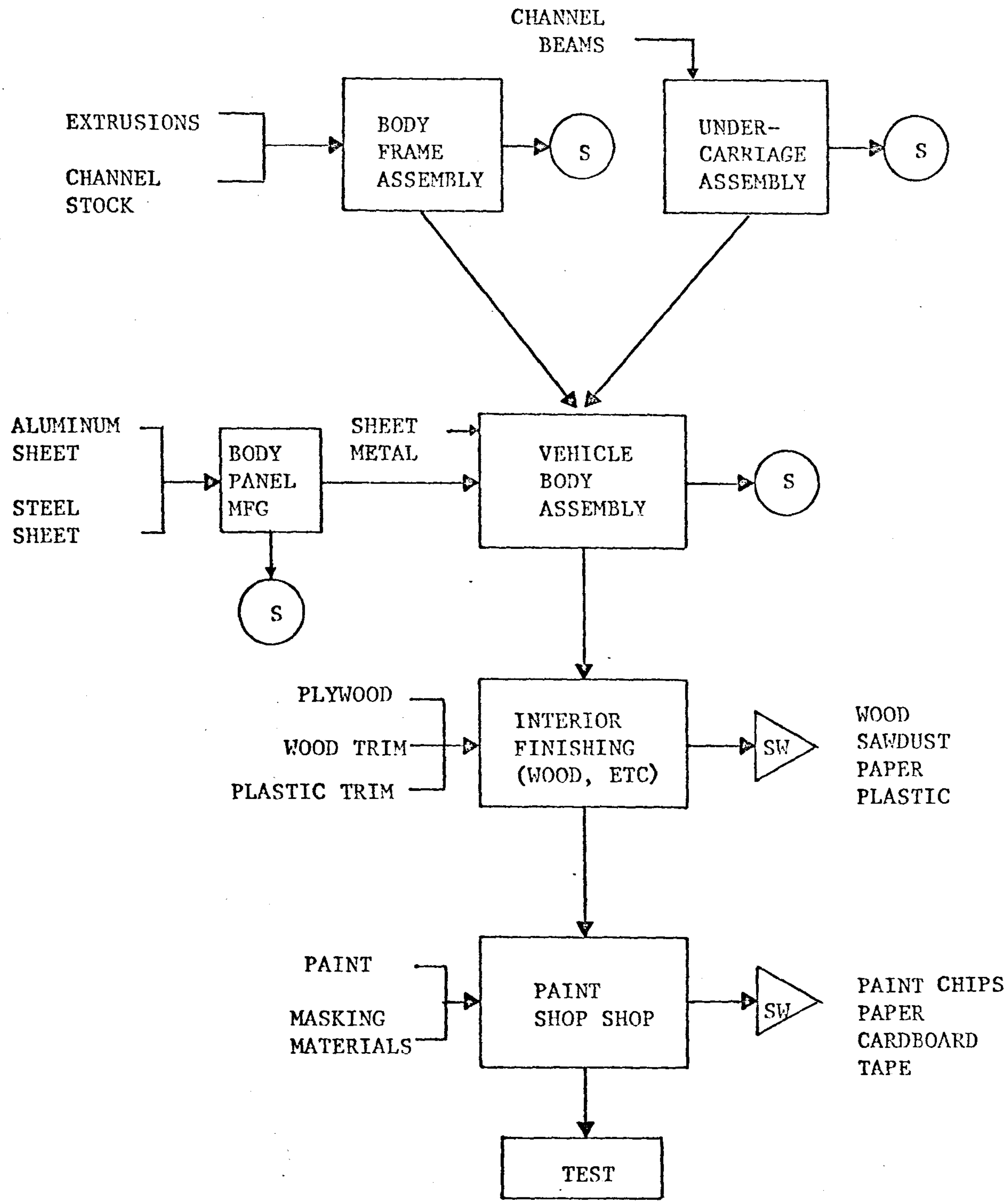


Figure 20. Custom bus assembly plant.

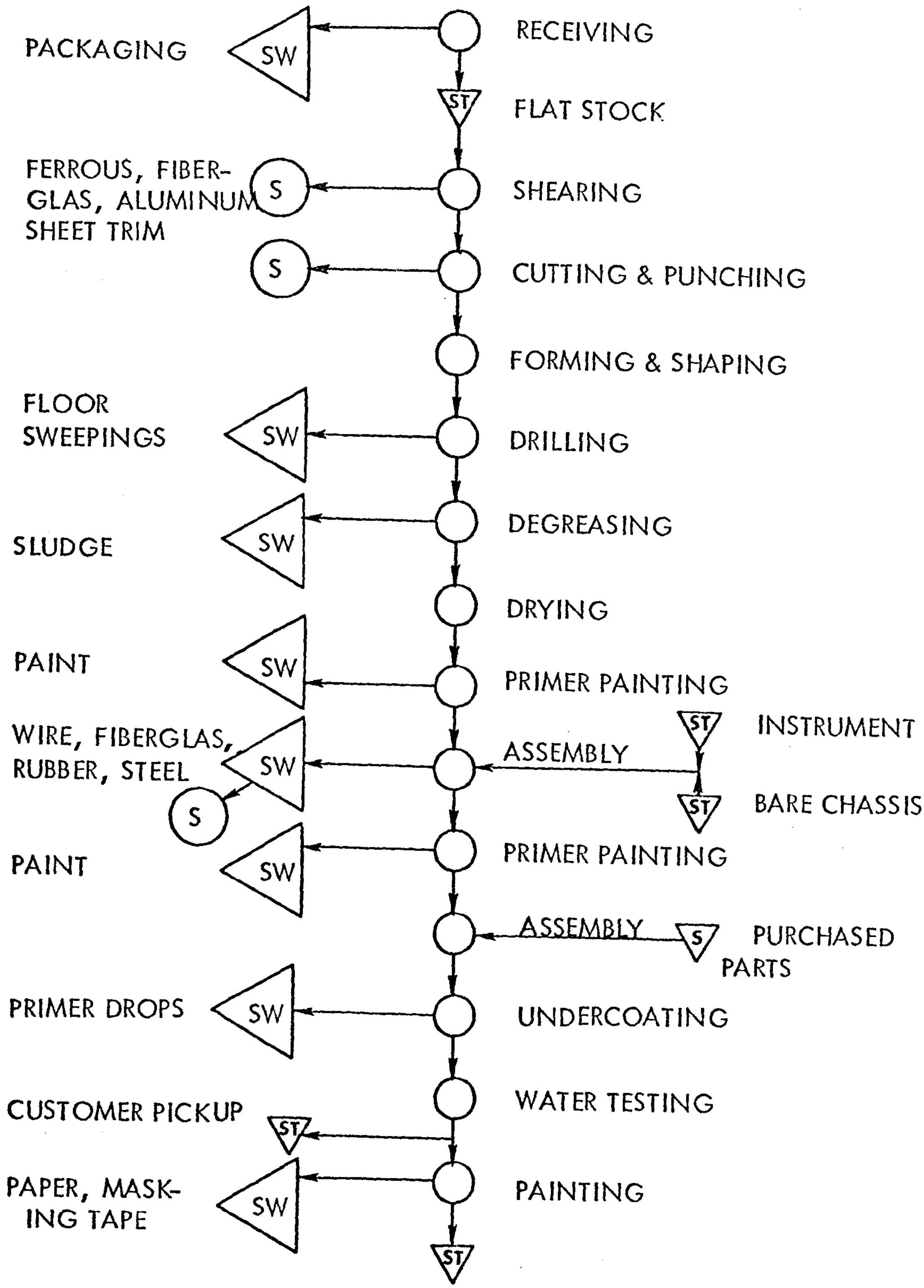


Figure 21. Custom truck body and vehicle manufacturing-- SIC 3711.

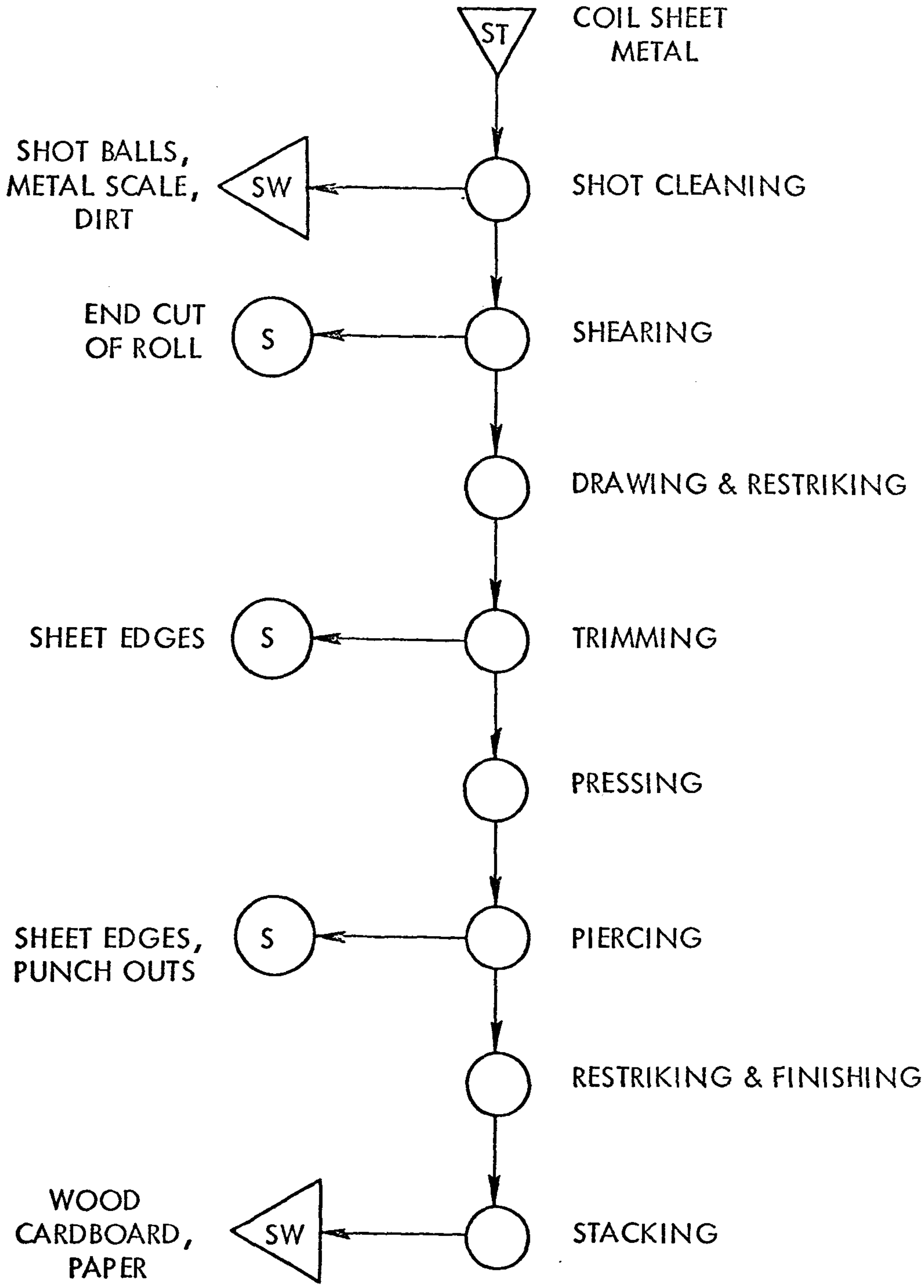


Figure 22. Automobile bodies, mass production--SIC 3712.

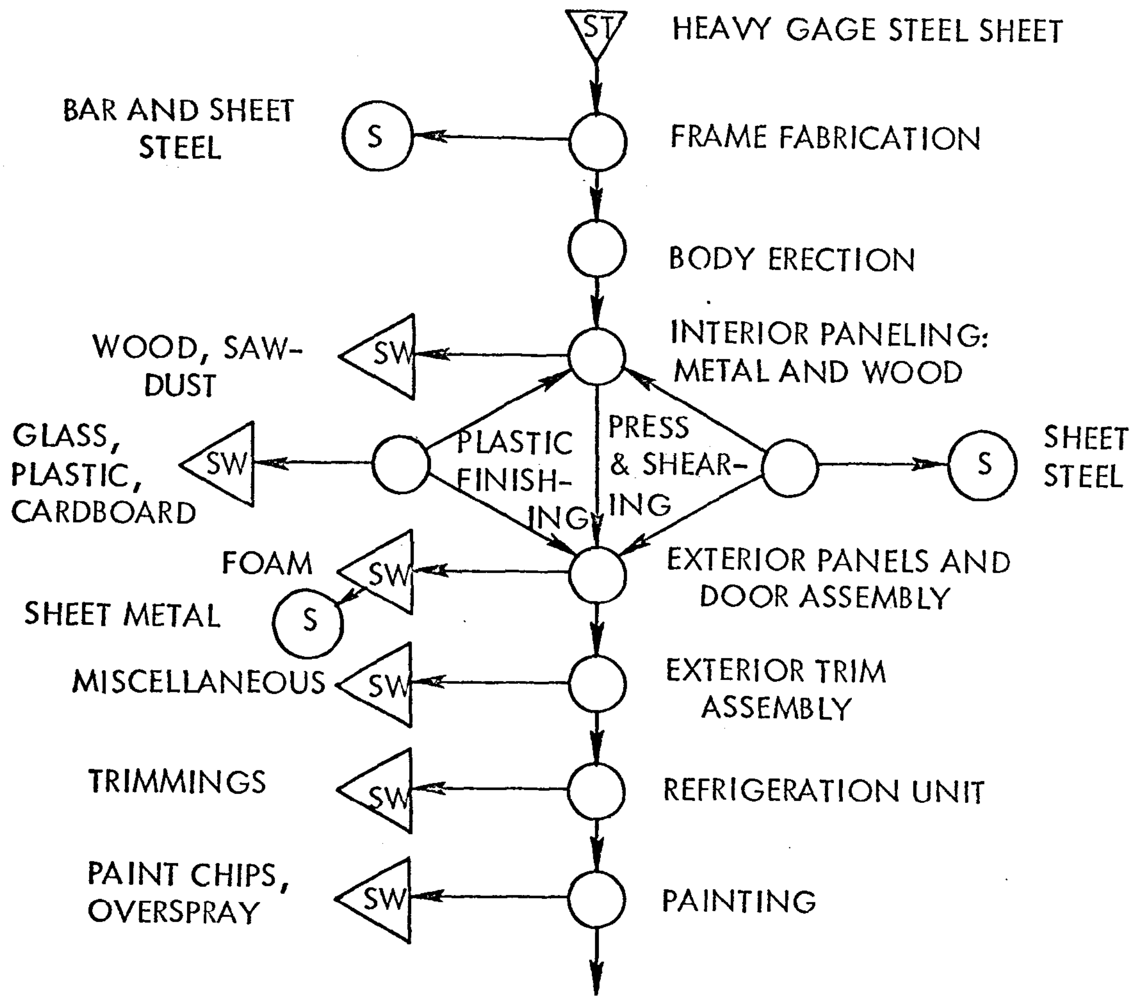


Figure 23. Custom truck body production process schematic SIC 3713.

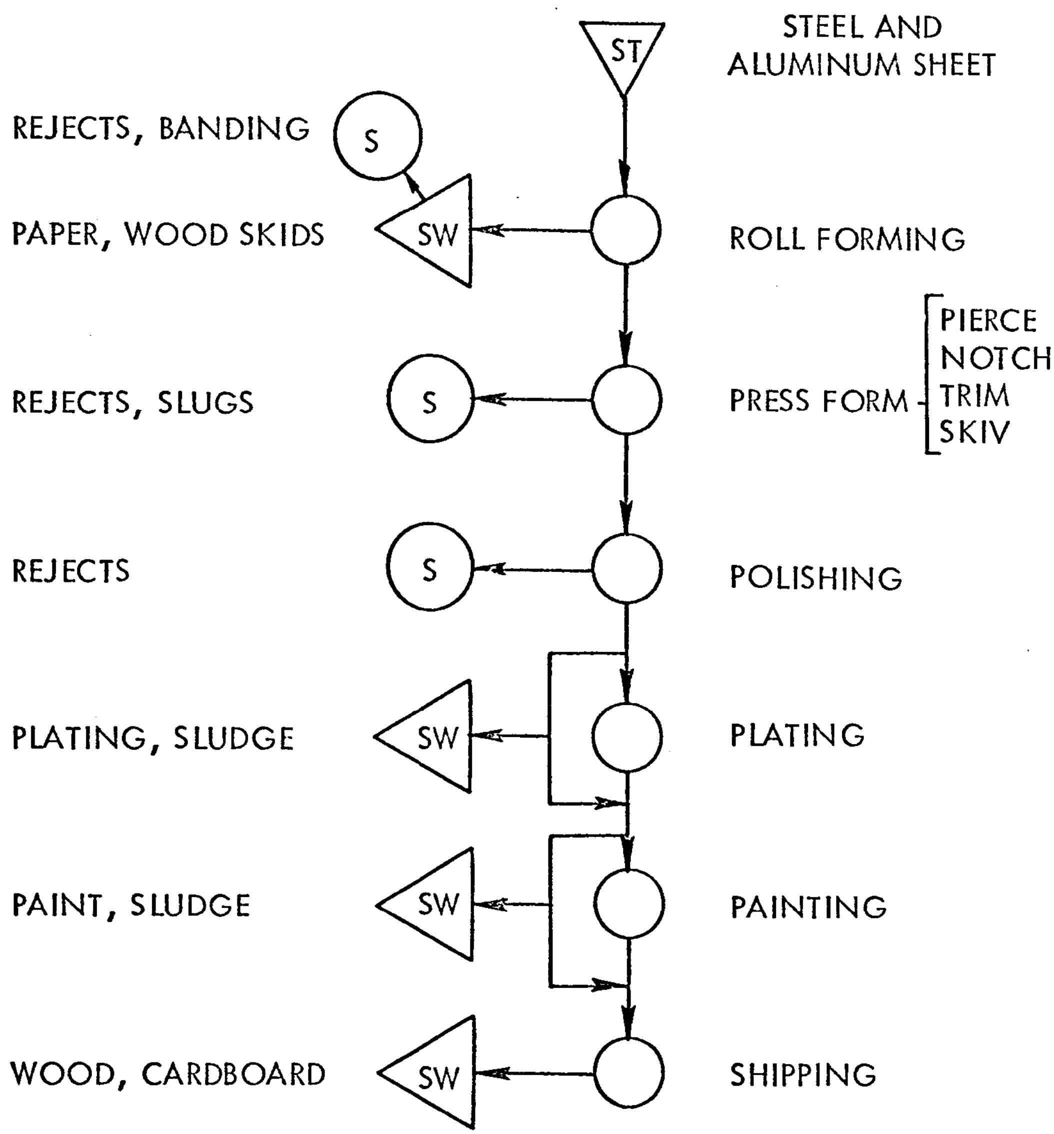


Figure 24. Vehicle trim production schematic.

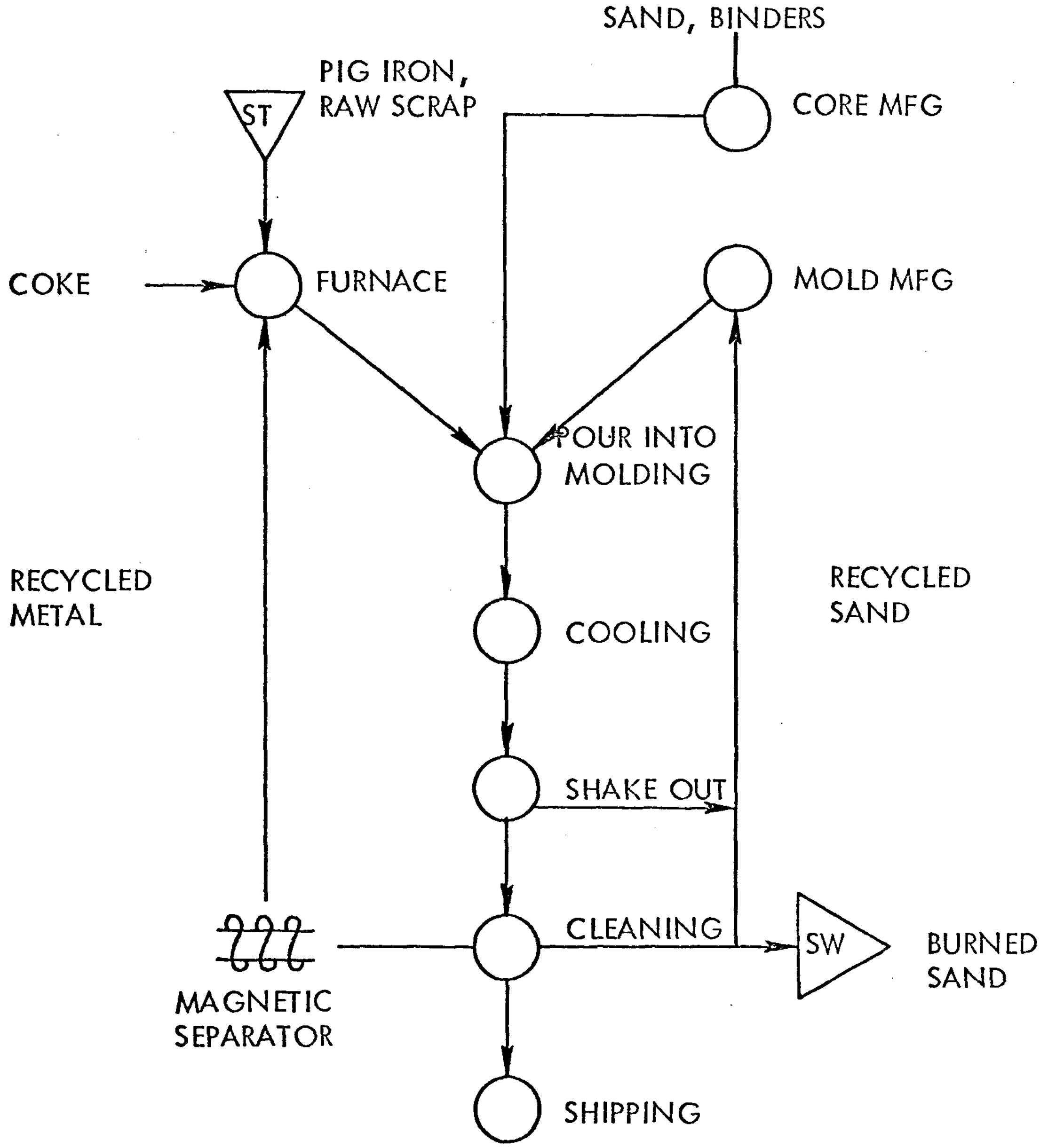


Figure 25. Automotive engine block, head, and camshaft casting schematic.

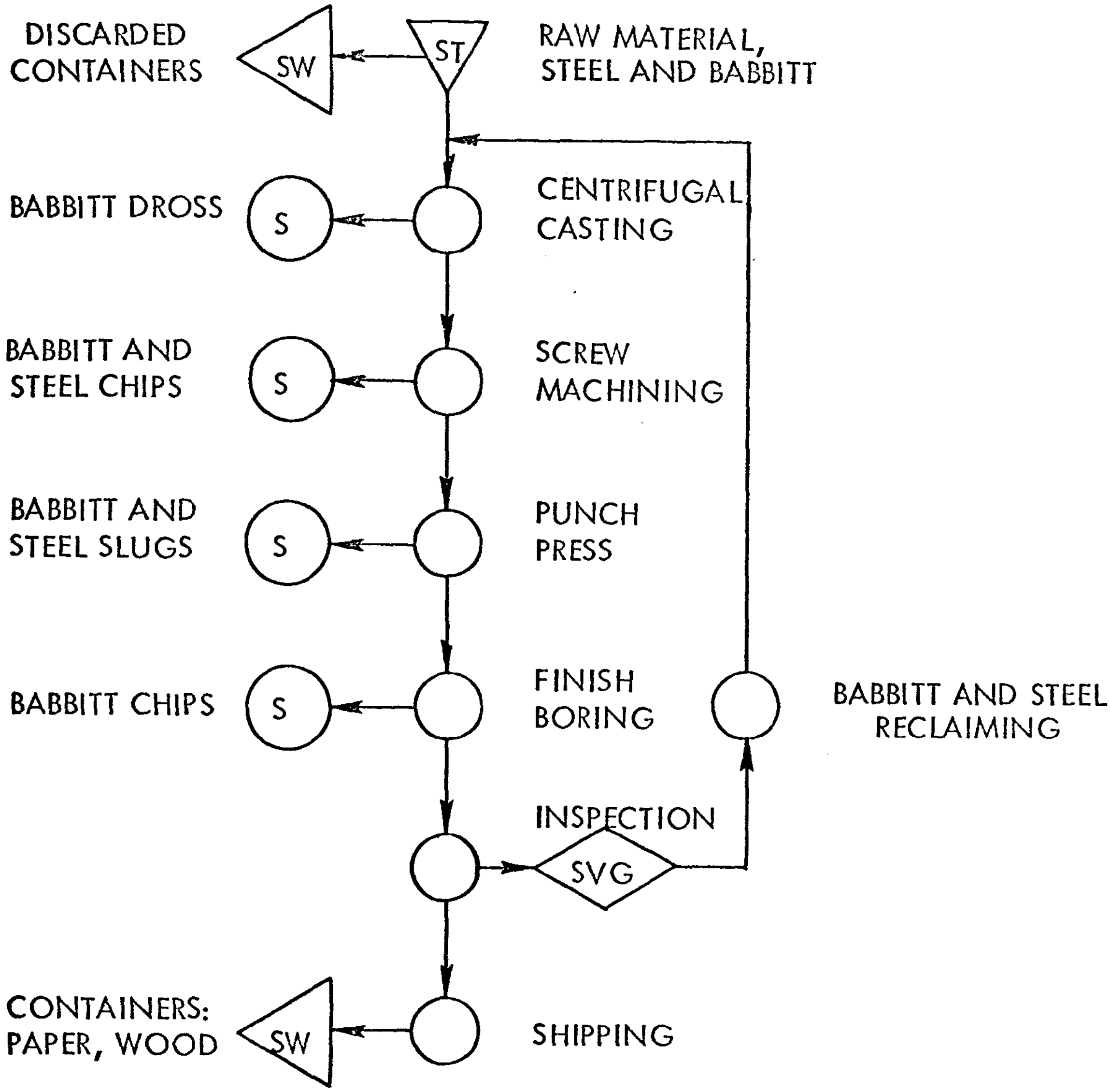


Figure 26. Crankshaft and camshaft bearing process schematic.

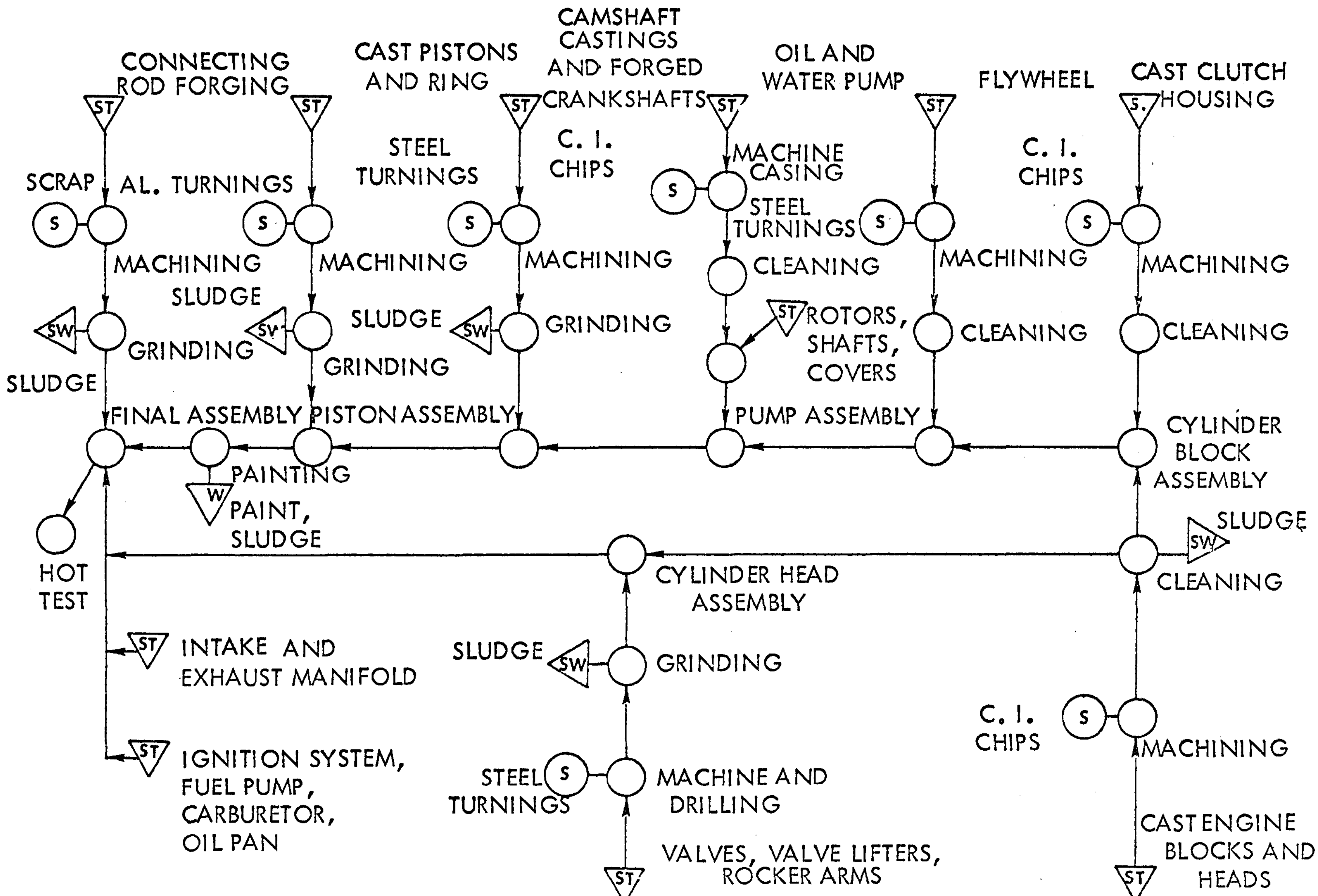


Figure 27. Engine manufacturing and assembly.

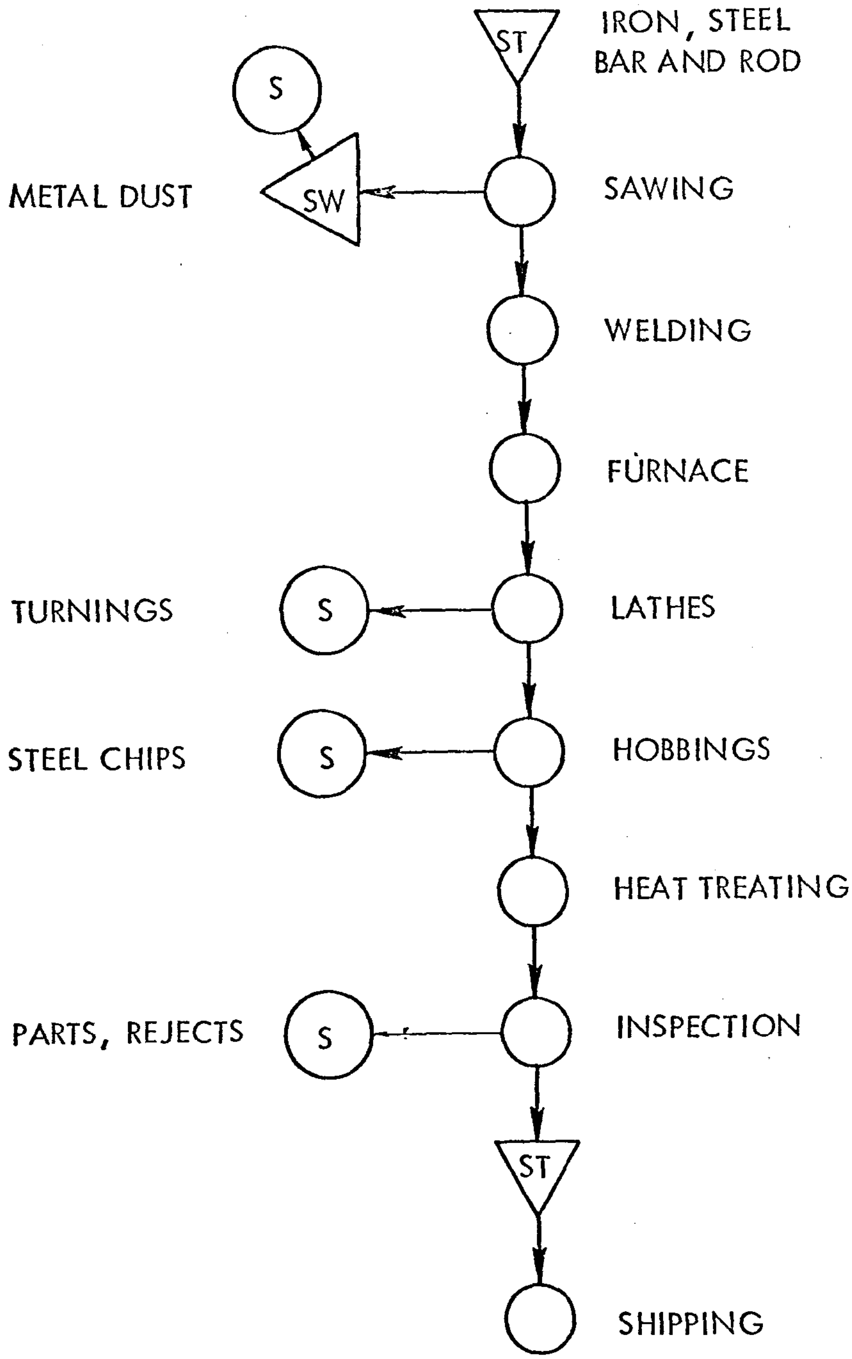


Figure 28. Flywheel and ring gear manufacturing.

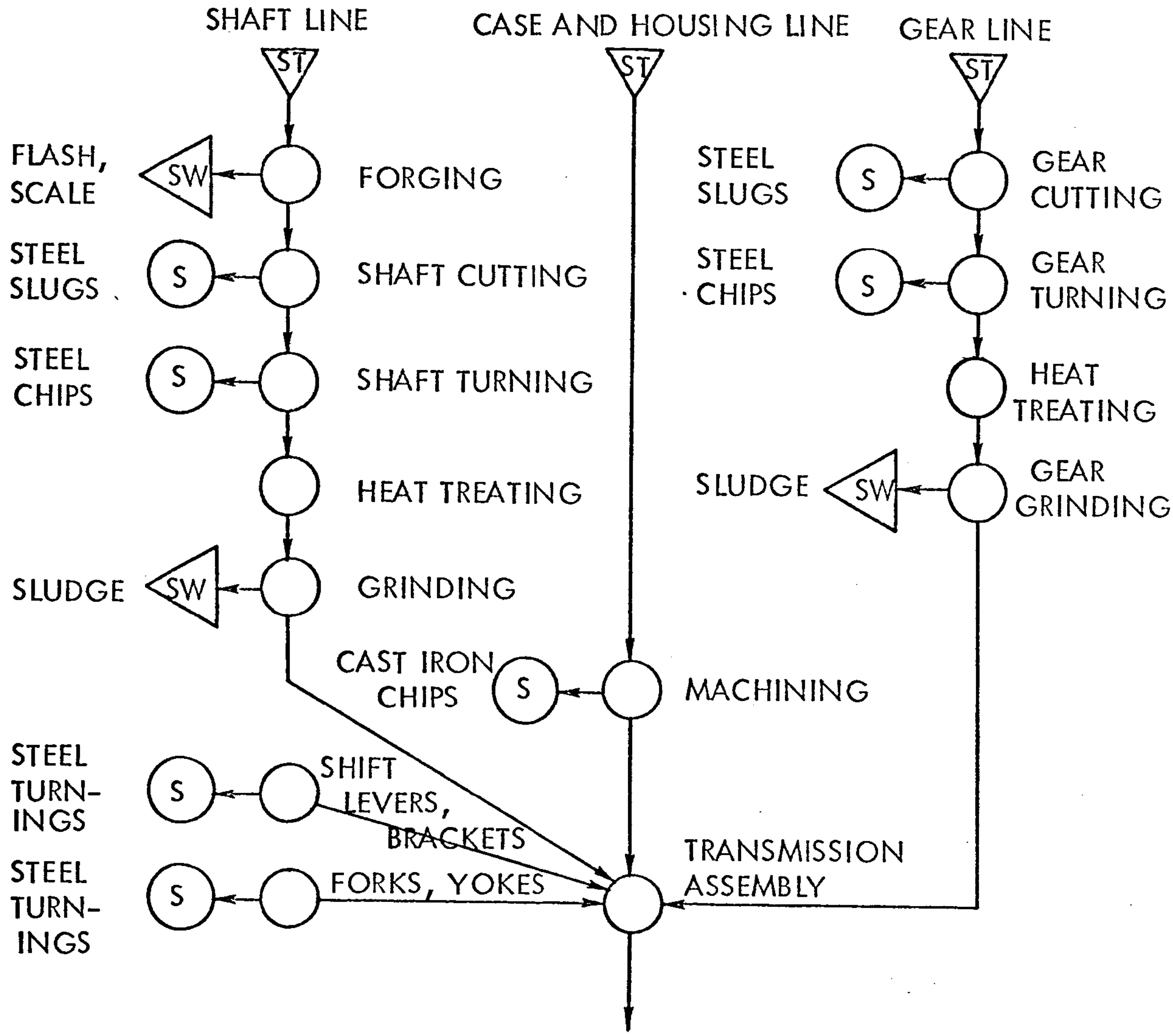


Figure 29. Transmission production and assembly.

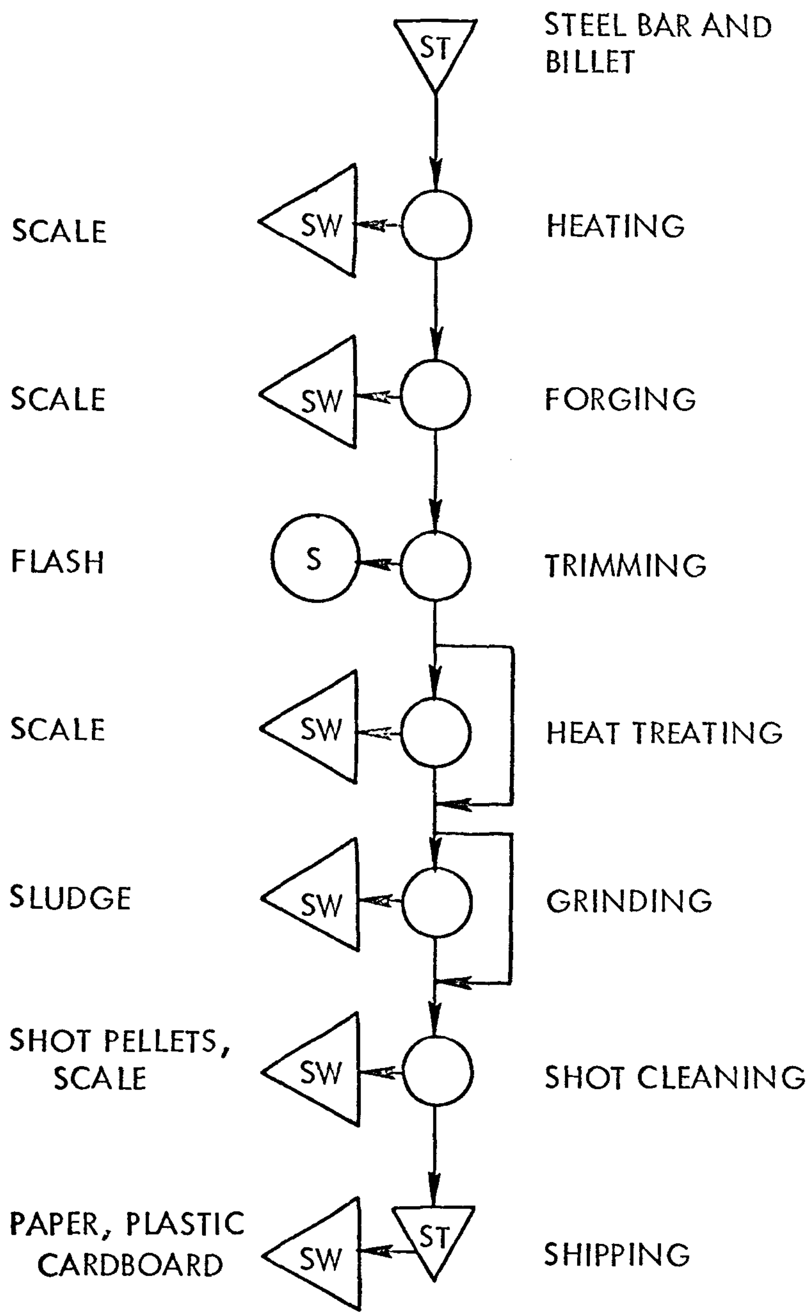


Figure 30. Forging: transmission and differential gears, and axle shafts.

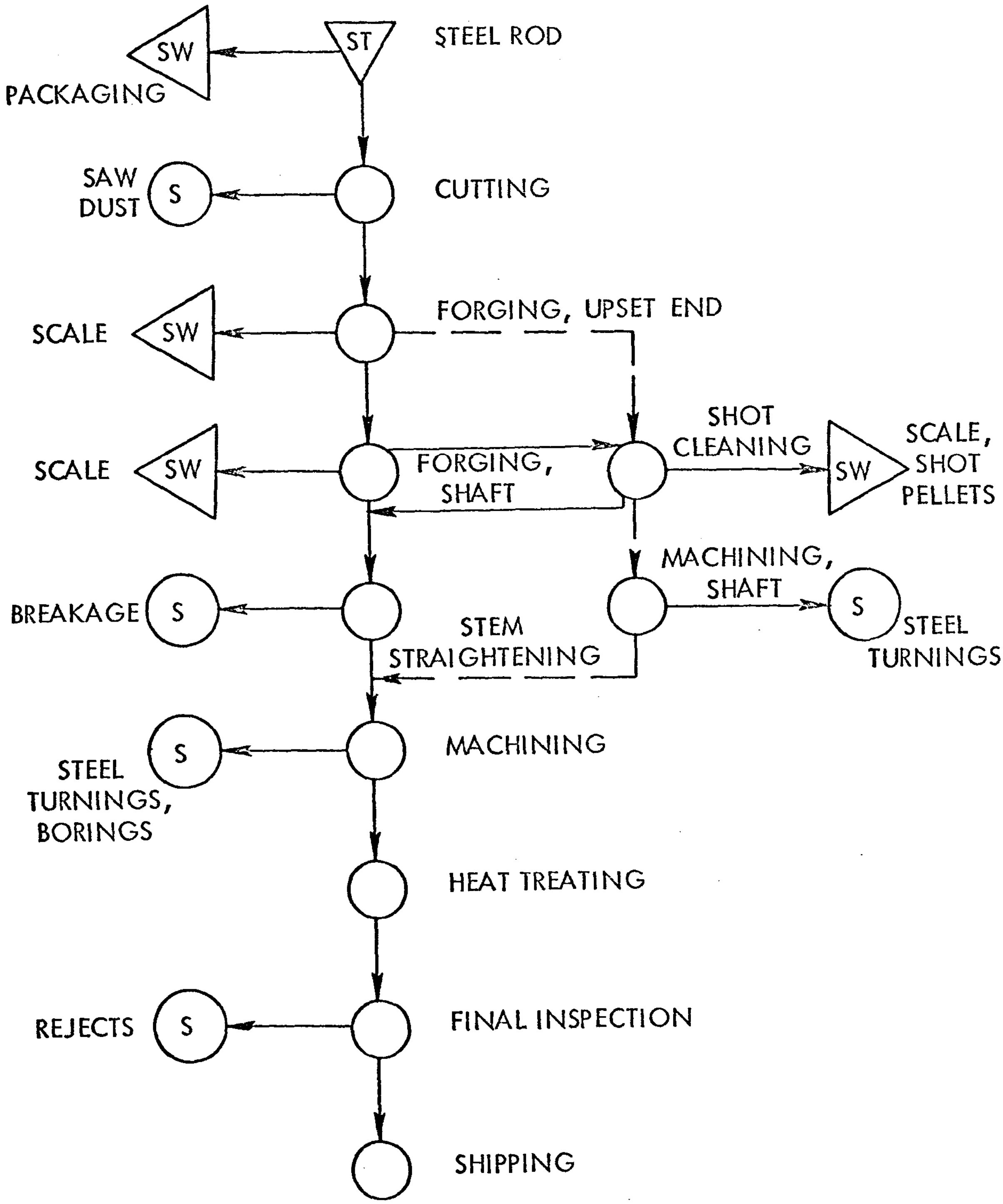


Figure 31. Axle shaft manufacturing.

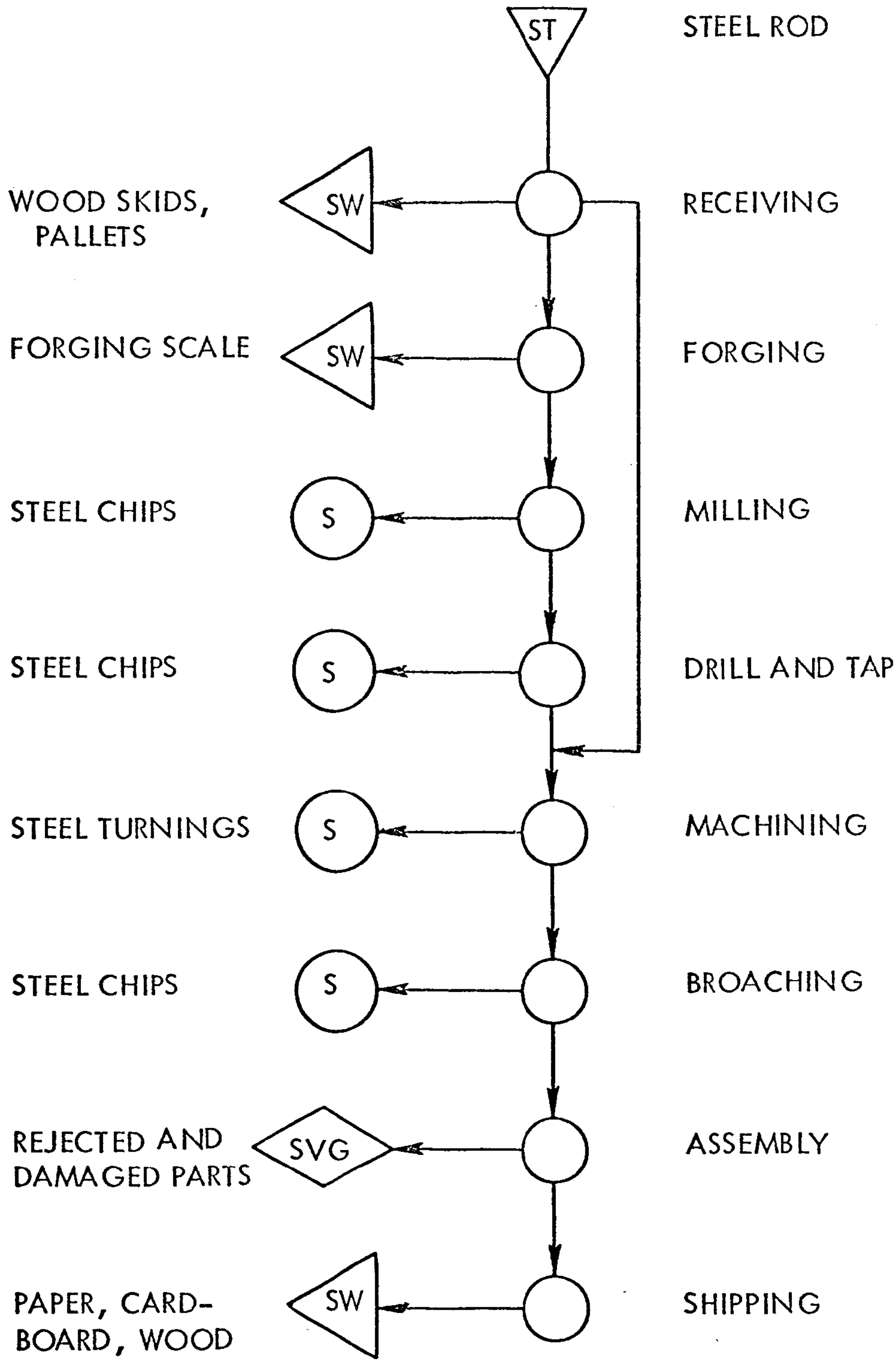


Figure 32. Front end: linkage and universal joints.

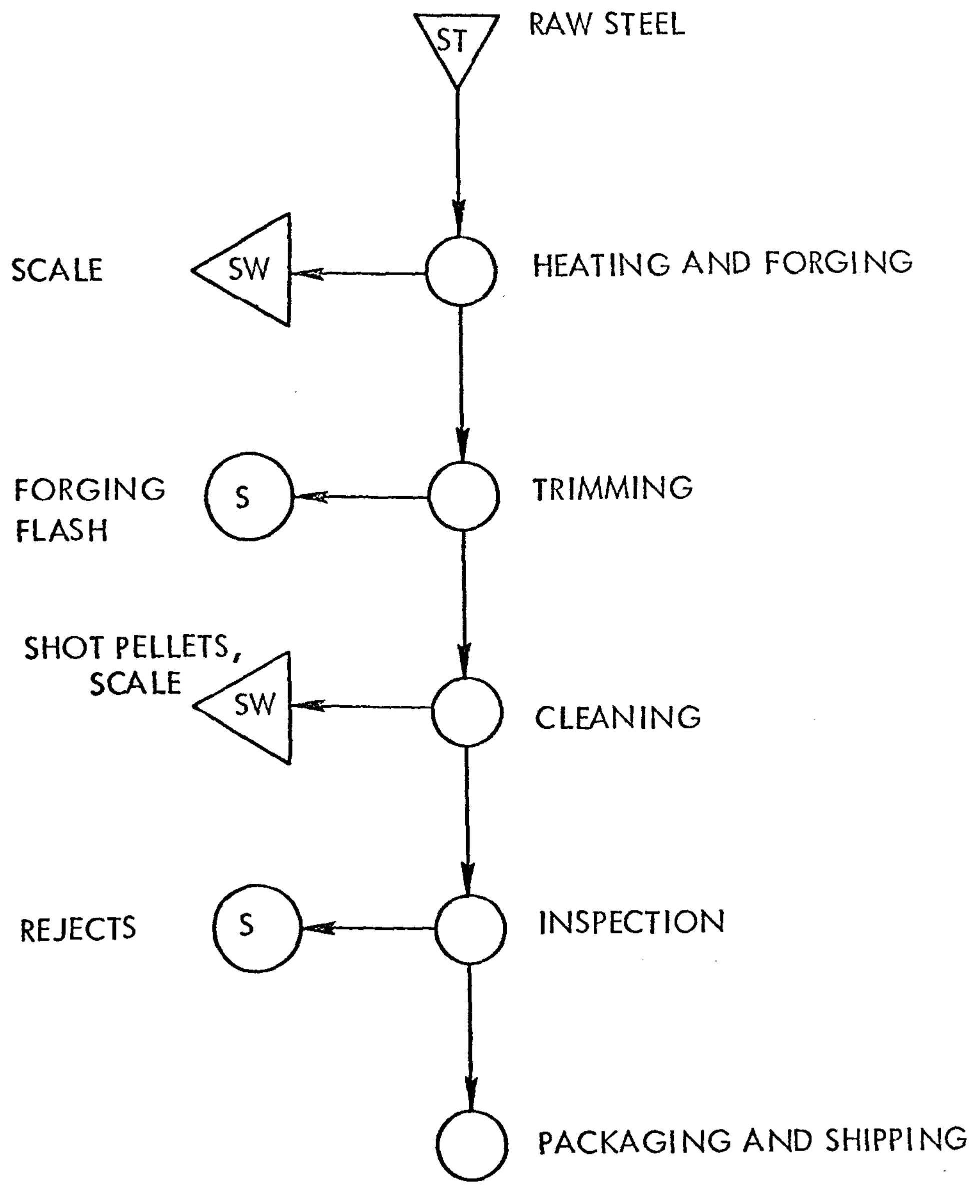


Figure 33. Front end: idler arm, yoke, and tie rod ends.

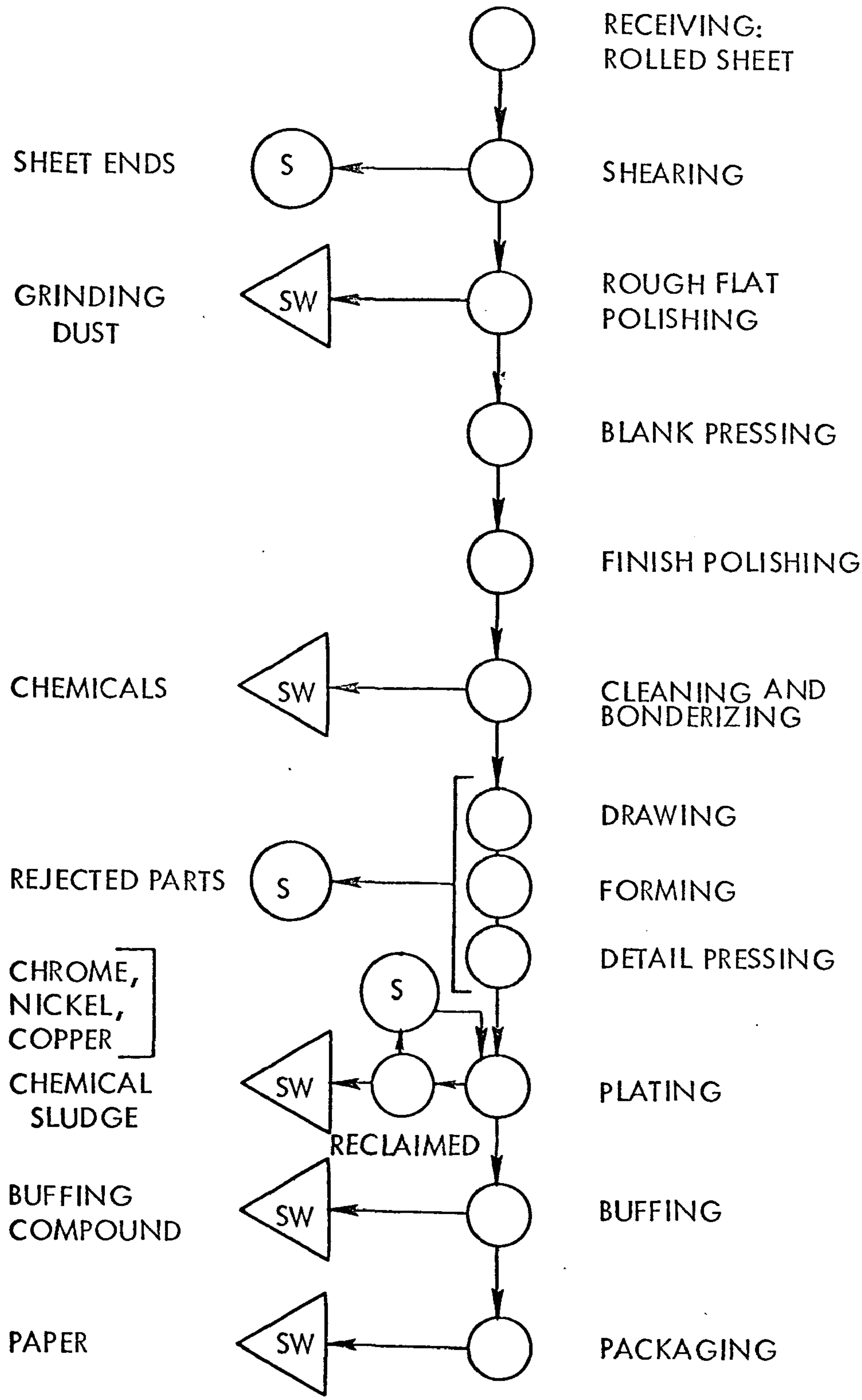


Figure 34. Bumper manufacturing.

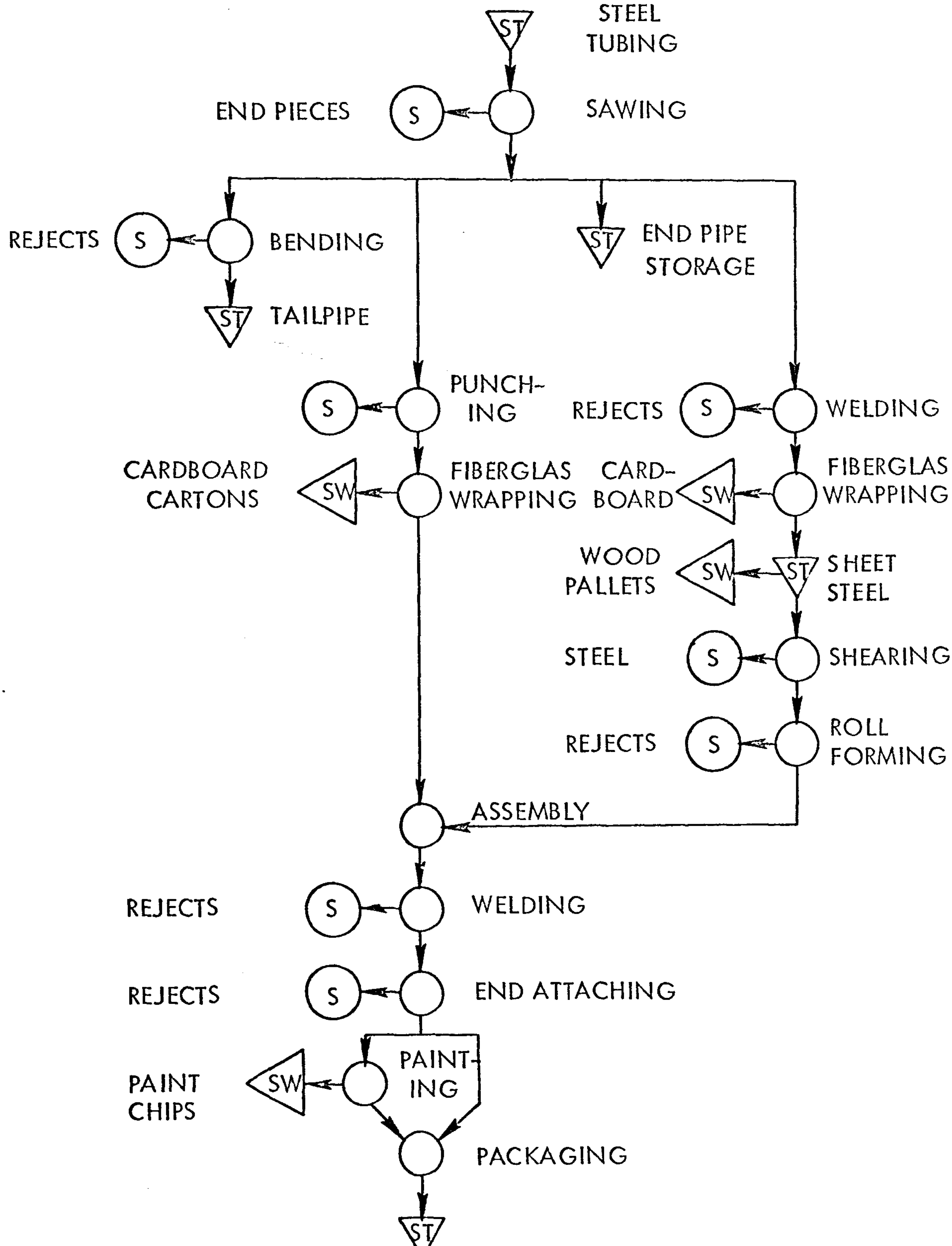


Figure 35. Muffler and tailpipe fabrication.

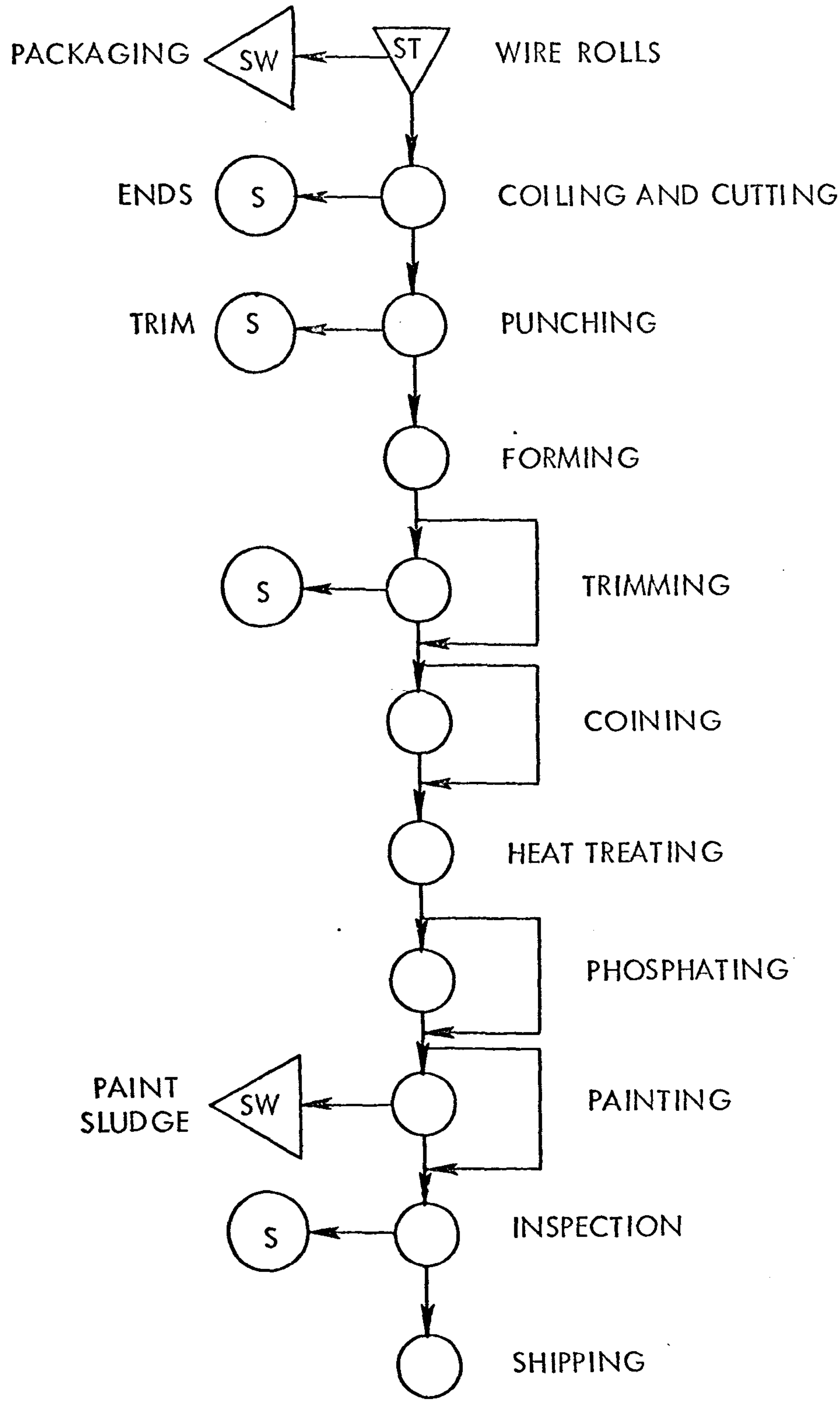


Figure 36. Automotive spring manufacturing.

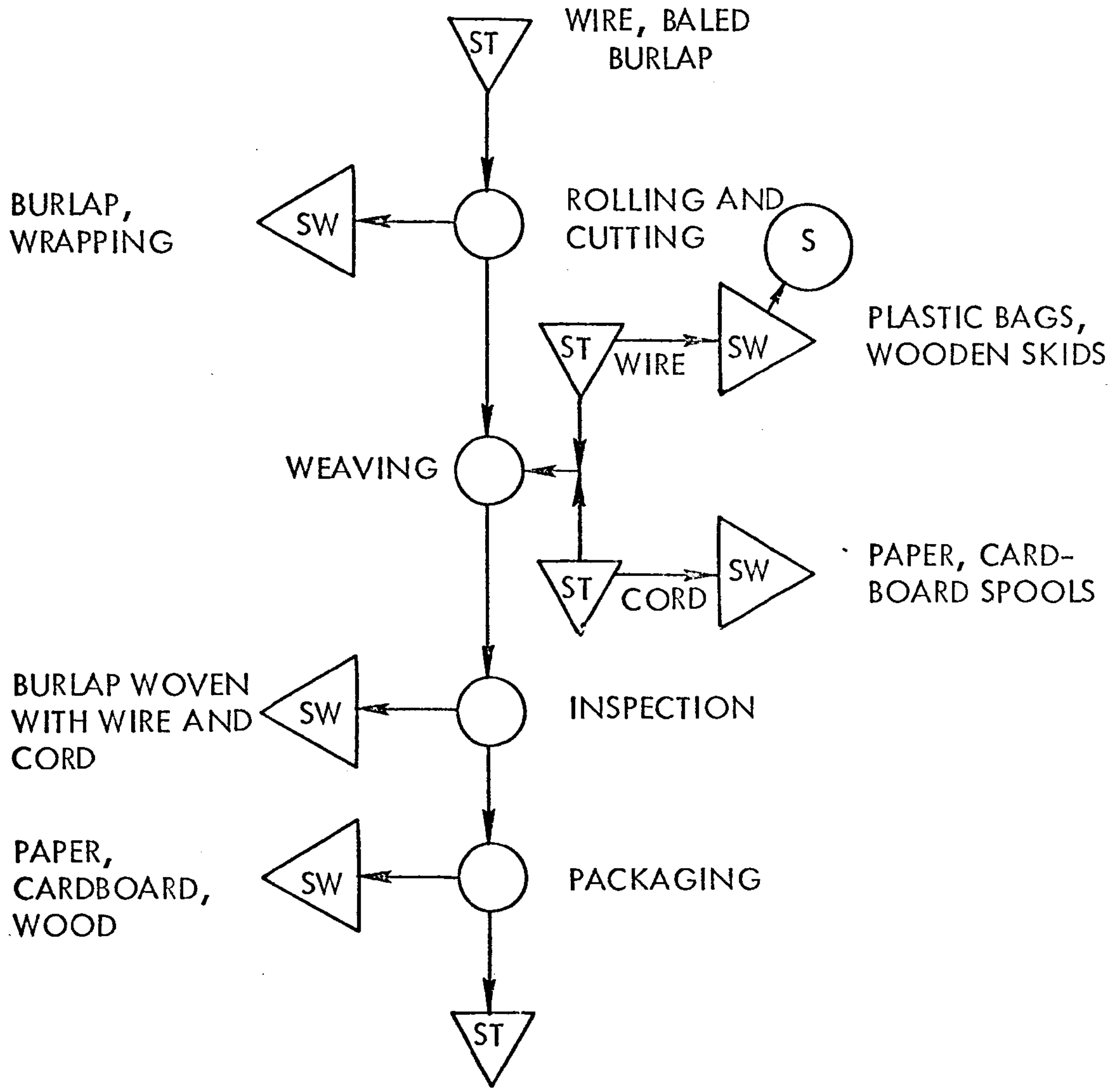


Figure 37. Seat manufacturing.

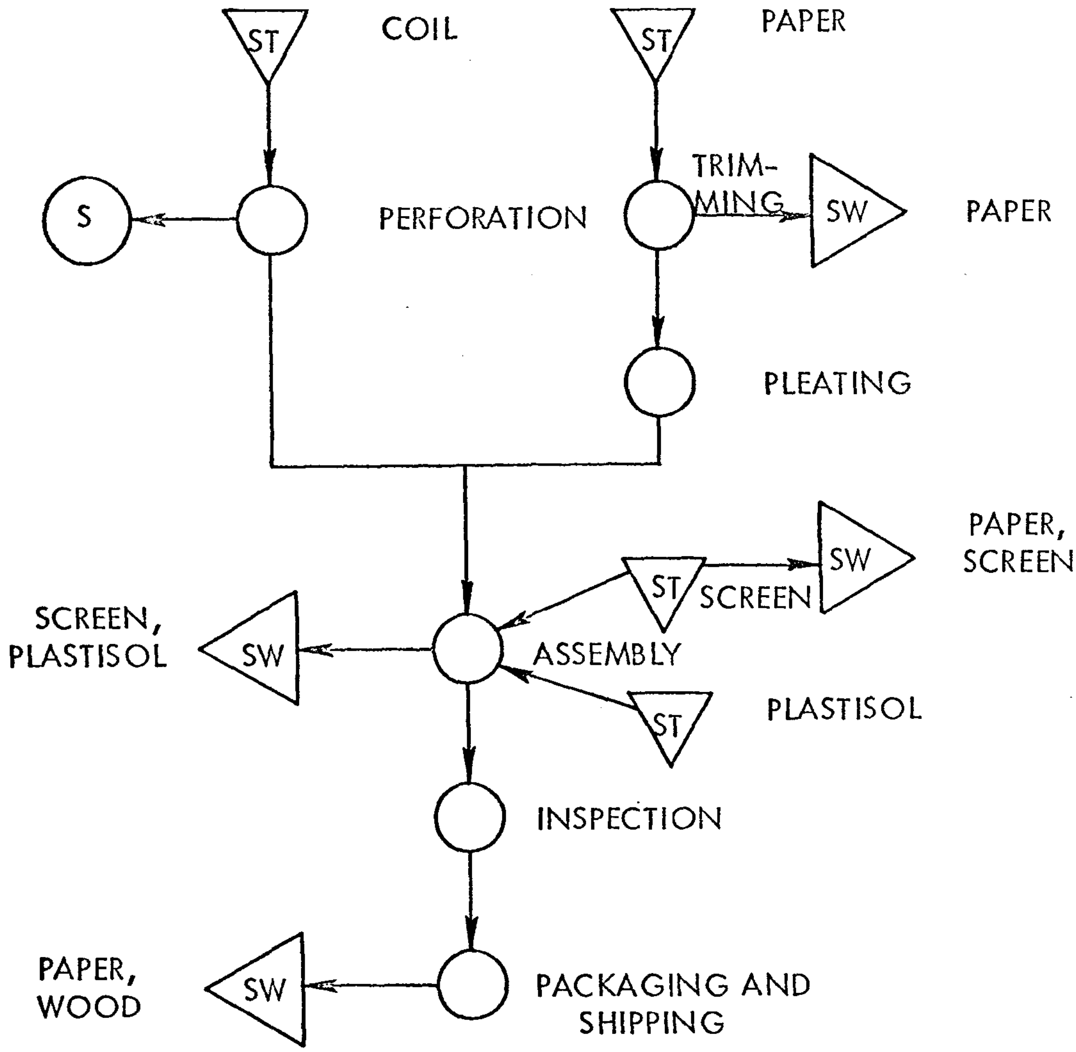


Figure 38. Air cleaner/filter, oil filter fabrication.

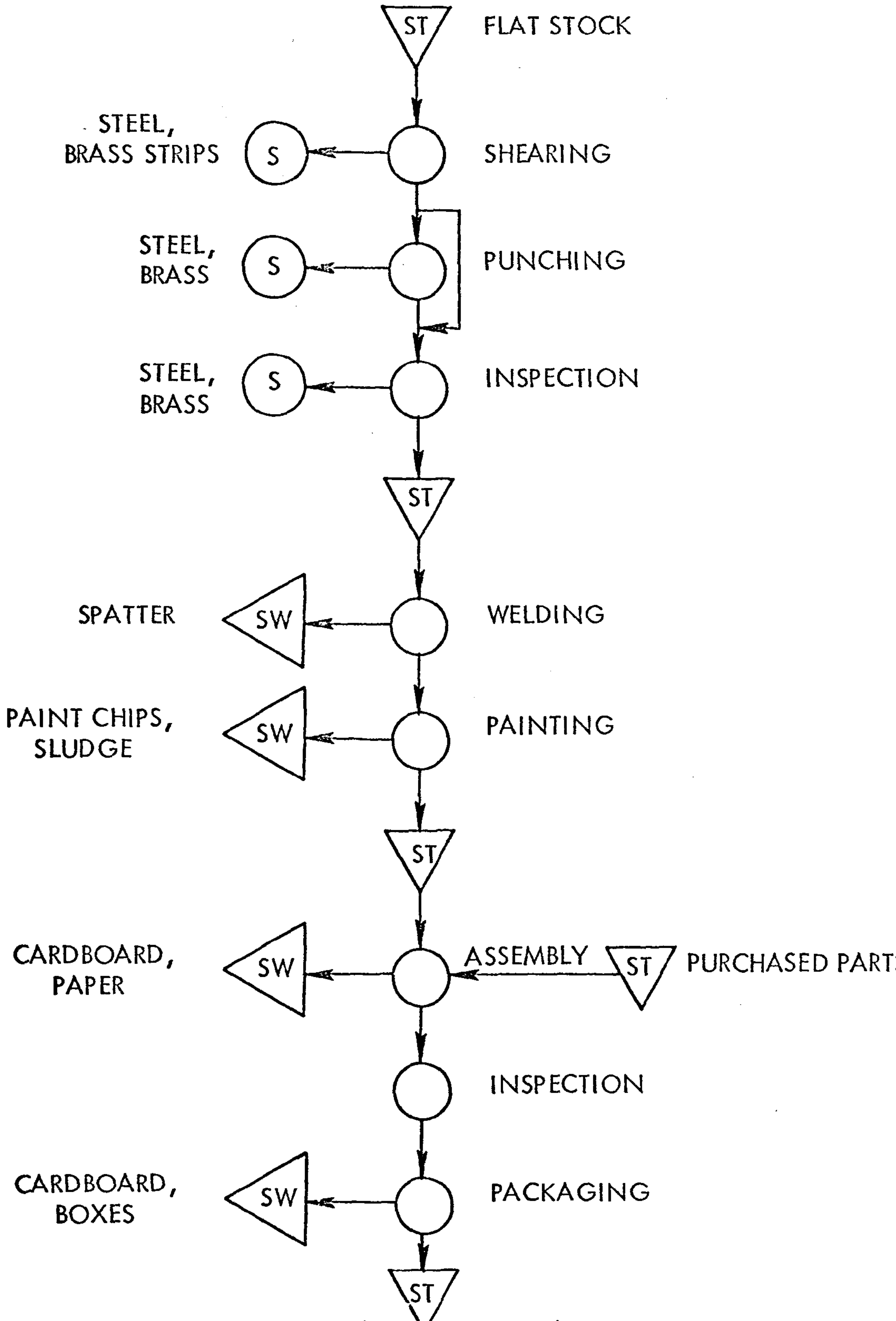


Figure 39. Flow process chart for manufacturing of compact air conditioning and heater units.

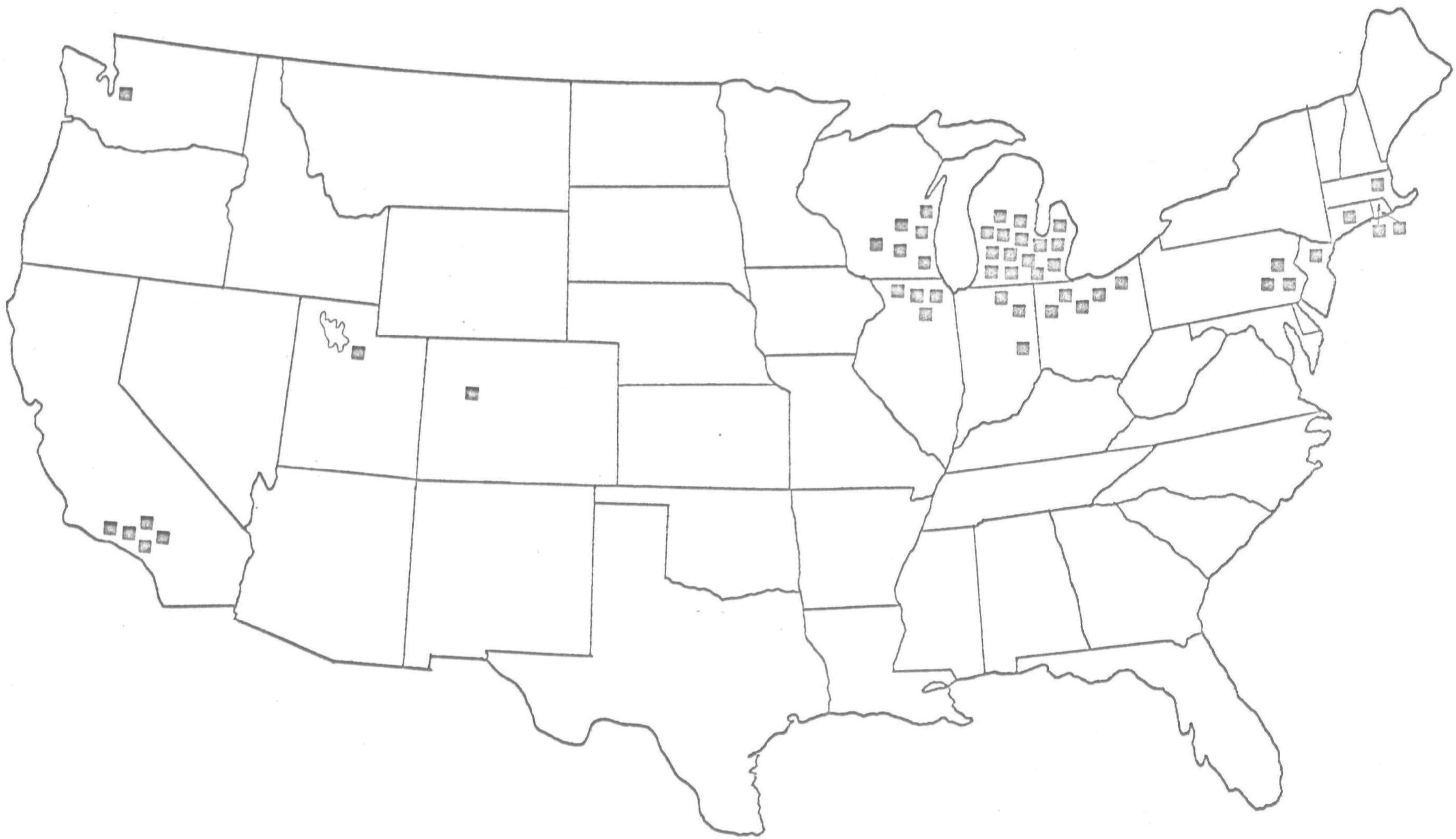


Figure 40.. Plant sites visited.

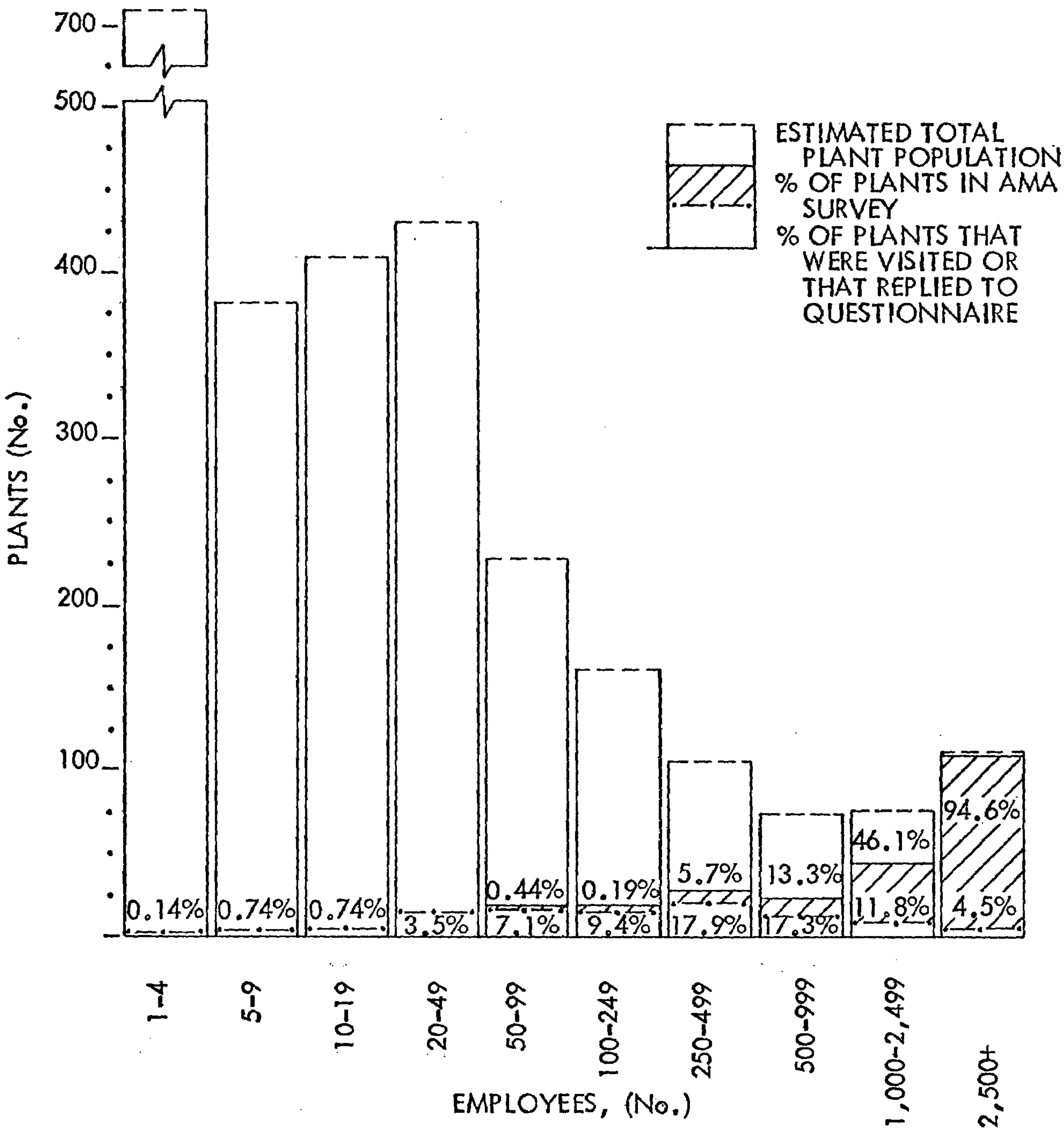


Figure 41. Plant survey sample distribution. (Source: 1963 and 1967 Census of Manufactures Projected Estimate For 1969.)

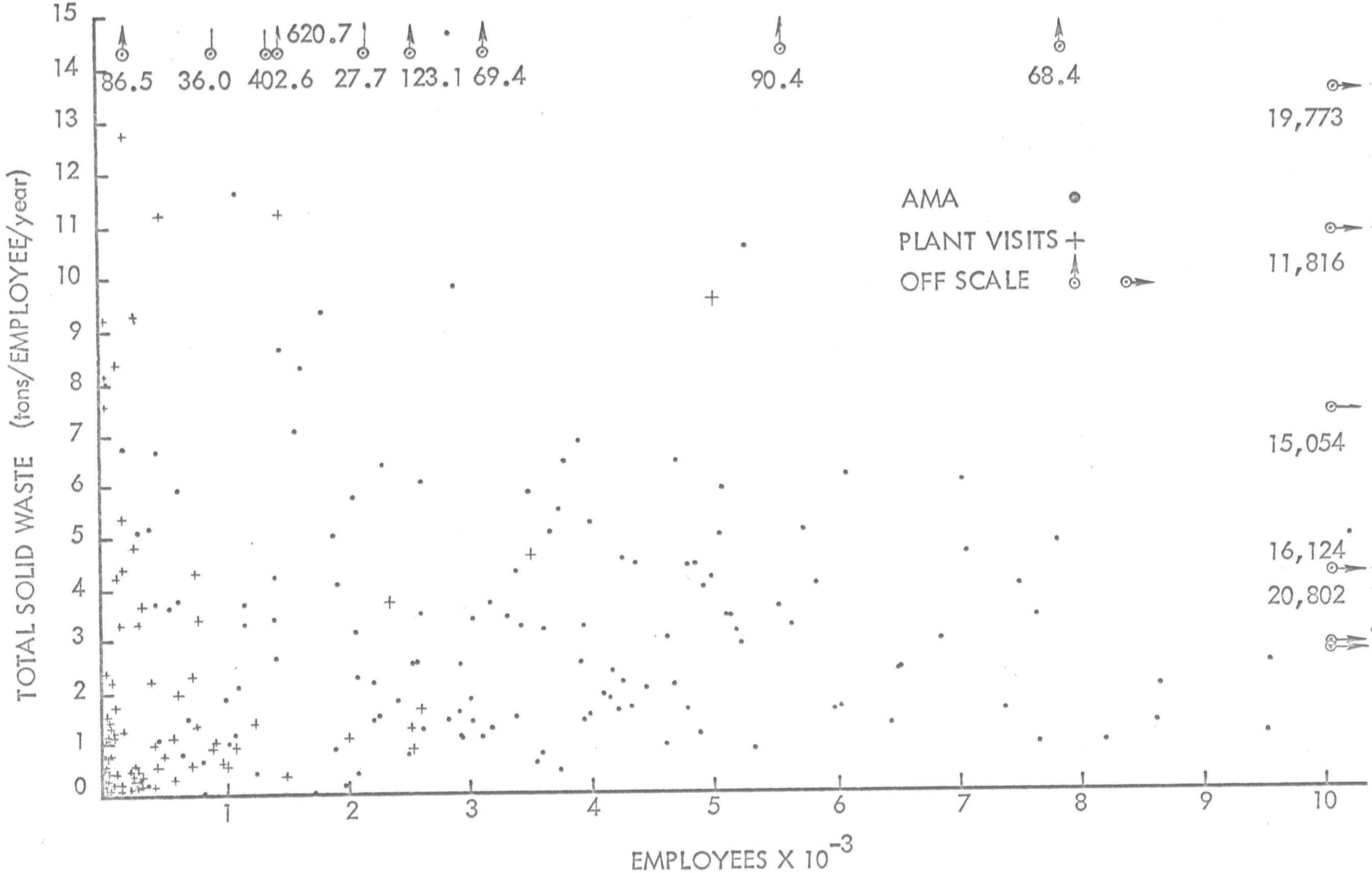


Figure 42. Waste production per employee in automotive industry plants.

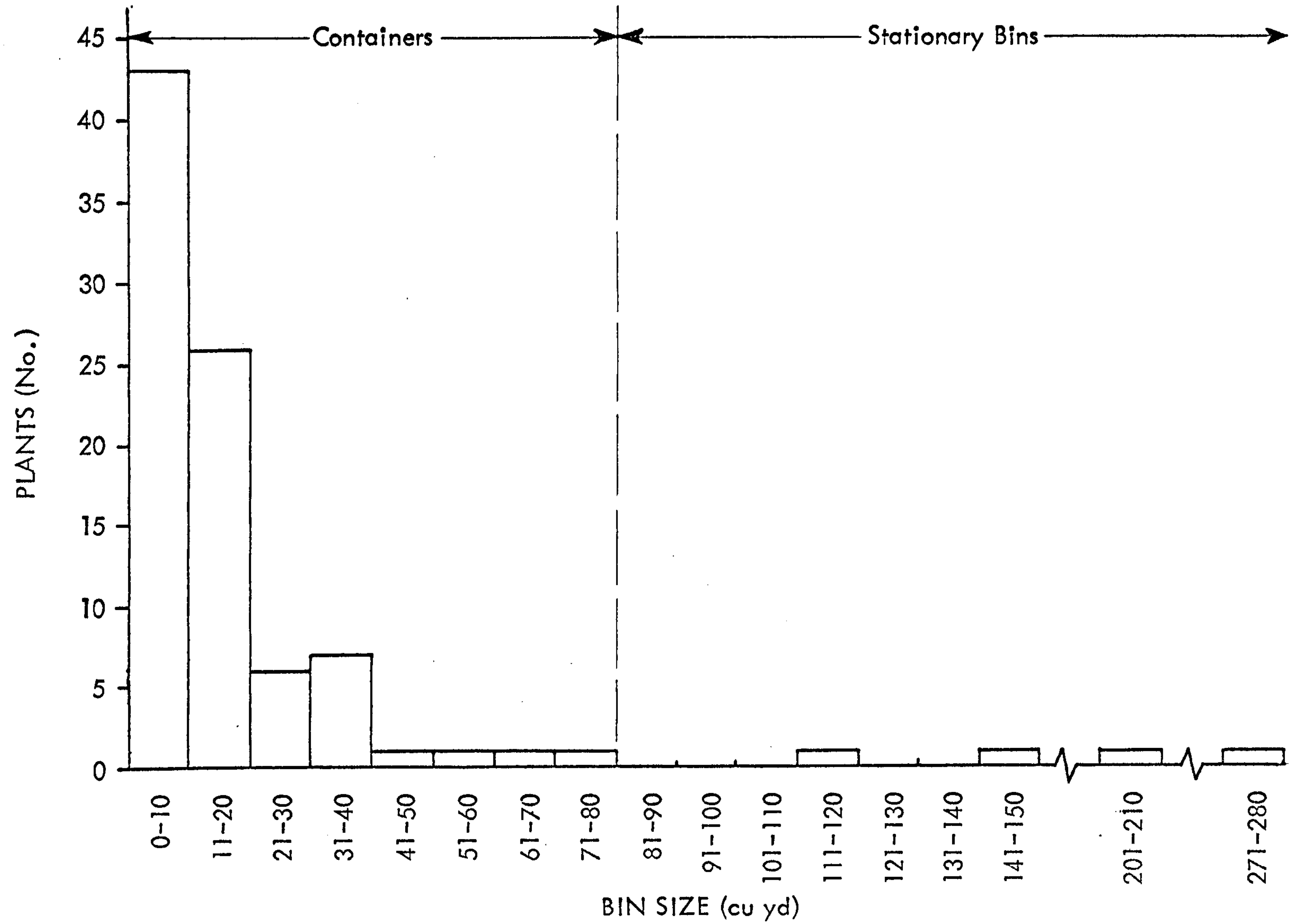


Figure 43. Distribution of bin sizes in automotive plants.
(From information supplied by 65 plants visited.)

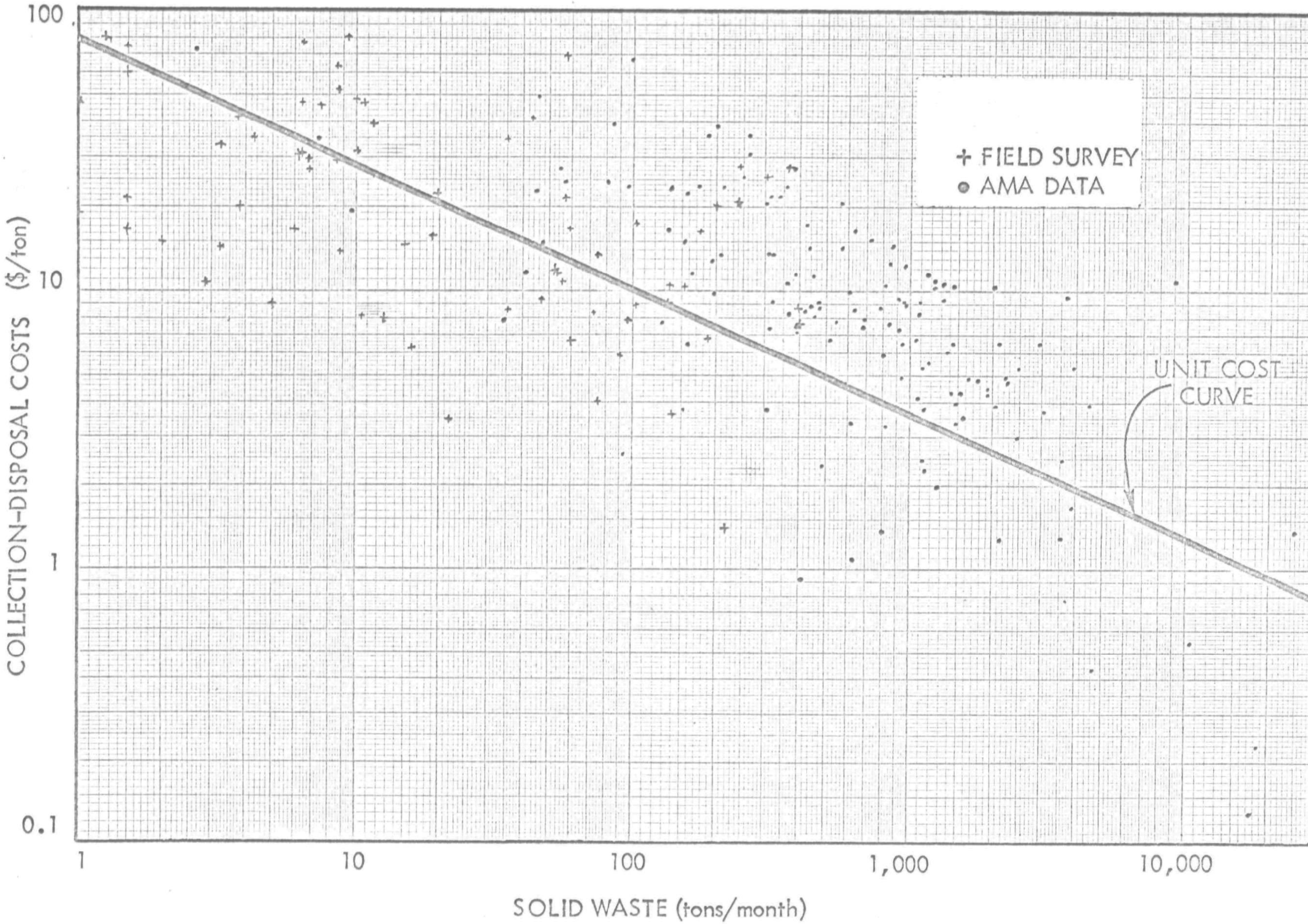


Figure 44. Solid waste collection-disposal costs

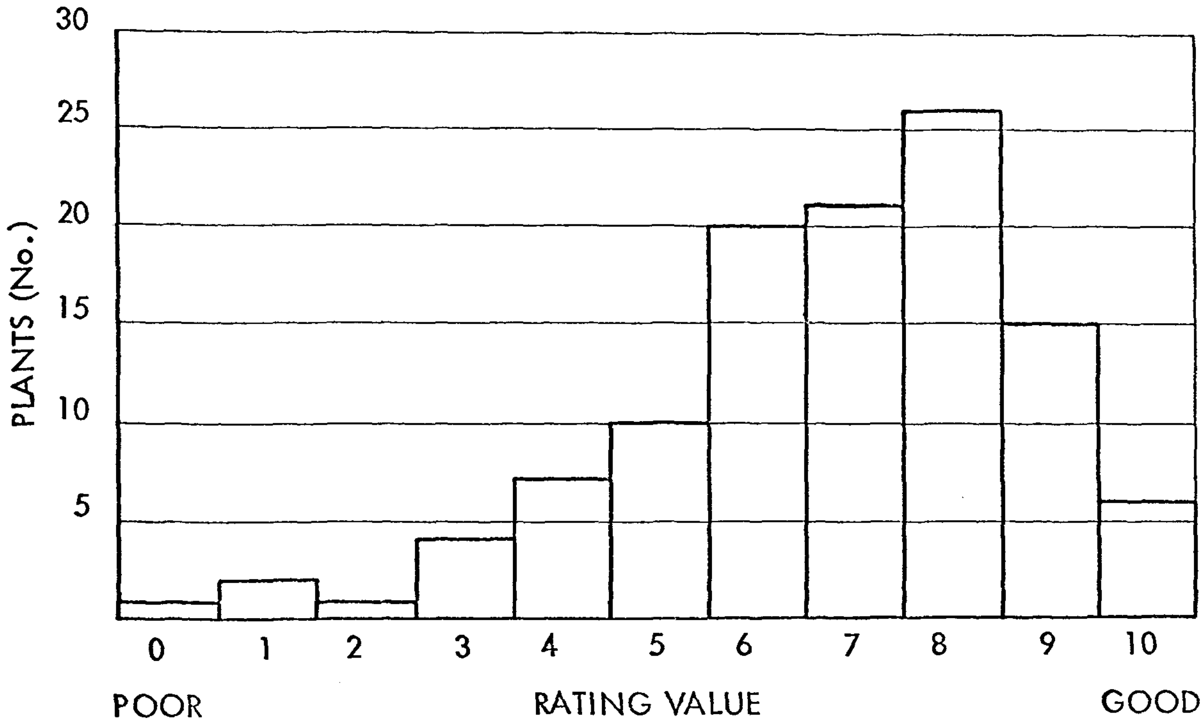


Figure 45. Self-rating by plants of their waste-handling and disposal methods.

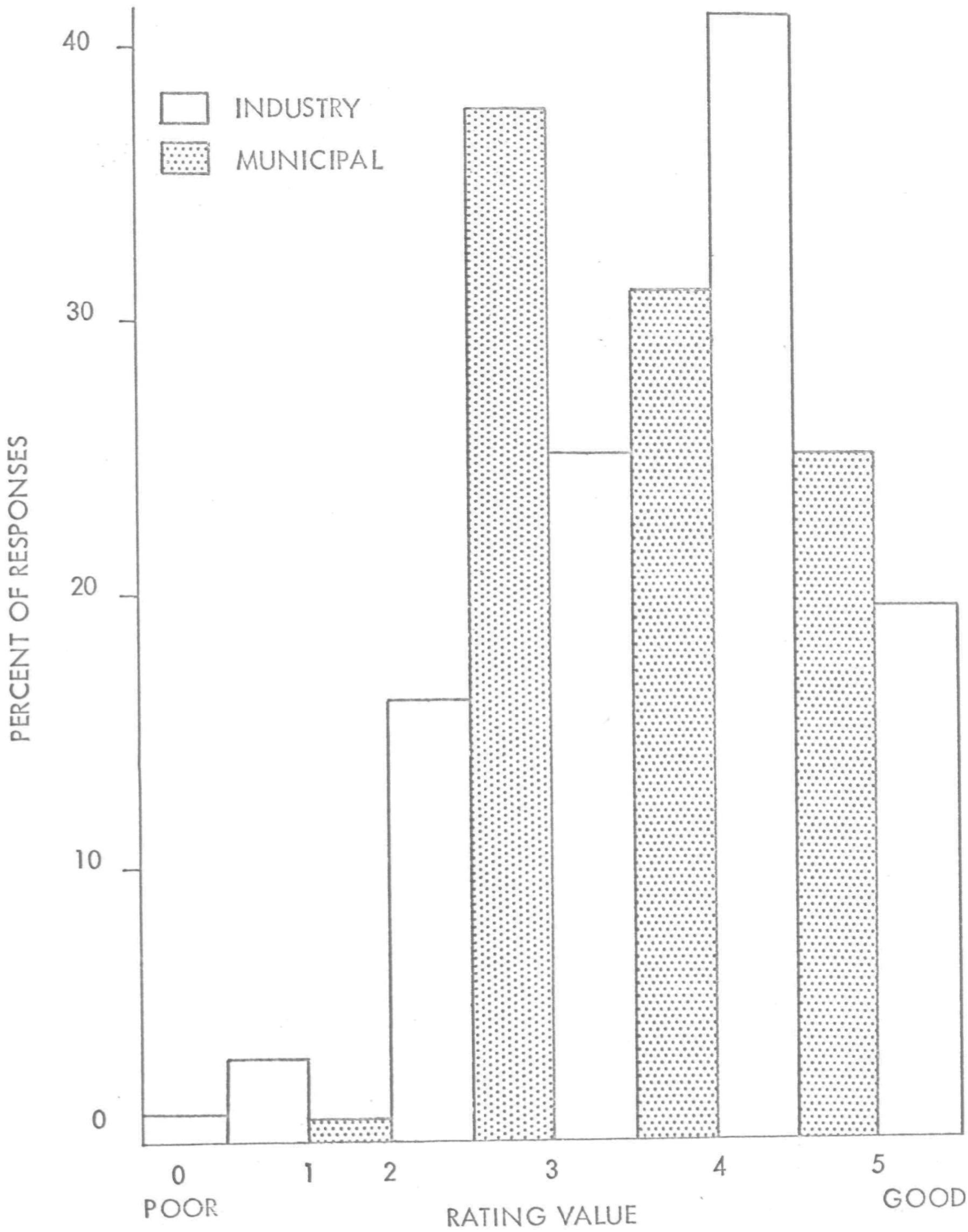


Figure 46. Industry/municipality cross rating of present waste management

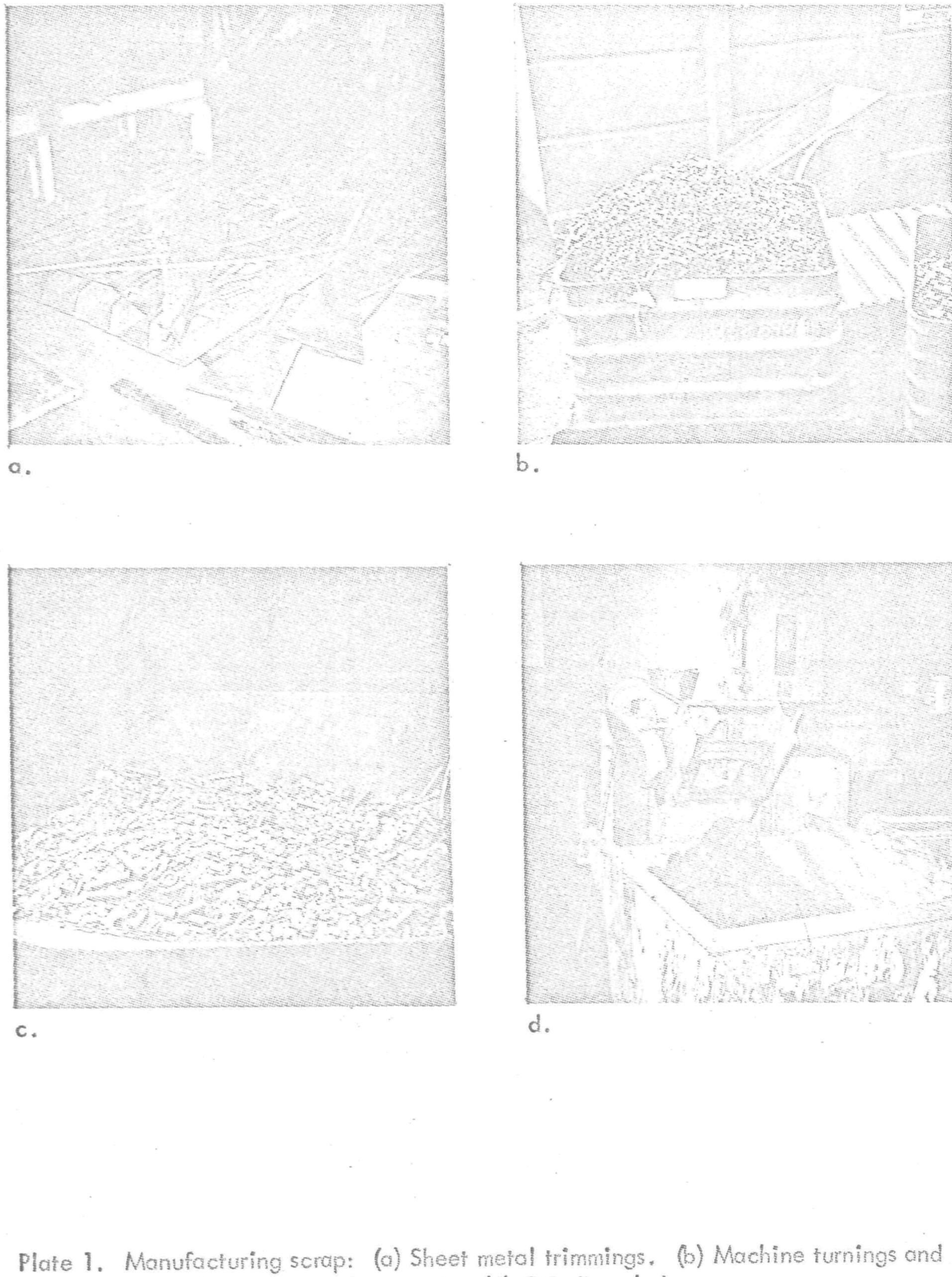
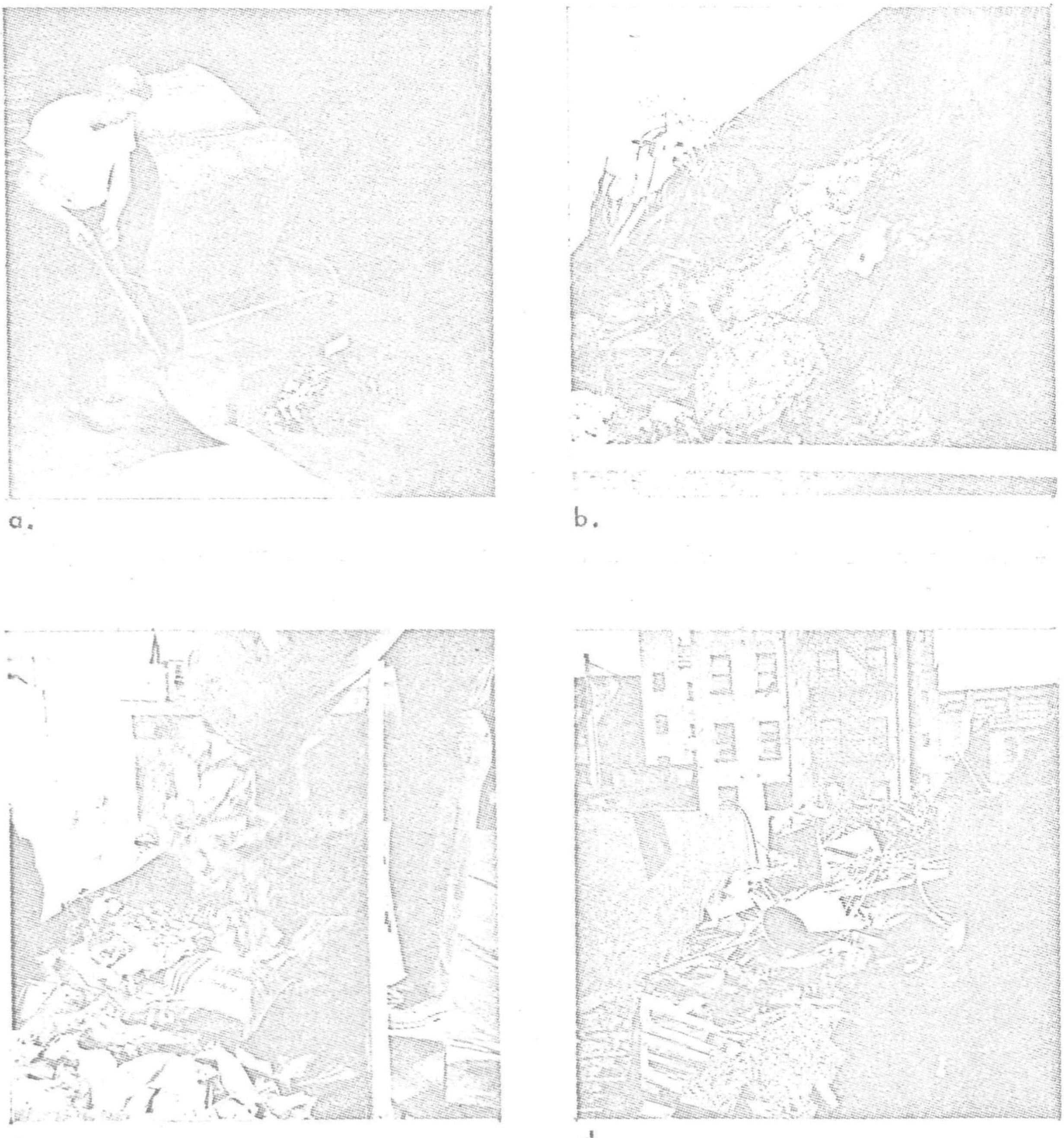


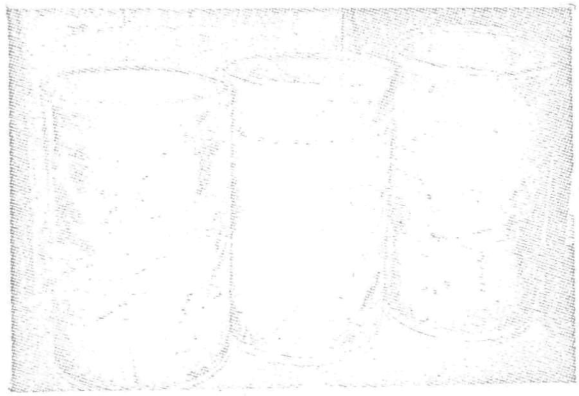
Plate 1. Manufacturing scrap: (a) Sheet metal trimmings. (b) Machine turnings and chips. (c) Metal stamping and cut ends. (d) Grinding sludge.



a. b. c. d.

Plate 2. Typical plant solid wastes: (a) Floor sweepings. (b) Mixed bands, wire and nonmetal waste. (c) Paper packaging waste. (d) Mixed plant waste.

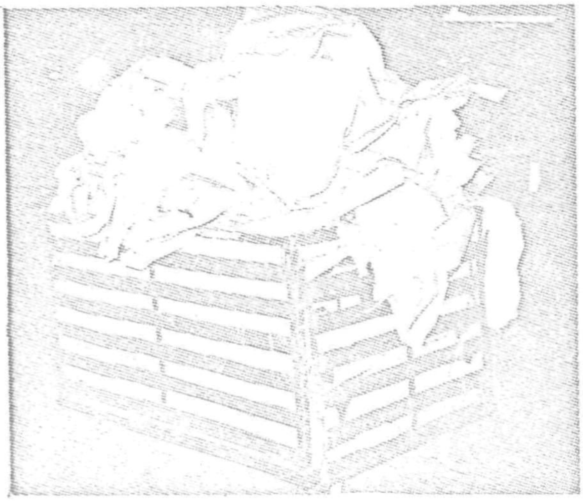
a.



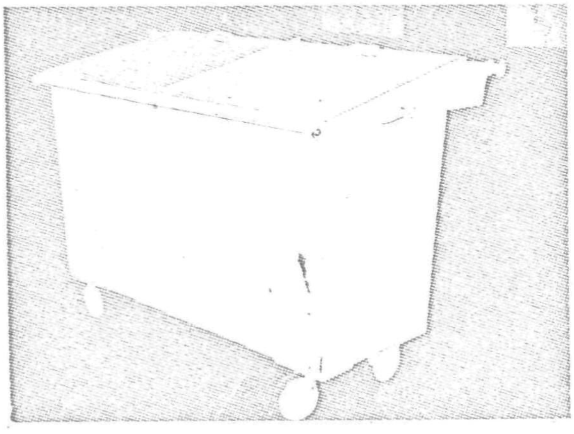
b.

c.

d.

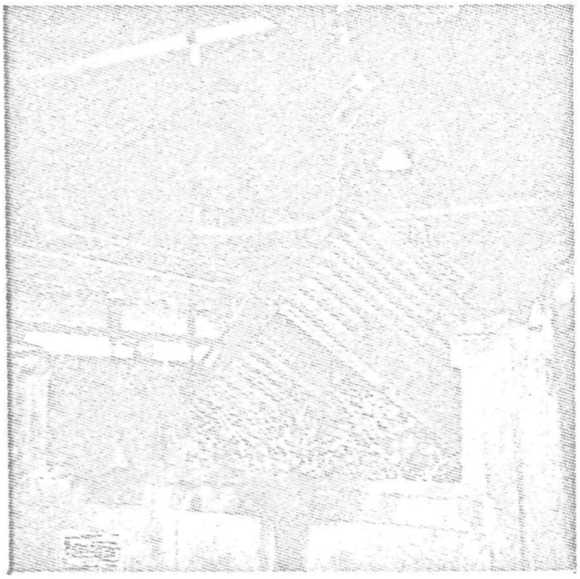


e.



f.

Plate 3. Typical in-plant waste and scrap containers: (a) Garbage cans in food canteen area. (b) Plant waste drums, 55 gal. (c) Plant scrap drum, 55 gal. (d) Scrap bin, 2 cu yd. (e) Paper packaging waste bin, 2 cu yd. (f) Waste container, 1 cu yd.

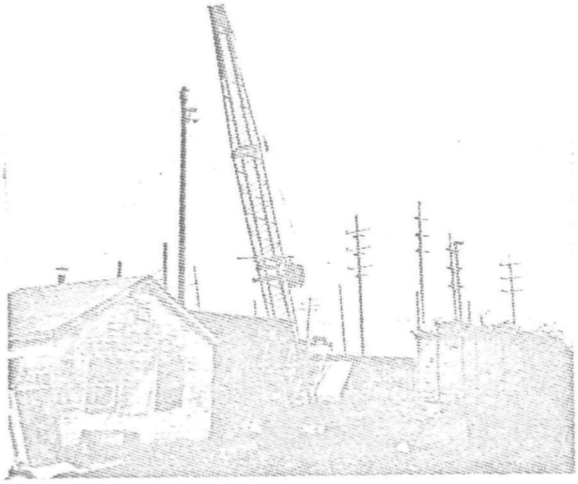


a.

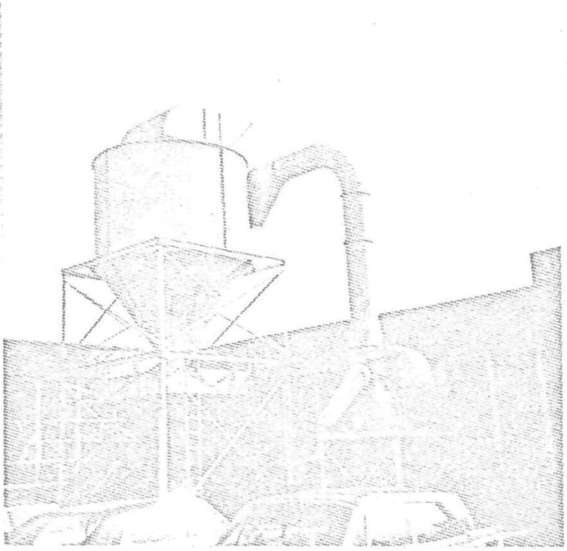
b.

c.

Plate 4. In-plant waste- and scrap-handling equipment: (a) Overhead crane. (b) Inclined conveyor. (c) Floor conveyor.



a.



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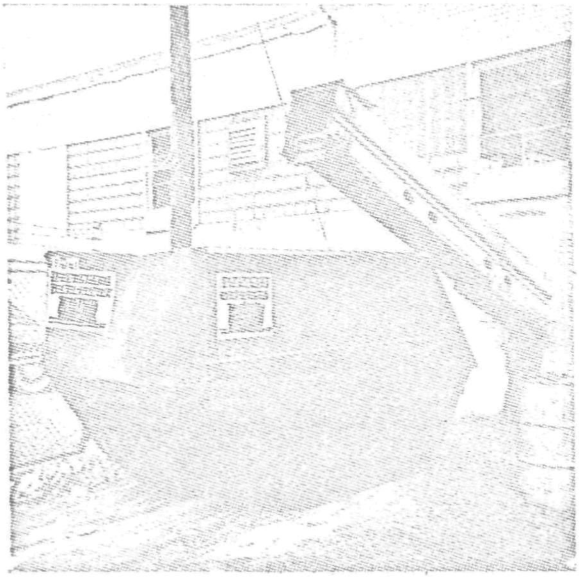

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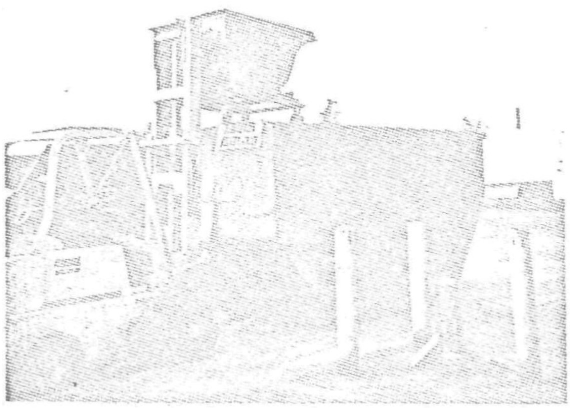
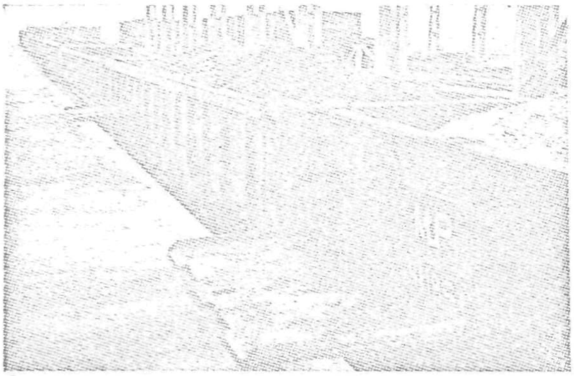
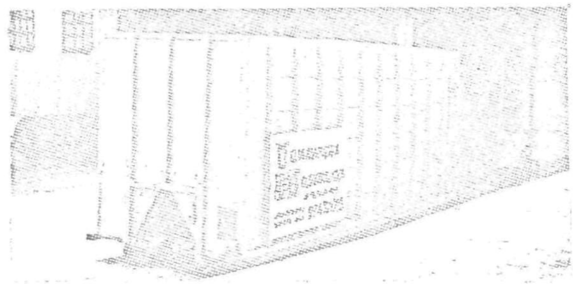


d.

Plate 5. Waste- and scrap-handling equipment in outside storage areas: (a) Crane magnet. (b) Vacuum exhaust system. (c) Conveyor feed system. (d) Forklift bin.



a.



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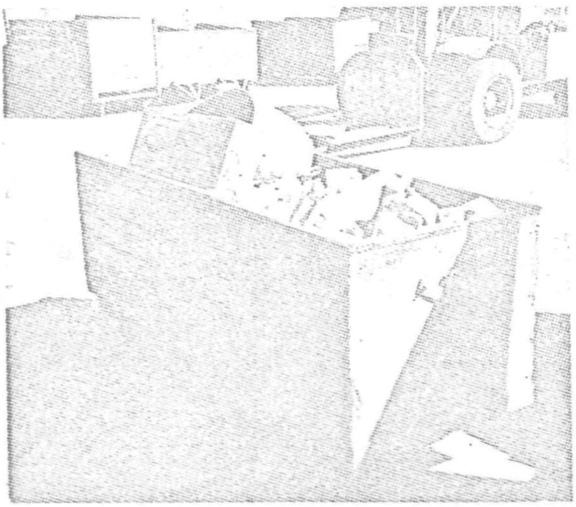
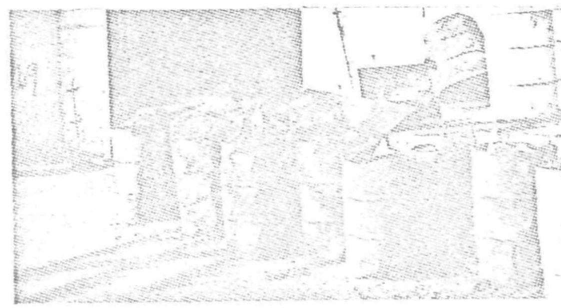
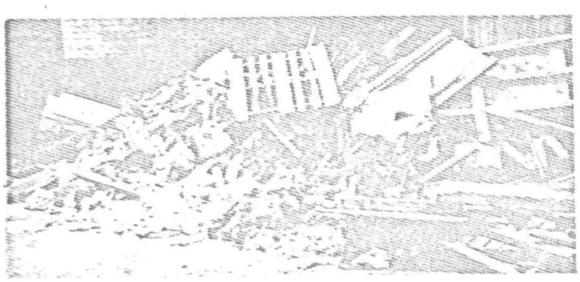


c.



d.



e.

f.

Plate 6. External waste and scrap storage: (a) Railroad gondola cars. (b) Waste compactor. (c) Open storage bin, wheeled. (d) Storage barrels, 55 gal. (e) Storage on ground. (f) On-site plant dump.

Plate 7. Waste burners in small automotive plants.

APPENDIX A

Glossary

Accessories--equipment that is not necessary for the operation of a vehicle, such as air conditioners, power windows, etc. They are often called optional.

Blanking--the process of cutting metal blanks by a die and punch set in a press, or by sawing or shearing.

Cast iron borings--clean cast or malleable iron borings and drillings, free from steel turnings, chips, lumps, scale, corroded, or rusty material.

Clean auto cast--clean auto blocks; free of all steel parts except camshafts, valves, valve springs, and studs; free of nonferrous and nonmetallic parts.

Component--any part, accessory, or other equipment, body section, or subassembly on a vehicle.

Diced turnings--machine shop turnings reduced by hammer or cog mill attrition to a length of less than 2 inches.

Discards--materials generated from all plant operations that do not become part of the finished product and are removed from the plant for final disposal to another industry. Includes scrap and solid waste.

Estimated minimum plant value--plant value based on questionnaires and plant visits, and values of minimum total tangible assets from the 1968 Thomas Register of American Manufacturers. The Thomas Register values are listed as minimal; thus the data presented are expressed as minimum values.

Flash--the material lost in forging and casting operations; the material that overflows between the forging dies and between the casting mold surfaces.

Garbage--all waste food materials. Also includes paper and plastic containers. Approximately 70 percent moisture content.

Grindings--a conglomerate byproduct produced by the friction of a high-speed grinding wheel and consisting of somewhat oxidized metal particles and grinding wheel matter. The particles are usually less than 1/4 inch in screen size and tend to curl and intertwine to form a clump. "Free flowing" grindings signify that the grindings can be hand shovelled. "Frozen condition" implies that the grindings are wet and have become congealed or surface crusted.

Heavy melting steel--wrought iron and steel scrap, black and galvanized.

No. 1: 1/4 inch thick or greater; less than 60 x 24 inches.

No. 2: 1/8 inch thick or greater; not suitable for No. 1.

No. 3: maximum size 36 x 18 inches. May include all automobile scrap properly prepared.

Machine shop turning--long streamers intertwined and interlocked in an unwieldy clumplike mass.

Mating--the bringing together of body assemblies with chassis assemblies on a vehicle assembly line.

Millings--metal streamers, which consist of particles of metal finer than turnings, usually less than 3/8 inch in width, length, or thickness.

Optional equipment--the equipment installed on finished vehicles (primarily passenger cars) that the manufacturer designates as an extra item for pricing purposes; bears no relationship to the actual percentage of vehicles equipped with the item.

Parts--equipment without which a vehicle cannot be operated. Examples are engines, steering wheels, seats, etc.

Piercing--the punching of holes in sheet or strip, or walls of shells.

Prepared scrap--scrap, the physical dimensions of which conform to trade practice. Prepared scrap may be placed in bales or drums and be of crucible shape, open hearth size, etc.

Refuse--any material discarded from a plant from sources other than manufacturing processes. Refuse consists of floor sweepings, incinerator ashes, garbage, office trash, wood and sawdust, rags, etc.

Residue--any material resulting from a manufacturing operation or process that is not in itself a product. Scrap and waste are the major residues.

Runners--the metal removed from castings. Runners are metal feed tubes and channels allowing air to escape from the product mold, which is filled with metal.

Scale--(1) heavy oxide coating on metals resulting from exposure to high temperatures in an oxidizing atmosphere. (2) A product resulting from the corrosion of metals.

Scrap--salable wastes, resulting from manufacturing processes, primarily metals such as iron, steel, aluminum, zinc, and copper but may also include plastics, paper, cardboard, cloth, etc.

SIC--Standard Industrial Classifications.

Sludge--a mudlike residue material originating from chemical processes or grinding operations.

SMSA--Standard Metropolitan Statistical Areas; geographical regions defined by the U.S. Bureau of the Budget to denote areas that are economically and commercially integrated.

Solid wastes--discarded solid materials having no use, resulting from a manufacturing or support operation; any combination of process wastes; general plant packaging, and shipping wastes; and office wastes.

Springs and crankshafts--clean automotive springs and crankshafts either new or used.

Standard equipment--the equipment installed on a finished vehicle that is designated by the manufacturer as a basic item for pricing purposes; has no relationship to the percentage of vehicles equipped with the item.

Trimmings--sheet metal, plastics, wood, etc, resulting from cutting, sawing, shearing, blanking, and punching operations; usually refers to shearing and cutting of metals.

Turnings--(also called borings and shavings) the residue from the machining operation and processing of bars, rods, castings or billets, or the machine dressing or finishing of any metal; appears as sliverlike or curlicue shapes.

APPENDIX B

CONFIDENTIAL COOPERATIVE INDUSTRY-WIDE SOLID WASTE QUESTIONNAIRE

FORM APPROVED
BUDGET BUREAU NO. 85-568021

PLEASE COMPLETE AND RETURN TO:
RALPH STONE AND COMPANY, INC., 10954 Santa Monica Boulevard
Los Angeles, California 90025; Telephone: (213) 478-1501 and 879-1115

DEFINITION: INDUSTRIAL SOLID WASTE INCLUDES ANY DISCARDED OR SALVAGED SOLID MATERIALS RESULTING FROM INDUSTRIAL OPERATION OR PLANT ACTIVITIES

PLEASE ESTIMATE YOUR ANSWERS WHERE REQUIRED. IN RETURN FOR YOUR COOPERATION IN ANSWERING THESE QUESTIONS, YOU WILL RECEIVE A SUMMARY OF THE QUESTIONNAIRE DATA. INDIVIDUAL INDUSTRIAL PLANTS WILL NOT BE IDENTIFIED.

A. PLANT FACILITIES

List automotive parts or assemblies produced:	Average No. units produced per month	Average No. workers employed on this product
1. ________	________	________
2. ________	________	________
3. ________	________	________
4. ________	________	________
5. ________	________	________
6. ________	________	________

B. TOTAL PLANT CAPITAL (BOOK) VALUE FOR AUTOMOTIVE PRODUCTION (Check Nearest $)

( ) $ 10,000
( ) 50,000
( ) 100,000
( ) 300,000
( ) 500,000
( ) 1,000,000
( ) 10,000,000

C. QUANTITY OF SOLID WASTE BY SOURCE AND TYPE (AVERAGE lb/month)

Source of solid waste	Metals		Nonmetals			
	Ferrous	Nonferrous	Plastics	Paper	Wood	Other
Machine & foundry operations*						
Trimming & cutting						
Office						
Cafeteria						
Pkg & ship						

* Include casting, forging, machining, drilling, and grinding operations.

D. SOLID WASTE DISPOSAL METHOD FOR EACH SOURCE (% of TOTAL)

Source of solid waste	Reclaimed In plant	Scrap sales	Incinerated In Plant	Landfill at plant	Collection by		
					Public	Private	Other
Machine & foundry operations*							
Trimming & cutting							
Office							
Cafeteria							
Pkg & ship							

* Include casting, forging, machining, drilling, and grinding operations.

E. AVERAGE MONTHLY COST FOR EACH DISPOSAL METHOD LISTED

Disposal method	Cost/month ($)
1. Reclaimed in plant	________
2. Incinerated in plant	________
3. Burial by plant	________
4. Collection - Private	________
Public	________
5. On-site storage	________

F. AVERAGE MONTHLY SALES OF SALVAGED SOLID WASTES

Description of salvage	Average total monthly sales ($)
________	________
________	________
________	________
________	________
________	________
________	________

G. Rate your present method of handling and disposing of your solid wastes. (Circle appropriate number)

GOOD: 10 9 8
FAIR: 7 6 5 4
POOR: 3 2 1 0

H. Please attach a schematic diagram of your plant(s) showing locations of major solid waste production.

I. Do you have any special solid waste disposal problems? ( ) YES ( ) NO
Describe briefly ________
____

J. Are municipal authorites taking adequate steps to alleviate your solid waste disposal problem? ( ) YES ( ) NO - Comment: ________
____

CONFIDENTIAL COOPERATIVE INDUSTRY-WIDE
SOLID WASTE QUESTIONNAIRE (Continued)

K. Does the generation of solid waste vary significantly with changes in the production process? ( ) YES ( ) NO
Comment: ______________________________
____

L. Do you foresee a significant change in your methods of waste handling for the future?
( ) YES ( ) NO
Comment: ______________________________
____

PLEASE INDICATE IF YOU WISH YOUR IDENTITY KEPT CONFIDENTIAL:
( ) YES ( ) NO

IF YOU DESIRE A COPY OF THE REPORT ON THIS STUDY, PLEASE FURNISH YOUR NAME AND ADDRESS BELOW:

Name of person completing questionnaire: ______________________________
(Title)

Company name ______________________________

Address ______________________________
(Street) (City) (State) (Zip)

12/69

Plant Visit Interview Information

A. Discuss the following aspects of solid waste management with responsible staff members:

1. Are records kept of SW: sources__________ types__________ handling__________ disposal__________

2. Have SW management practices changed:

   a. In the past: year__________ type of change____________________
   ____

   b. Anticipated future changes: year__________
   discuss____

   c. What factors contributed to these changes?
   Past____
   ____
   Future____
   ____

3. Identify SW and S processing and disposal problems related to municipal agencies.

   a. Disposal____

   b. Codes and Regulations___________________________________
   ____

4. Approximate age: plant__________ equipment__________

5. Obtain a sketch of the process sequence.

6. Obtain a copy of the plant layout.

7. Does the plant have its own waste treatment facilities?
   No__________ Yes__________ Obtain layout sketch.

   Capacity: Solids______________________________________
   Liquids______________________________________

B. Obtain the following data in the manufacturing/assembly area:

1. Sketch the manufacturing/assembly sequence of the product.

   a. Identify the type of process or machine.

   b. Designate the location and type of SW and S handling and storage equipment.

2. Determine the quantity by weight and volume of the following:

   a. The raw material stock for each product:

      material_________ weight_________

   b. Finished product weight_________

   c.

	type	weight	volume
SW			
S			

   d. Identify major components purchased for assembly and their packaging materials.

	component	pkg material	approx size/wt
1)			
2)			
3)			
4)			
5)			

   e. Identify packaging used to ship finished products.

	product	pkg material	Quantity: lb/month
1)			
2)			
3)			
4)			
5)			

f. Shop handling methods for SW and S

Pick-up: equip. ______________________
schedule ______________________

Processing: equip. ______________________
quantity ______________________
type of material ______________________

g. Storage of SW and S on plant premises.

	Size (cu ft)	Storage area (cu ft)	Owned by plant collector
Containers:	______	______	______
	______	______	______
	______	______	______
	______	______	______

Are storage areas fenced or enclosed? ______________
Are rats, vermin, flies, birds, etc, in the storage area? __________
__________ comment ______________________________
____

h. Private solid waste and scrap collectors:

Size of collector: large medium small

Rate collector good: 5 4 3 2 1 0 :poor

MUNICIPAL QUESTIONNAIRE — FORM APPROVED
BUDGET BUREAU NO. 85-568021

INDUSTRIAL SOLID WASTE STUDY OF THE AUTOMOTIVE INDUSTRY
RALPH STONE AND COMPANY, INC.

I. Name of city and State ____________ Population ____________

II. Industry information

A. Number of industrial plants producing automotive components, accessories, or complete vehicles including trucks ____________
(Please list names and addresses of plants on back of questionnaire.)

B. Total annual production of cars, trucks, vehicles, etc, and vehicle parts in your city:

	Vehicles	Vehicle parts	Total annual production
1. Number of units	______	______	______
2. Total weight (tons)	______	______	______

III. Waste Information

A. Quantity, tons, of waste produced by these industrial plants per year:

1. Office waste (paper, garbage, etc) ______
2. Plant scrap and salvage ______
3. Plant wastes to private or public disposal (other than 1 or 2) ______
4. Total ______ tons

B. Plant waste disposal:

	Office waste	Quantity (tons) plant waste
1. Incineration	______	______
2. Landfill	______	______
3. Other	______	______

C. Waste collection agency: % of total waste

	Office waste	Plant waste
1. Municipal	______	______
2. Private	______	______

D. Collection and disposal charges:

	Cost ($/ton) Collection	Disposal	Combined coll & disposal
1. Collection and disposal agency			
a. Municipal	______	______	______
b. Private	______	______	______
2. Type of waste			
a. Office waste	______	______	______
b. Plant waste	______	______	______

E. Please describe special problems in handling/disposal.
Comments ____________

F. Are there any air pollution or liquid waste problems related to these plants?
____

NOTE: Please provide copy of solid waste and industrial waste ordinances.

Prepared By: Name ____________ Date ____________
F.N. 106-0 Title ____________ Address ____________

Municipal Interview Sheet

City ______________________ State ______________________

City official ______________________ Position ______________________

C. Municipal solid waste role

1. Are records on SW disposal available? No ________ Yes ____________

   Type of records ____

2. Collection agency:

	Cost ($/ton) Collection	Disposal
Public	____________	____________
Private	____________	____________

3. Acceptability of automotive collection and disposal to:

Municipal agencies	good:	5	4	3	2	1	0	:poor
General public		5	4	3	2	1	0	

   Comments ____

   ____

4. Are there any public health and safety problems directly attributable to automotive industry SW and S such as water and air pollution, vermin, flies, birds and fires at landfill, etc ? No________ Yes ________

   Comment ____

   ____

5. Do any hazards or special problems result from automotive industry waste generation such as landfill fires, waste seepage into streams, etc ? No________ Yes________

   Comment ____

   ____

6. If the answer to 4 or 5 above is Yes, is the industry taking appropriate corrective action? Yes________ No________

   Why not? ____

   ____

AMA QUESTIONNAIRE

A. PLANT FACILITIES

Type of plant	____________
Current production rate	____________
Total number of employees	____________

B. COSTS OF COLLECTION AND DISPOSAL

METHOD	AVERAGE ANNUAL COST
Collection (public)	____________
Collection (private)	____________
Collection (self)	____________
Collection (total)	____________
Disposal (dump or burial)	____________
Disposal (incinerate)	____________
Disposal (other or combined)	____________

C. PLEASE ATTACH A SIMPLIFIED BLOCK DIAGRAM OF YOUR PLANT SHOWING MAJOR MANUFACTURING PROCESSES.

D. PLEASE LIST SOLID WASTE SOLD EXTERNALLY EXCLUDING METALS AND LIQUIDS (ITEM AND tons/yr)

E. PLEASE DISCUSS ANY SPECIAL PROBLEMS OR PROCEDURES YOU HAVE IN COLLECTING, HANDLING, STORAGE, OR DISPOSING OF A PARTICULAR SOLID WASTE AND SPECIFY THE WASTE.

F. IS A LOCAL GOVERNMENTAL AGENCY CONCERNED WITH OR INVOLVED IN EITHER OF THE FOLLOWING ASPECTS OF YOUR PLANT'S SOLID WASTE MANAGEMENT ACTIVITIES:

Collection Yes__________ No__________

Disposal Yes__________ No__________

PLEASE EXPLAIN (e.g., CITY PROVIDES WASTE COLLECTION; COUNTY PROVIDES DISPOSAL SITE; etc)

G. DO LOCAL OR STATE REGULATIONS AFFECT YOUR SOLID WASTE MANAGEMENT ACTIVITIES?

Yes______ No______

H. QUANTITIES AND CLASSIFICATIONS

	Classification (1)	Tons Per year (2)	Method of disposal (see Code below) On site (3)	Off site (4)	Hauled by: Self Other (specify) (5)
1.	Garbage				
2.	Cardboard				
3.	Paper, cloth, grass, etc				
4.	Wood				
5.	Rubber				
6.	Plastics				
7.	Oils				
8.	Flammable liquids				
9.	Residues and tars				
10.	Wastewater treat sludges				
	(a) Oily				
	(b) Lime bearing				
	(c) Metallic hydroxide				
11.	Inert solids				
12.	Cans, bands, wire, etc				
13.	Special wastes				

METHOD OF DISPOSAL CODE:

a. Open burning dump
b. Landfill
c. Burned in boiler or furnace
d. Incinerator
e. Teepee waste burner
f. Sold

APPENDIX C

FIELD SURVEY STAFF-TRAINING PROCEDURE

The field staff-training procedure for standardized waste estimation in automotive industry plants was developed from information gathered on preliminary visits to seven automotive industry plants by the project engineer. Wide variations noted in waste composition and waste and scrap container sizes necessitated previsit training to standardize the observation methods of the field survey staff. The training program consisted of the following: (1) instruction in developing standard waste density values for common waste types noted in containers; (2) instruction in establishing interview, measurement, and observation procedures; instruction in developing questionnaires; and (3) field training on plant visits where two or more staff members were accompanied by an experienced interviewer.

Weight Estimates. Standard waste densities for paper and cardboard were established by pilot studies at the project engineer's headquarters. A 3-cu-yd bin was filled with loose paper weighing 20.7 lb/cu yd. Then the paper was hand compacted, and this resulted in a density of 130 lb/cu yd. The procedure followed for cardboard was to fill a 3-cu-yd bin with cardboard boxes varying in size from 2 x 1-1/2 x 3 ft to 2 x 3 x 4 ft. The loose boxes had a density of 17 lb per cu yd. The boxes were then broken down, compacted, and measured to determine their compacted volumes. The broken-down density was 32 lb per cu yd, and the compacted density was 170 lb per cu yd. Densities for wood, sawdust, ashes, plaster, sand, concrete, plastics, and metals were obtained from standard weight tables. Packing factors were standardized and applied in the field to estimate the volume filled by these materials. The resulting waste and scrap densities were used for estimation when plant data were not available.

Questionnaires and Interview Procedure. Several sample questionnaires were discussed with plant personnel during seven pilot visits. The pilot study visits were conducted to establish a simplified questionnaire format, clarify terminology, use industry definitions where applicable, and estimate the expected level of response. The final questionnaire format was then submitted and approved by the Bureau of the Budget. An interview format sheet was developed to standardize, for comparative analysis, the plant interviewer's answers. Two experienced staff members then instructed other field investigators in the use of the questionnaire and interview sheet (Appendix B).

Field Training. Each field interviewer was accompanied by a trained staff member to three automotive plants prior to conducting independent interviews. The experienced staff member acted as an observer on these visits to monitor the trainee's adherence to standardized practices and waste estimation procedures.

APPENDIX D

AUTOMOTIVE INDUSTRY PROCESS DESCRIPTION

Casting

Cast metal parts are normally produced from metal ingots or scrap purchased by the manufacturer and melted down in foundry furnaces. Metal patterns formed in the shape of the desired part are pressed into boxes of sand to form the mold. The molten metal is poured into the mold, after the patterns have been removed, and allowed to harden. Then the casting is taken out of the mold and trimmed to remove the runners and flash (excess metal sticking to the part). Sandcasting requires that the part be cast slightly oversize and then machined down to final dimensions. Other casting methods such as shell molding and die casting provide good dimensional accuracy and do not require as much machine work as sand castings. Owing, however, to their high cost, the latter two methods have been applied mainly to aluminum and zinc parts requiring fine finishes.

The cast metal part is subsequently inspected and then sent to the machine shop for finishing and painting. Rejected parts are accumulated in bins and recycled through the foundry.

In addition, die casting is used to form plastic parts. The liquid plastic is injected under pressure into close-tolerance metal molds that forms a product needing only minor finishing to remove the flash.

Forging

Forging is a metal-working process used for parts requiring greater strength than is achievable in sand castings. This process alters the grain structure of steel so that it is parallel to the direction of stress on the part.

Forging operations can be classified into five common forms as follows: hammer, drop, press, upset, and roll forging. Only drop forging and press forging involve the use of dies and provide excellent dimensional accuracy. The other methods are less accurate and require that the part be made slightly oversize. The schematic diagram, Figure 15, shows a connecting rod being drop forged. The flash and tonghold materials are trimmed and sold as scrap. The scale is cleaned off and disposed as waste. These losses vary with the complexity of the part shape and represent about 50 percent by weight of raw stock for connecting rods.

Following the forging process, the parts are machined to final form. The machined parts are gauged and inspected. Rejects are sold for scrap.

Machining

Basically, machine shop operations consist of drilling, turning, milling, and grinding (see Figures 16 and 17). Any or all of those operations may be applied to cast parts, forged parts, or to raw material stock.

Drilling (Figure 17) is an operation in which round holes are cut through wood and metal. This is usually accomplished in a drill press holding one or more bits having hardened cutting edges that are spun rapidly into a stationary workpiece. Other related operations carried out on a drill press include core drilling, which is the enlargement of holes that have been cored into the casting; counterboring, which is the enlargement of a portion of a previously drilled hole; reaming, which is the enlargement of the full length of a hole previously drilled undersize; and tapping or thread cutting into the walls of a drilled hole. Metal drilling chips are sold as scrap and wood chips are disposed of as solid waste.

Turning operations are accomplished as a lathe that holds the work in a chuck and rotates it while a cutting tool is brought to bear against it, removing metal in the form of chips (Figure 16 and Plate 1b). Turning operations include the reduction of an outside diameter; the facing of ends or the squaring of shoulders between different diameters; boring or enlargement of inside diameters; cutting of screw threads on both inside and outside diameters; and drilling (Figure 17).

In milling operations, the work is fed to a rotary cutter, generally for the purpose of cutting flat surfaces at high speed. Rotary cutters may also be used to cut notches, slots, shaped surfaces, and gears. The milling machine is one of the most versatile machine tools used in industry. In high production automotive machine shops, however, broaching has replaced milling in many operations. Broaching is a specialized machining process involving a multitooth cutter that resembles a file. The broach is capable of cutting a surface in a single pass, requiring only a fraction of the time required in milling.

Hobbing is a generating process employing a number of straight-sided rack teeth positioned helically around a cylindrical body. Gears are generally hobbed in the automotive industry because rapid production and good accuracy are obtainable.

Grinding operations are metal-cutting processes similar to those previously described with the exception that rotating grinding wheels made of abrasive material such as sandstone are used as the cutting tool. Grinding produces a smoother finish than other cutting operations and is usually used as a finishing process following rough milling or turning (Plate 1d). Grinding generates a sludge composed of metal and abrasive particles in cutting oil that is disposed of as solid waste. Superfinishing is a grinding operation using an extremely fine particled honing stone. This process is used only when the highest dimensional accuracy is sought. When a shiny finish is required without the need to maintain a close dimensional tolerance, the surface is polished by a stacked leather wheel coated with special abrasives.

Cutting fluids are used to cool and lubricate both the part and the tool during machining. Cast iron is generally machined dry to avoid clogging of cutting tools.

The high-volume production required by automobile manufacturers has led to the development of automatic, multistation transfer machines that provide drilling, tapping, reaming, and milling machines positioned on a common base with a conveyor feed to transfer parts between each station. Several machining operations may be completed at one station, and then the part is transferred to the following station and positioned automatically. Figure 18 shows a six-station transfer machine and describes its operational sequence on an exhaust manifold. Other transfer machines capable of handling all the machine operations on an engine block at a rate of more than 100 units per hour have also been developed for use by the major automobile manufacturers. These transfer machines are often valued at more than $1 million and are highly specialized equipment commonly built specifically for the handling of a single part.

Fabrication--Cutting, Trimming, and Forming

This category includes all parts fabricated from sheet metal by cutting, pressworking, and welding. Large body-panel stampings are included in an SIC Code of another industry and will not be considered here.

The general procedure begins with the shearing press, which cuts large sheets or rolls of metal into rectangles of appropriate size. The sheet is then blanked on a punch press. This operation cuts out a piece in the desired shape and leaves a skeleton that is placed in a scrap bin. Perforations, slots (skiving), holes, etc. may be cut at the time the piece is blanked by use of appropriate dies. Often the blanked part is the finished product, but more generally the blanked part is bent or drawn on a series of power presses to form a three-dimensional part. Valve covers and oil pans are examples of parts drawn from a flat blank. Embossing of patterns and textures onto sheet metal is another operation carried out on a press (Plates 1a and c).

Drawn parts are usually made oversize and must be trimmed with a shearing die on a punch press.

Sheet metal parts that cannot be stamped in one piece are fabricated by welding two or more stampings together.

Following pressworking operations, most stamped parts require heat treatment (annealing) to relieve the internal stresses induced during coldforming. This is particularly critical for deep-drawn parts such as oil pans, which develop high internal stresses during forming.

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