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AUTOMOTIVE MANUFACTURING PROCESSES
VOLUME IV - METAL STAMPING AND PLASTIC FORMING PROCESSES

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16. Abstract

Extensive material substitution and resizing of the domestic automotive fleet, as well as the introduction of new technologies, will require major changes in the techniques and equipment used in the various manufacturing processes employed in the production of automobiles. The purpose of this report is to document (and analyze) the publically available data on current and projected motor vehicle production processes and equipment and to report on impending changes.

This report describes the details of the metal stamping and plastic forming process, the advantages and disadvantages compared to competitive processes, the equipment and facilities required by the automotive industry, typical plant configuration and cost. The important issues facing these industries are discussed in detail.

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PREFACE

This report is Volume IV of a series of five reports which address changes occurring in motor vehicle manufacturing processes, materials, and equipment during the period 1978 to 1980. The reports present an overview of the major manufacturing processes and materials, and a summary of historical improvements in motor vehicle fuel economy, emissions reduction, and safety. Also included are detailed discussions of vehicle components designed to improve motor vehicle fuel economy, emissions, and safety. The reports also present detailed examination of motor vehicle manufacturing process industries, trends, and issues.

The five volumes in this "Automotive Manufacturing Process" series are listed below:

Volume I - "Overview"

Volume II - "Manufacturing Processes for Passive Restraint Systems"

Volume III - "Casting and Forging Processes"

Volume IV - "Metal Stamping and Plastic Forming Processes"

Volume V - "Manufacturing Processes and Equipment for the Mass Production and Assembly of Motor Vehicles."

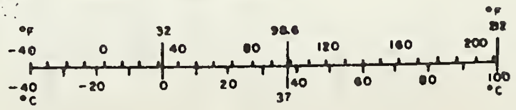
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION

1.1 GENERAL

Government regulations, gasoline prices, and consumer demands are causing unprecedented modifications in the design and manufacture of automobiles. As the auto manufacturers strive to downsize and increase the efficiency of their vehicles, they are changing their requirements for materials and the processes used to manufacture automotive parts. This is having a significant impact on companies that supply materials to and perform manufacturing services for the auto industry.

For example, some suppliers of stamped metal components are facing sudden increases in orders for stamped aluminum and high strength steel parts. Similarly, suppliers of plastic products are also experiencing an increased demand in orders, particularly for automotive fiber reinforced parts. With these trends come problems, however:

- HSLA steels are difficult to form because of their strength and they tend to crack if the necessary deformation is severe. Solutions are therefore needed which will enable the stamping industry to fully utilize HSLA.

- The expanded application of plastics into the auto industry is largely contingent upon the availability of capital to purchase new equipment. Given today's inflationary economy, this is likely to be a problem.

In addition, many metal stampers see plastics as a major threat to the stamping industry and are taking measures to slow the growth of automotive plastic parts. These actions combined with the cyclical nature of the automotive industry may in turn cause the suppliers of plastic parts to think twice before expanding capacity. Thus, the resulting actions taken by these affected automobile suppliers can have significant impacts on the overall health of the economy and on industry, employment, material, and capital needs.

A full understanding of the effects of manufacturing changes on the econony requires a relatively detailed knowledge of the manufacturing processes and industries involved.

Many important questions that are significant to the economy center on manufacturing issues. For instance:

- Will the suppliers of plastics be able to raise the necessary capital to purchase new plastic forming equipment which is needed to satisfy the increased demand for automotive plastic parts?

- Will the suppliers of stamped metal components be able to find new techniques for forming the high strength, low alloy steels, as well as titanium, graphite composites and other sophisticated materials, which are being talked about, but which cannot be formed using conventional machinery?

The answers to these specific and rather technical questions would lead to an understanding of significant general changes likely to take place in our economy.

1.2 SCOPE AND OBJECTIVES OF THIS REPORT

This report defines the techniques, equipment and capital requirements for stamping and forming processes in the automotive industry. It is the fourth in a series of five detailed analyses of automotive manufacturing processes and equipment. The information presented will hopefully provide the broad background and industry understanding that will aid government decisionmakers in evaluating the effects of changing regulations on manufacturers. The report covers the various processes and segments of the stamping and forming industries that are important to automotive production. For each process, information is provided as follows:

- The mechanics of the process, process variations, and different materials involved as they are used in the auto industry.

- The advantages and disadvantages of the process compared to competing technologies.

- The equipment used for the technology in an automotive manufacturing environment.

- The size and structure of each industry, including major companies in the industry supplying automotive parts.

- A typical plant layout with a description of the manufacturing operation and the materials flow.

- The capital requirements for a representative plant serving the automotive industry, including costs by equipment category. Labor and energy requirements are also given.

- Key issues in the industry.

The report should provide enough detailed information to allow the reader to intelligently deal with the automotive issues related to the stamping and forming industries.

In presenting the above material, the chapter on stamping is limited solely to metals and the chapter on forming is limited solely to plastics. The reason for this is that the term "forming" actually encompasses a broad range of manufacturing processes—in its broadest sense, the processes of casting, forging and stamping. The processes of metal casting and forging were covered in detail in Volume III of this series. Thus, since plastic is becoming more popular in automotive manufacturing, it seemed desirable to devote a separate chapter to the processing (forming) of plastics.

1.3 METHODOLOGY

The major sources of information for this report were:

- Technical journals, pamphlets, and books describing current technology

- Industry experts from the various metal stamping and plastic forming industry sectors who are familiar with the latest manufacturing techniques

- Literature from numerous metal stamping and plastic forming companies and discussions with many of their executives and technical personnel

- Literature from metal stamping and plastic forming equipment suppliers and discussions with sales engineers and company executives.

Special effort was made to develop typical automotive plants for each of the metal stamping and plastic forming processes used in the auto industry. These plants serve to clarify the technology involved, portray realistic labor, materials, capital, and energy requirements, and provide a basis to understand the specific effects of changing technology.

In addition, technical information is provided on the various processes so that plant modifications as a result of industry changes may be readily comprehensible. The relationship between the various technologies and particular automotive uses is stressed throughout the report.

1.4 ORGANIZATION

This report is organized into two major chapters—one on metal stamping and the other on plastic forming. The plastic forming chapter is further divided into sections on injection molding, compression molding, and reaction injection molding, the major plastic forming techniques used in the auto industry. Each chapter covers the topics outlined under SCOPE AND OBJECTIVES above.

2. METAL STAMPING

2.1 GENERAL

The stamping of automotive parts and components--primarily sheet metal which is stamped into a myriad of shapes from small washers to large body panels--is one of the most diversified and critical areas of automotive production. In the stamping process, metal stock in the form of sheets, strips and coils is pressed between matching dies under large amounts of pressure in presses. Usually each piece is pressed or stamped a number of times before the final shape of the auto part is achieved. This is accomplished by moving the metal stock through a series of presses or a press "line." The press line is the heart of every stamping operation.

2.2 STEPS IN THE STAMPING PROCESS

Figure 2-1 illustrates the basic steps in the stamping process. At the beginning of the process, the metal stock, usually steel, is uncoiled and fed into the first stamping press. This press performs a blanking operation to form blank pieces of metal from which the auto part will be formed. The metal blank is then automatically transferred down the press line where each press forms a sequential action which helps to form or mold the metal into its final shapes. Some of the pressing actions may include piercing of holes in the blank. Normally the part is transferred down a line of three to six presses, depending on the amount of deformation that is required. When the part has been formed, it is cleaned in a series of baths before being welded and joined with small brackets or other supporting pieces. The finished part is then shipped to the assembly plant for final finishing and assembly.

2.3 PRINCIPAL TYPES OF STAMPING

Stamping processes may be distinguished by the following:

- Stamping Operations
- Materials Used.

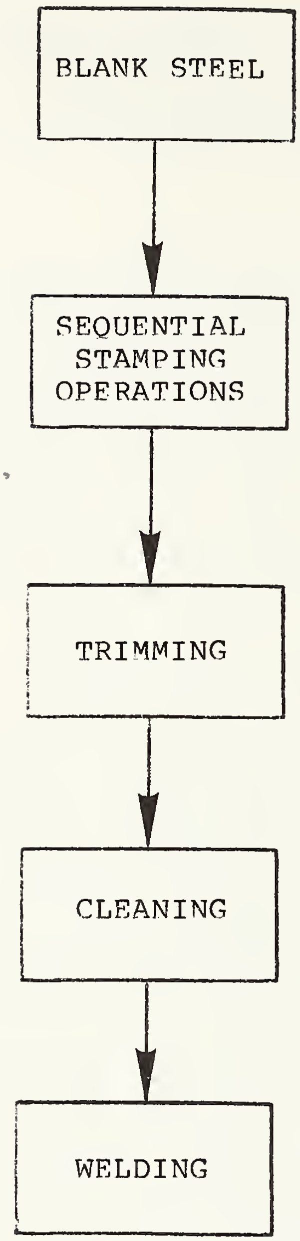


FIGURE 2-1. STEPS IN THE STAMPING PROCESS

2.3.1 Stamping Operations

The major stamping operations used in the automotive industry are blanking, piercing, forming, drawing, coining and bending. Each is described in detail below. Other stamping operations which are used to a limited degree in the automotive industry include:

- Embossing, which is essentially a light forming operation used to produce a pebbled surface or a raised pattern in low relief. The identification plates on an automobile which carry the serial number and other data are embossed.

- Louvering, which is a specialized form of piercing (described below) that produces a series of hooded slots. Typical applications include radio and stereo housings, air conditioning and heating vents.

- Spinning, while not true stamping, spinning is often combined with stamping to produce cylindrical parts. Typical applications include wheel covers and reflectors.

Blanking

Blanking (see Figure 2-2) is a relatively simple process in which a desired shape is cut from a sheet or coil of material. Usually the blank will be further processed, either in the same piece of equipment or as a secondary operation. A typical application of blanking is in producing a round disk from which a cover may be drawn or spun.

Piercing

Along with blanking, piercing (see Figure 2-3) is the most common press operation. The purpose is to produce accurate, precisely located holes, usually for assembly purposes. As with blanking, piercing (also referred to as perforating) is rarely performed alone. It is usually combined with another operation or operations. The applications of piercing are many. Mounting holes in automobile radio mounting brackets is a typical piercing operation.

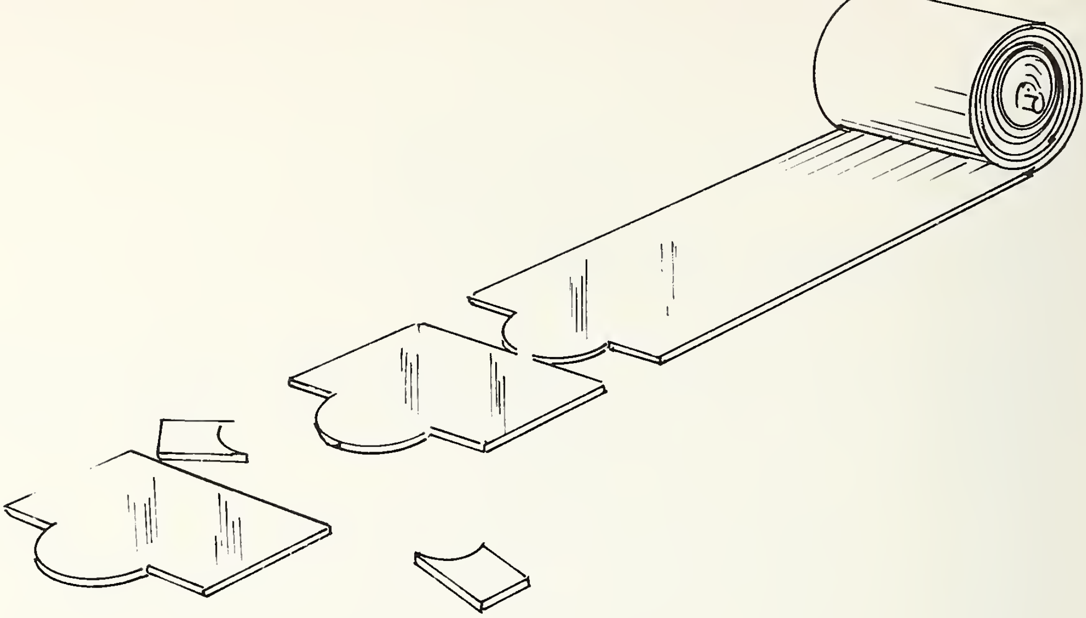


FIGURE 2-2. BLANKING OPERATION

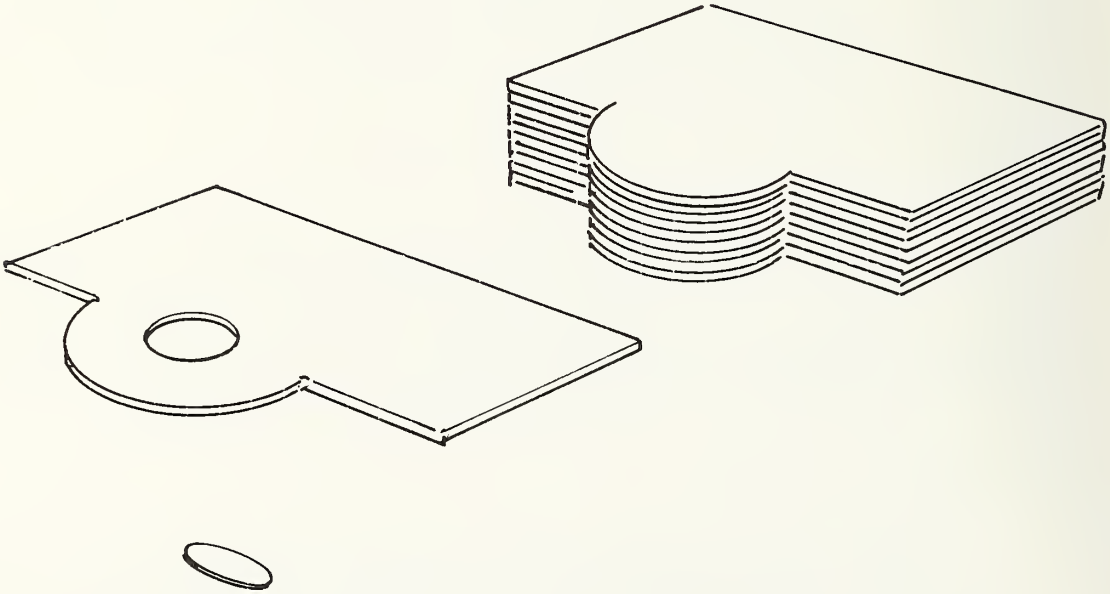


FIGURE 2-3. PIERCING OPERATION

Forming

Forming (see Figure 2-4) is a process that transforms a flat piece of metal into a three-dimensional part without exceeding the plastic flow limits of the metal. It may involve simply turning up one edge of the blank to produce a right angle. Making a "bead" in a flat piece of metal to make it stiffer is forming. About 50 percent of all automotive stampings are formed to some extent. Forming is usually combined with blanking and piercing but it is often a stand-alone operation. A forming operation adds considerably to the cost of a metal stamping die. Some typical forming applications include radiatortanks, crankcase and transmission filler caps. The applications are numerous.

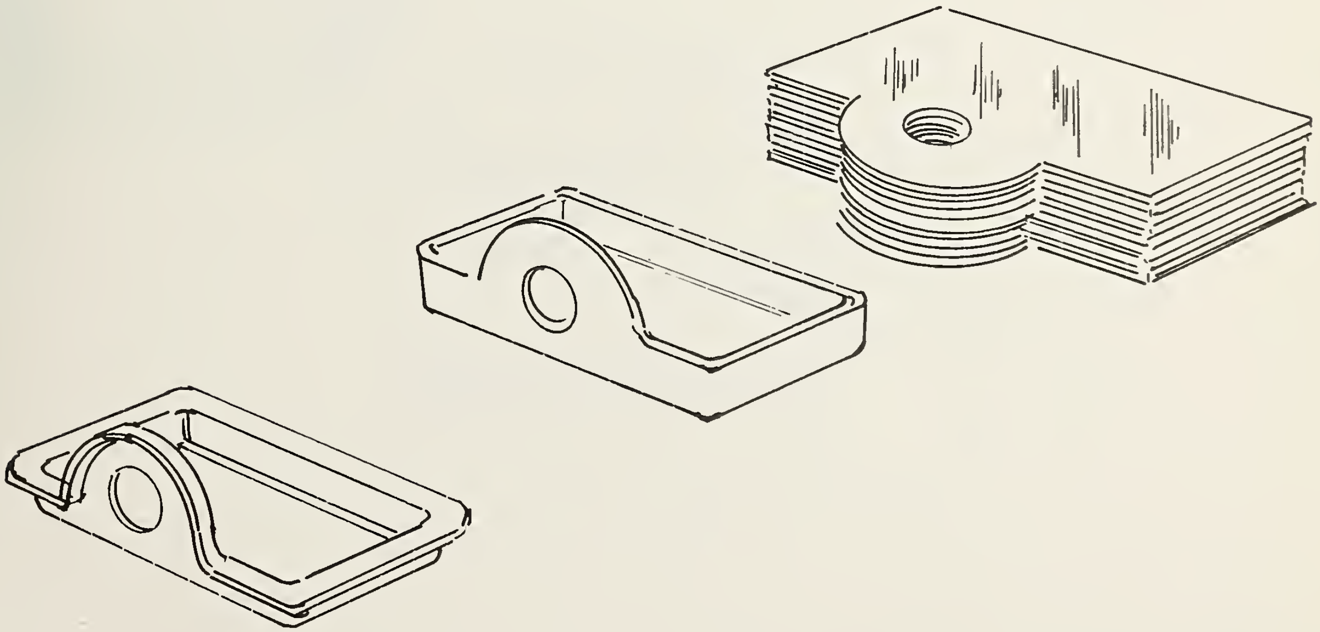


FIGURE 2-4. FORMING OPERATION

Drawing

Drawing (see Figure 2-5) is the most difficult of all stamping operations and one of the most expensive in terms of total cost. In drawing, a flat blank is transformed into a cylinder or box shape--there are infinite variations--by forcing the metal beyond its yield point. Usually a double or triple action press or a press with air cushions is required. Applications of drawing include rocker arm covers, valve covers, and crankcase oil pans.

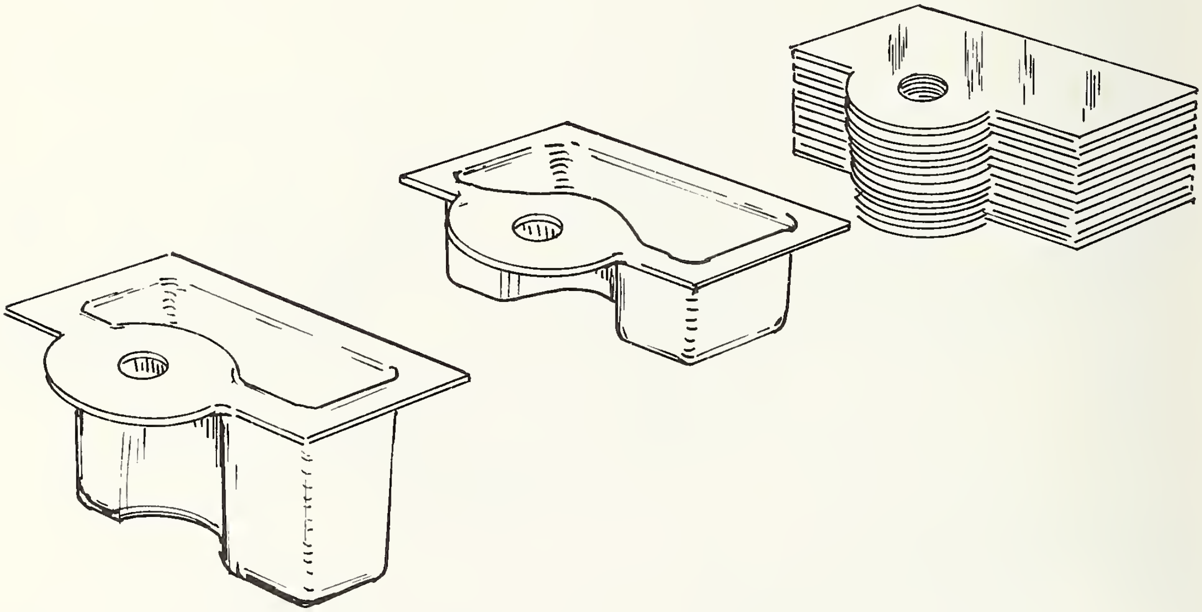


FIGURE 2-5. DRAWING OPERATION

Coining

Coining (see Figure 2-6) involves striking a blank with great force to reduce its thickness and improve its physical properties. Most often it is a final sizing operation following other processes to uphold critical tolerances. A variant of the process is called swaging and the purpose is to flatten the end of a round rod to produce a flat section of much greater diameter. Coining applications include rod ends and valve lifters.

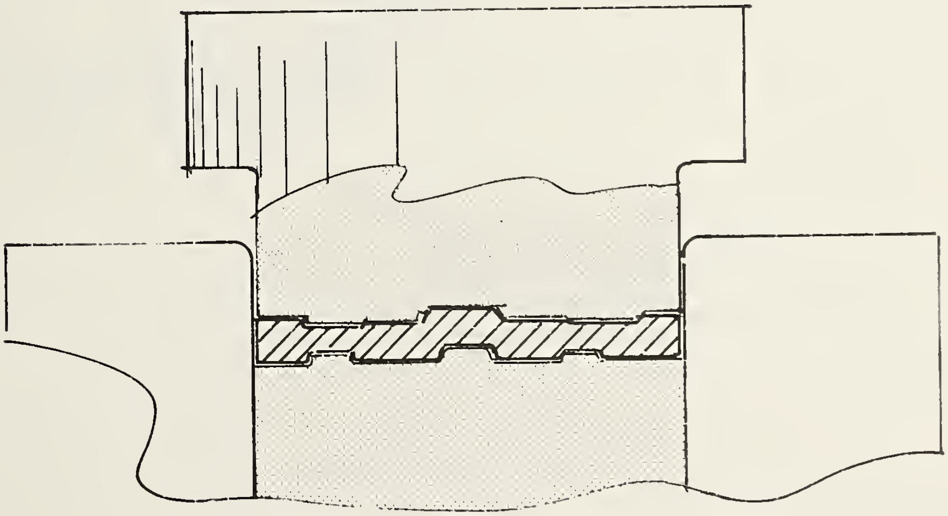


FIGURE 2-6. COINING OPERATION

Bending

Small parts are formed by bending (see Figure 2-7) on a press. Larger parts may be bent on a press brake. This is a relatively simple operation. The tolerances are usually generous. Usually bending is combined with other operations. It is one of the more common operations. There are hundreds of applications. For illustrative purposes, consider an automotive ash tray which is usually made up of one member bent into a U-shape to which side pieces are attached by tabs or by welding.

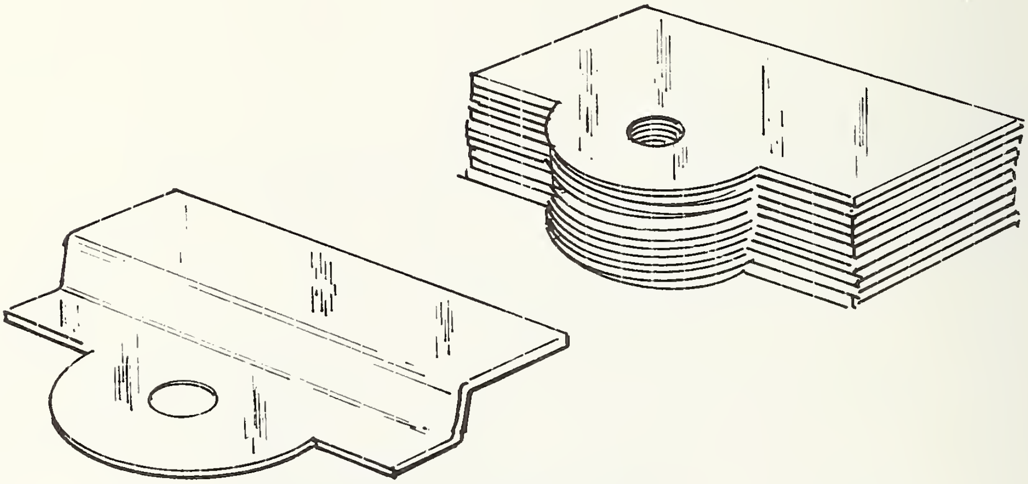


FIGURE 2-7. BENDING OPERATION

2.3.2 Types of Materials Used

Virtually all metals can be and are used in automotive applications. The workhorse is hot rolled steel, pickled and oiled. The runner up is cold rolled steel. Other widely used metals include stainless steel, aluminum and various copper alloys. Even platinum and gold are used; such as platinum catalytic convertors and gold contacts in the computer mechanisms of certain luxury cars.

There is a strong thrust toward the use of zinc clad steels as a corrosion resistant measure. These present no problems to the light stamping industry. They are quite easy to form. The HSLA (high strength low alloy) steels have had some impact but they present some technological problems.

One interesting development is the wider use of dual and triple metals. Typically they consist of a brass or aluminum body to which silver, palladium and even gold are selectively applied, usually as contact materials in automotive electronics. This is a very new area but one which shows much promise.

2.4 ADVANTAGES AND DISADVANTAGES OF STAMPING

The following is a summary of some of the advantages and disadvantages of stamping compared to other manufacturing processes.

2.4.1 Advantages

The major advantages of the stamping process include its versatility, productivity, low cost and the uniformity of its product. In many applications there is no economically viable alternative manufacturing method. The alternatives, in other applications, are confined to machining and forging, both of which are more expensive than stamping. Die casting might substitute for stamping in some cases but die casting is slower, more expensive and has inherent disadvantages. In recent years the trend has been to replace die castings with stampings rather than the reverse.

Stamping is highly productive--probably the least labor intensive of all metal working processes. It is not uncommon to see an operator running as many as three presses, all producing parts at 500 strokes per minute. In a typical stamped part, the direct labor cost is often less than 0.1 percent of the total cost.

Another advantage of stamping is its ability to produce extremely complex parts as a single unit rather than as an assembly of parts. Parts produced in a die are highly uniform which is very important in later assembly work. The only variant is the metal itself.

Finally, stampings have excellent physical properties including high tensile strength, excellent impact resistance and shear strength. The development of selective heat treating technology adds to their versatility.

2.4.2 Disadvantages

The disadvantages of metal stamping include tool and equipment cost and scrap loss. In the long runs typical of automotive production, the high tool cost can readily be amortized. In short runs, this may not be possible. However, the industry has developed what are called short run methods which generally use interchangeable tooling. When this approach is used, the tool charge may be minimal or may even be absorbed by the vendor. High equipment costs are usually offset by long equipment lives.

All processes generate scrap to some extent. Unlike die casting scrap which can be recycled in the plant, stamping scrap must be returned to the furnace. In general, the scrap produced in metal stamping--the skeletons, trimmings, slugs from hole piercing, etc.--averages 17 percent of the total material processed. This compares with the 20 percent average of 10 years ago and is the result of more sophisticated die design. (Some dies are literally "scrapless.")

Because the scrap commands an average of 20 percent of the original material cost, the actual scrap loss is considerably less than the 17 percent in terms of dollars so that scrap, all things considered, is not really a serious disadvantage.

2.5 AUTOMOTIVE APPLICATIONS

It is difficult to determine just how many automotive applications there are for stampings. The average automobile contains between 2,500 and 3,000 stampings. As shown in Figure 2-8, they range from such large parts as the hood, fender, doors, trunk lid and roof to such smaller parts as the oil pan cover, timing chain cover, valve cover, fan and wheels. Other stamped parts include laminations in the

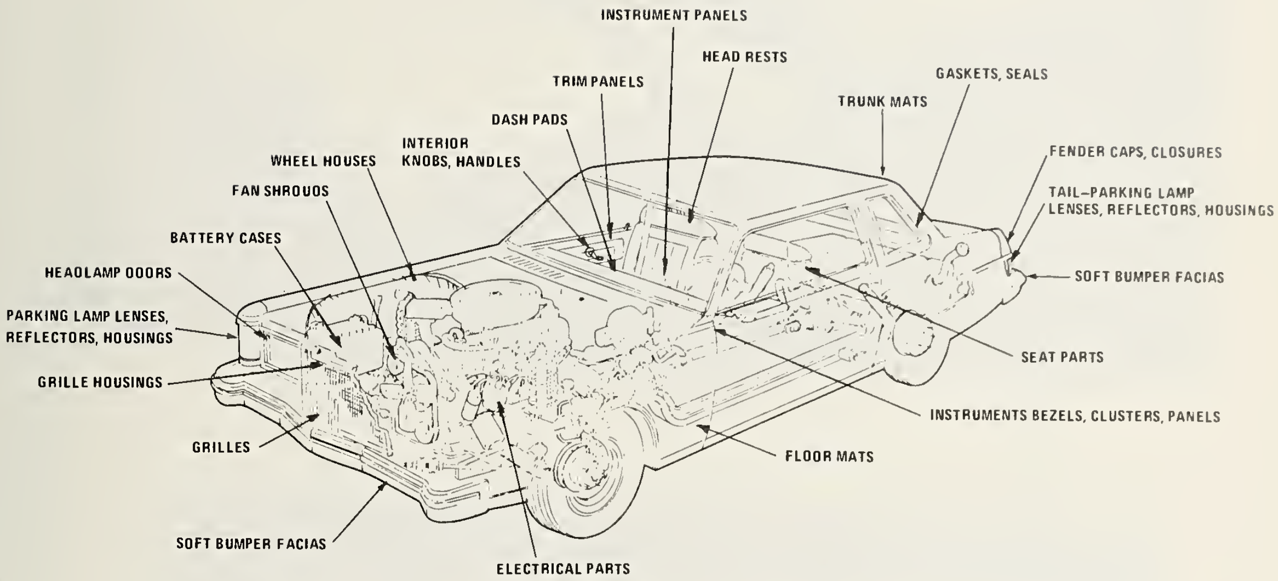


FIGURE 2-8. SCHEMATIC OF AUTOMOBILE
SHOWING COMPONENTS WHICH ARE STAMPED

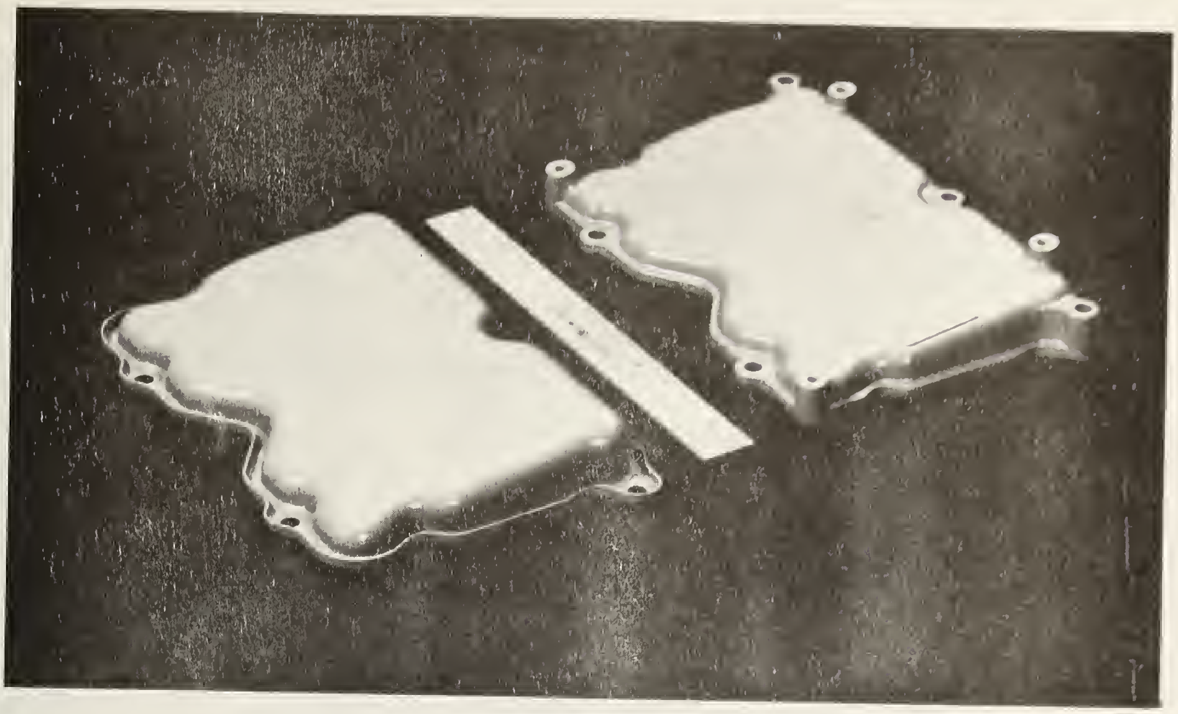
starter and the alternator and the brackets that support them--not to mention the key that turns on the ignition. There are also a great many stamped components in the new electronic engine control devices and because of the many advantages of stamping over other manufacturing processes, other components (e.g., engine crank case breather, rocker cover, oil pan, turbocharger manifold) are being redesigned for stamping. A listing of some of the many typical automotive applications of stamping together with the method and equipment used to make the part and the part production rate is presented in Table 2-1.

Photographs of stamped components are shown in Figure 2-9.

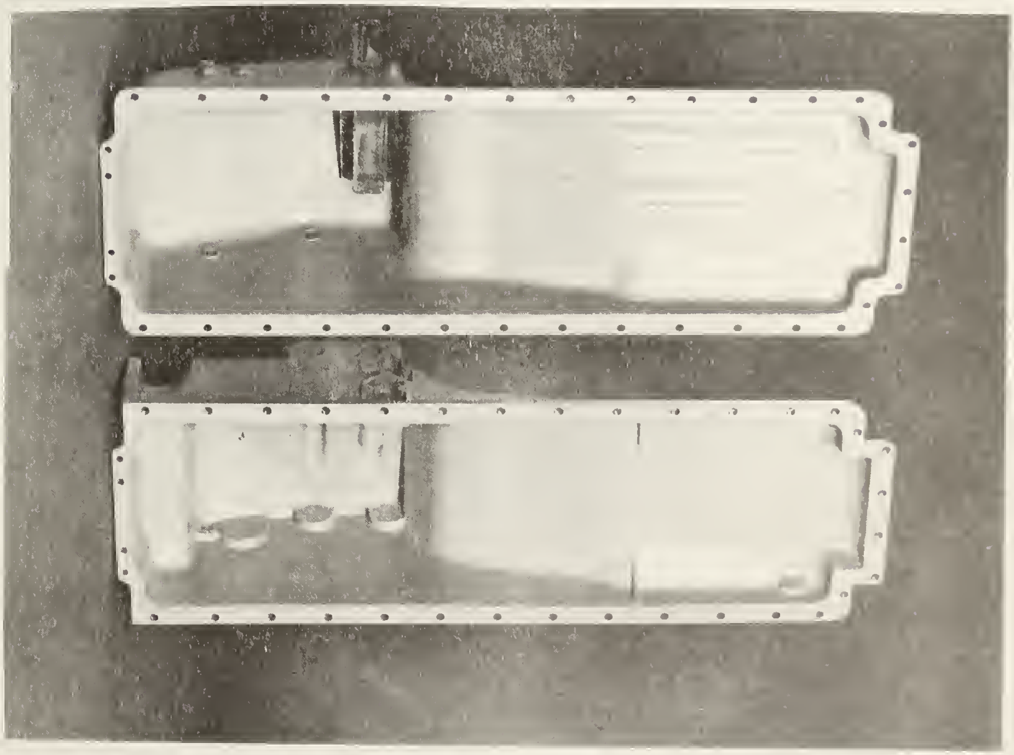
TABLE 2-1. SOME TYPICAL AUTOMOTIVE APPLICATIONS OF STAMPING WITH MANUFACTURING METHODS AND EQUIPMENT

Part	Method	Equipment	Production Rate
Wheel Cover	Spinning	Spinning Lathe	3 per min
Ignition Contact	Transfer	Eylet Press	600 per min
Oil Filter Can	Deep Draw	Double Action Press	30 per min
Solenoid Cover	Blank & Draw	Transfer Press	80 per min
Fuse Box Cover	Magneforming	Capacitor Discharge	6 per min*
Stereo Contact	Progressive die	High Speed Press	1200 per min
Lug Nuts	2-stage Die	Cold Header	300 per min**
Headlight Press	Urethane Forming	Hydraform	80 per hour
Bumper	Form	Heavy Press	160 per hour
Alternator Lamination	Blank & Pierce	Underdrive Press	380 per min
Brake Pedal	Blank & Form	Hydraulic Press	190 per hour
Windshield Wiper	Form and Cutoff	OBI Press	70 per min
Body Trim Insert Nuts	Blank, Pierce, Thread	Four-Slide	80 per min
Carburetor Spring Return Arm	Blank, Pierce, Form	OBI Press	200 per min
Hose Clamps	Pierce, Cutoff, Asemble	High Speed Press	180 per min
Frames and Chassis Members	Pierce, Form, Bend Weld	Heavy Press & Welder	240 per hour
Hoods, Doors, Trunk Covers	Blank, Form, Pierce	Heavy Press Lines	120 per hour

*Experimental
**Two at a Time



Rocker Cover



Oil Pan

Source: American Metal Stamping Association.

FIGURE 2-9 PHOTOGRAPHS OF STAMPED COMPONENTS

2.6 EQUIPMENT REQUIRED

Types of equipment required for stamping include the following:

- <u>Uncoiling and Press Feeding Equipment</u>--Includes an uncoiler, straightener and press feed.
- <u>Stamping Presses</u>--Includes blanking presses, single and double action presses, trim presses and transfer presses.*
- <u>Auxiliary Equipment</u>--Includes conveyors, lubricant applicators, and extractors.

2.6.1 <u>Uncoiling and Press Feeding Equipment</u>

Metal stock is received at the stamping plant in the form of coils or precut blanks for feeding into the stamping presses. Equipment which is needed for handling of the stock prior to the actual stamping includes coil storage racks, uncoilers, straighteners and press feeds. Detailed information on manufacturer, capacity and price of this equipment is listed in Table 2-2. A brief description of each piece of equipment is provided below.

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* In addition to the stamping presses, a complete tool and die inventory is required.

TABLE 2-2. UNCOILING AND PRESS FEEDING EQUIPMENT

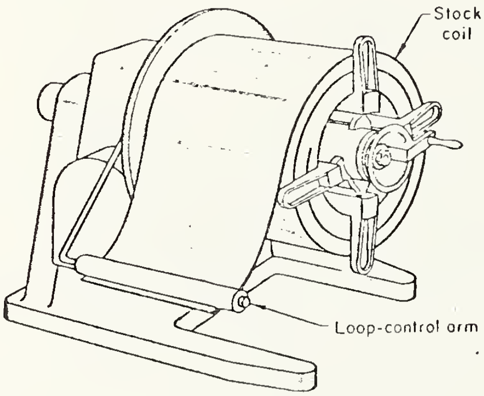
Equipment	Manufacturer	Capacity	Lead Time	Price
Uncoiler	F.J. Littell	20,000 lb. reel	12 mos.	$ 50,000
	Egan Machinery	40,000 lb. reel	12 mos.	$147,000
	Prab Company			
Coil Storage Rack	F.J. Littell			$ 10,730
Straightener	Egan Machinery			$ 35,000
	Rowe Machinery	60" width		
	Regal Industries Corp.			
Press Feed	U.S.I. Clearing			$ 50,000 to $100,000
	Egan Machinery			

Coil Storage Racks

Incoming coils of stock are stored on coil storage racks. A typical coil storage rack is manufactured by F.J. Littell and has a price of $10,730. Many stamping plants use as many as a hundred or more of these racks to store coils of varying sizes.

Uncoilers

Uncoiling or stock reels are used to uncoil the metal stock for feeding into the straightener and press feed. A typical uncoiler is shown in Figure 2-10. Generally, a nonpowered reel is used because the metal is uncoiled by the drive in the the press feed. Manufacturers of uncoilers include F.J. Littell and Egan Machinery and a typical lead time for the equipment is 12 months. Uncoilers range in price from $50,000 for a 20,000 pound stock reel to $147,800 for a 40,000 pound stock reel.

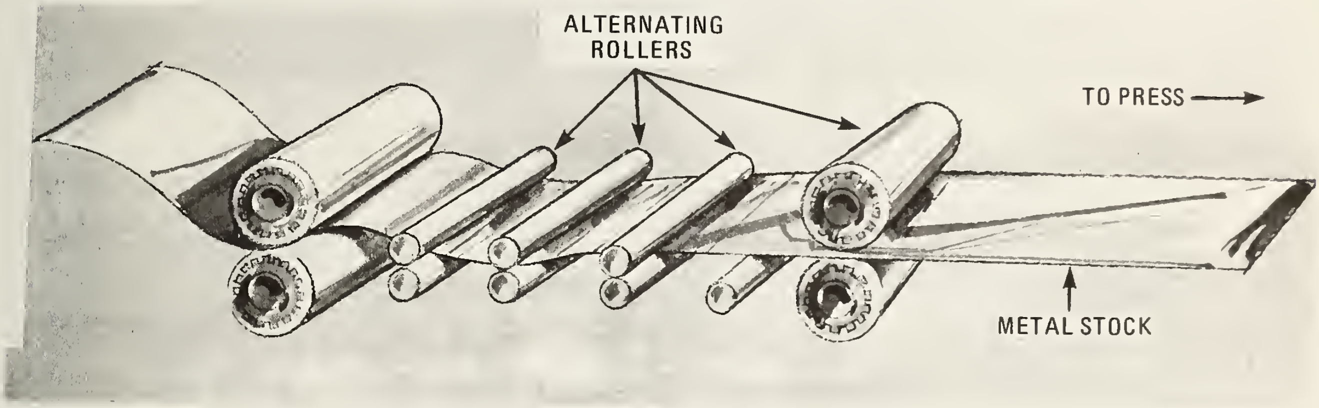


Source: Metals Handbook, Volume 4.

FIGURE 2-10. UNCOILER

Straighteners

As the metal stock is unwound from the coil it is fed through a straightener to reduce any curvature or "coil set" in the metal. The straightener has from five to eleven upper and lower rolls which are alternately mounted in a staggered position. The flat metal moves in between the rolls, as illustrated in Figure 2-11.



Source: Cooper-Weymouth Peterson

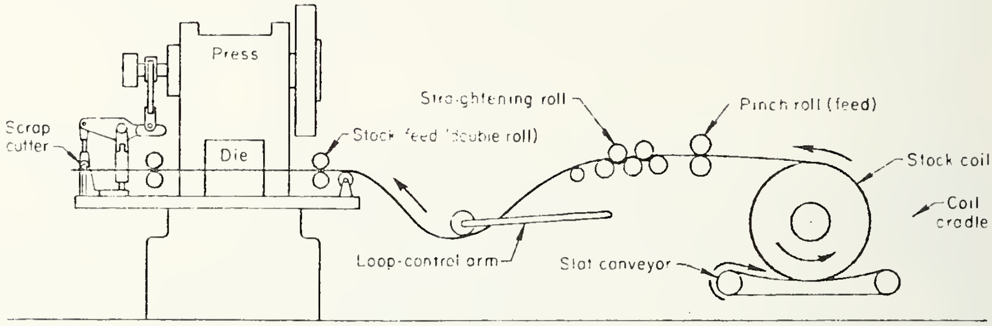
FIGURE 2-11. STRAIGHTENER

Straighteners are integral to the stamping process and are often combined with uncoilers or press feeders to conserve space. Principal manufacturers of straighteners include Egan Machinery, Regal Industries and Rowe Machinery. Straighteners are priced around $35,000 for auto body stock.

Press Feed

The uncoiled and straightened stock is fed automatically into the first press by a press feed. Mechanical press feeds are also designed to feed preformed blanks into the presses. Either kind of feed can be used with almost any kind of press. Figure 2-12 illustrates the combined work of the uncoiler, straightener and the press feed as the metal stock is fed into a press.

Press feeds are manufactured by U.S.I. Clearing, Egan Machinery and a number of other firms. They range in price from $50,000 to $100,000.



Source: Metals Handbook, Volume 4.

FIGURE 2-12. PRESS FEEDING EQUIPMENT

2.6.2 Stamping Presses

Stamping presses are made to perform a broad range of functions including the following:

- Blanking
- Piercing
- Forming
- Trimming.

Press sizes range according to the size of the bed they are designed to handle. A typical bed for an automobile roof is 80 inches wide and 240 inches long.

Typically a large number of presses are required and they are generally purchased in "families" where the presses are compatible but the bed sizes vary slightly. Presses for body stampings range in stamping pressure from 600 to 1,000 tons. Typical yields are 300 to 500 parts per hour.

Principal types of stamping presses used in the manufacture of exterior body parts include the following:

- Blanking Press
- Double Action Press
- Single Action Press
- Trim Press
- Transfer Press.

Each press is described below. Detailed cost and manufacturer information on the presses is shown in Table 2-3.

Blanking Press

Typically the first press in the stamping line is the blanking press. This press cuts the coil into individual blanks for forming into auto body parts and then ejects the blanks for continued transfer down the press line. Generally the blanking press is a single action press with the coiled stock fed in through the side or the front. Figure 2-13 shows a photograph of a typical blanking press preceded by an uncoiler and press feeder. Blanking press capacities for typical stock used in pressing body parts range from 400 to 600 tons. Manufacturers of blanking presses include Verson Allsteel, Danly Machine and U.S.I. Clearing. The typical lead time for a blanking press is 12 to 17 months, and prices range from $325,000 to $650,000.

Double Action Press

In an automotive stamping line a double action press typically follows the blanking press. Double action presses have two slides.* The outer, or blankholder slide, dwells and holds the blank while the inner, or punchholder slide, descends to perform the drawing operation. The action of the press is illustrated in Figure 2-14.

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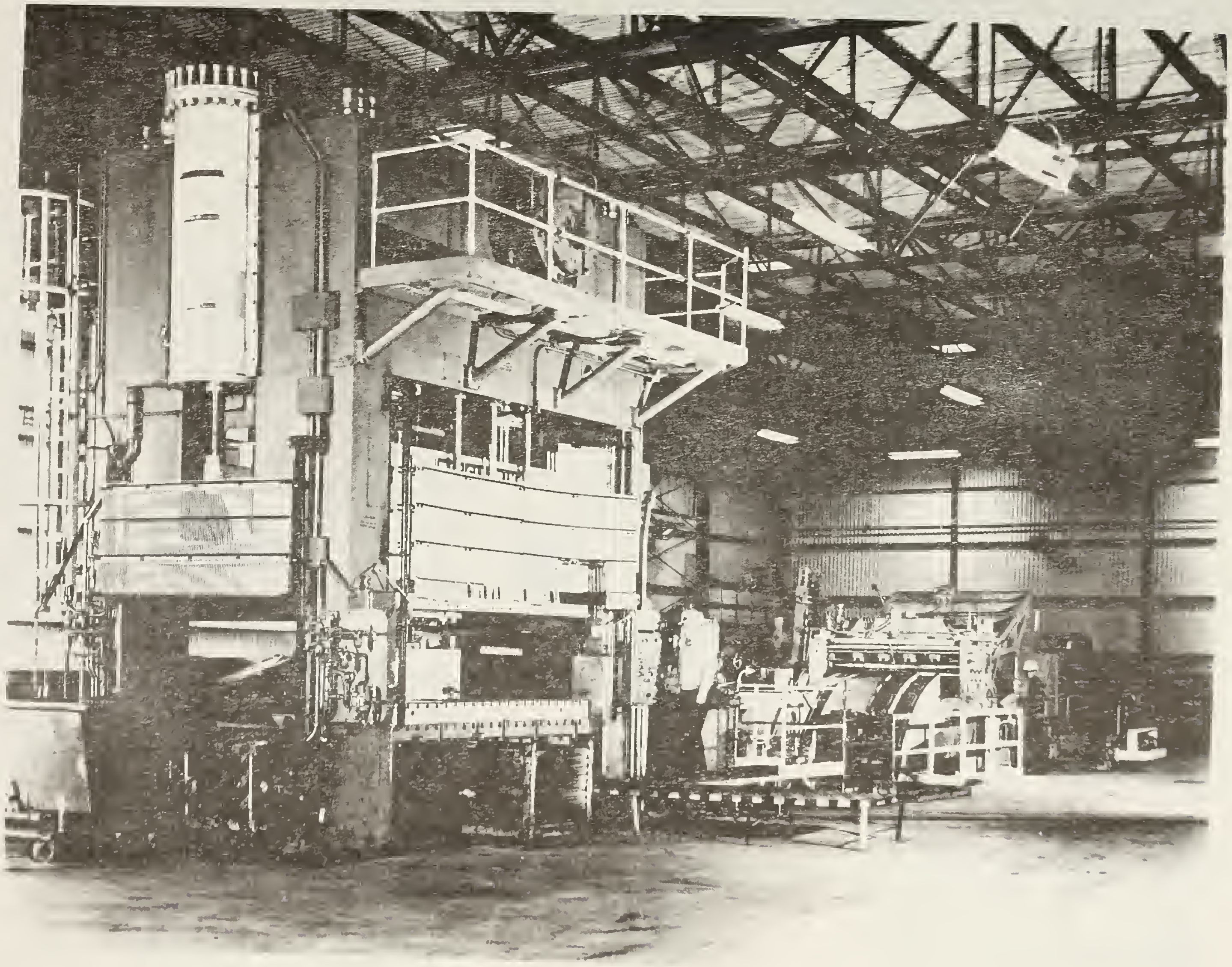
* The slide is the section of the press that moves, carrying the upper part of the die toward the mating tool part.

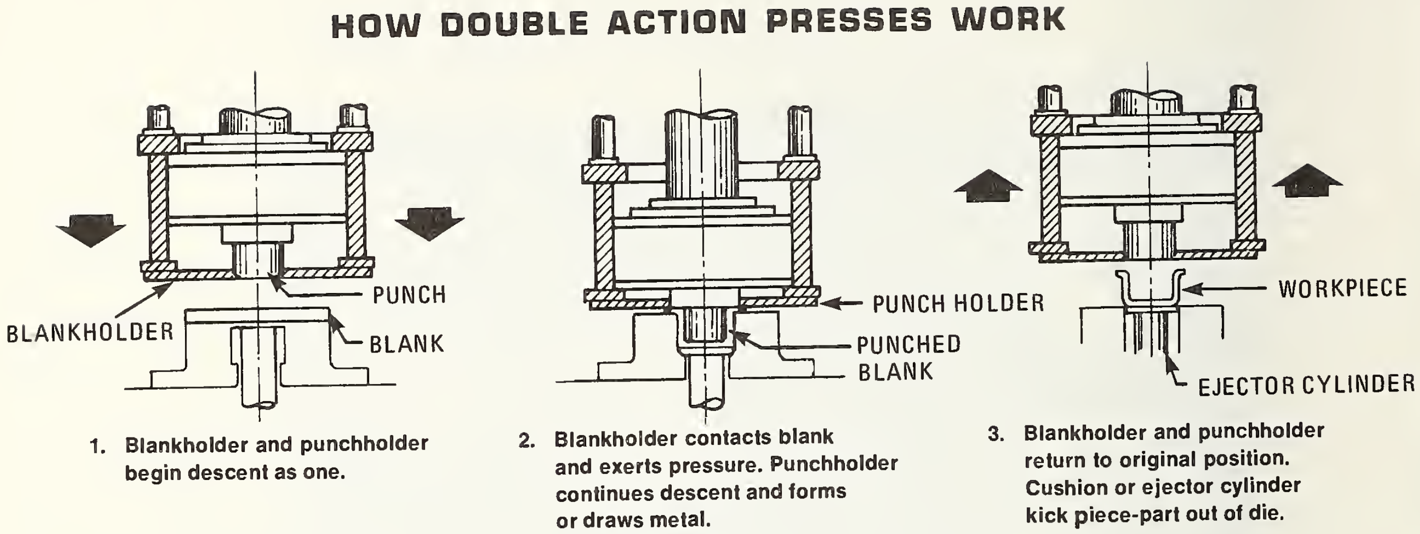
TABLE 2-3. STAMPING PRESSES

Equipment	Manufacturer	Capacity	Lead Time	Price
Blanking Press	Verson Allsteel Danly Machine U.S.I. Clearing	600 Ton 400 Ton	12 to 17 months 12 to 17 months	$325,000 to $650,000 $300,000
Double Action Press	Verson Allsteel Danly Machine U.S.I. Clearing E.W. Bliss	1,600 Ton		$1 million to $1.5 million
Single Action Press	Verson Allsteel Danly Machine U.S.I. Clearing	1,200 Ton 1,000 Ton 800 Ton 300 Ton	12 to 17 months	$950,000 $875,000 $400,000 $250,000
Trim Press	Verson Allsteel Danly Machine U.S.I. Clearing	600 Ton 300 Ton	12 to 17 months	$650,000 $450,000
Transfer Press	U.S.I. Clearing Verson Allsteel	4,000 Ton		$3.3 million



Source: U.S.I. Clearing.

FIGURE 2-13. A TYPICAL BLANKING LINE INCLUDING UNCOILER, STRAIGHTENER, PRESS FEED AND BLANKING PRESS



Source: Verson

FIGURE 2-14. MOTION OF SLIDES IN A DOUBLE ACTION PRESS

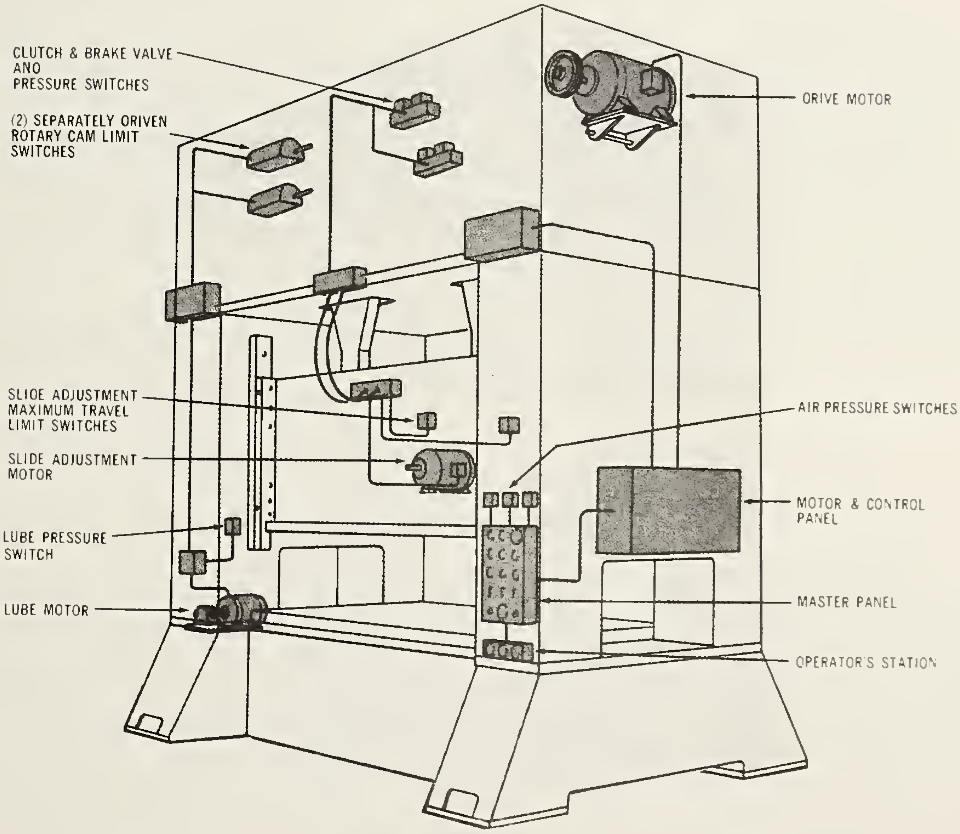
As with most presses in high volume stamping lines, the double action press comes equipped with sensors for detecting overloading. Misfeeds or double blanks are common causes of press overloading which can damage the die or the press. Built-in detectors stop the press before overloading occurs. Another common accessory to the press is rolling bolster assemblies which permit easy die changes. Dies are set up on an assembly outside the press. When a press run is finished, the punch and blankholder are unclamped from the slides and the assembly is rolled out from under the press. Then, the waiting assembly is moved into place, the punch and blankholder are clamped to the slides, and the press is made ready to run.

Double action presses are manufactured by Verson Allsteel, Danly Machine, U.S.I. Clearing and E.W. Bliss. Prices for a 1,600 ton double action press range from $1 to $1.5 million.

Single Action Press

Single action presses have one moving slide that applies force to the workpiece. The slide carries the punch, or upper part of the die, towards the press bed. Most single action presses in automotive press lines are mechanical rather than hydraulic. Mechanical presses cycle faster and are better suited to high production.

In a single action straight side press, work may be entered through the front or the side and is ejected through the back of the press. A single action straight side press permits the use of an endless variety of bed and slide sizes. Figure 2-15 shows the location of controls and motors on a typical single action press.



Source: Verson

FIGURE 2-15 . SINGLE ACTION PRESS

Single action presses are manufactured by Danly Machine, Verson Allsteel, U.S.I. Clearing and some 30 other manufacturers. Prices range from $250,000 for a 300 ton press to $950,000 for a 1,200 ton press. Lead times range from 12 to 17 months.

Trim Press

The trim press is typically the last press in the stamping line. Operations such as coining may be performed on the trim press to give final accuracy and dimension to the workpiece. Lower tonnages are required for trim presses than for the single and double action deep drawing presses. Manufacturers of trim presses include Verson Allsteel, E.W. Bliss, Niagara Danly Machine and U.S.I. Clearing. Prices range from $450,000 for a 300-ton press to $650,000 for a 600-ton press.

Transfer Press

Transfer presses combine a number of pressworking operations in a single self-contained unit equipped with sophisticated electronic controls. Blanks and workpieces are automatically transferred through multiple die stations in the transfer press by means of mechanical fingers. This eliminates expensive material handling requirements between conventional press systems. Other advantages of transfer presses are:

- With capacity for as many as 13 stations, transfer presses can replace a large group of individual presses and reduce the number of press line workers.

- A single transfer press equipped with electronic diagnostics is simpler to maintain than six, eight or twelve or more individual presses.

Transfer presses are designed and built to meet the user's specific requirements. Presses used in the stamping of suspension and transmission parts generally range in size from 3,000 to 4,000 tons. Manufacturers of transfer presses include U.S.I. Clearing, Verson and E.W. Bliss. The estimated price for a 4,000 ton transfer press is $3.3 million.

2.6.3 Auxiliary Equipment

Auxiliary equipment generally used in the press line includes:

- Conveying Systems
- Lubricant Applicators
- Extraction Equipment.

A description of each type of equipment is provided below. Detailed cost information is shown in Table 2-4 Additional equipment which is common to all stamping plants includes fork trucks, overhead bridge cranes and other material handling equipment. Typical quality control equipment includes height gauges, surface plates, optical comparator* and a wide range of go-no go dimensional gauges used at the press.

Conveying Systems

Careful material handling is necessary to the stamping operation to avoid damage to parts. Conveyor belts or vibrating platforms are used to move the partially completed workpieces to sequential operations in the press line. The design of the conveyor system can vary considerably, with as many as six individual conveyors removing workpieces and scrap from a single press as illustratd in Figure 2-16. Typically, each press requires from 3 to 4 conveyors. Conveyor belt systems are manufactured by Dorner Manufacturing and Prab among others.

Lubricant Applicators

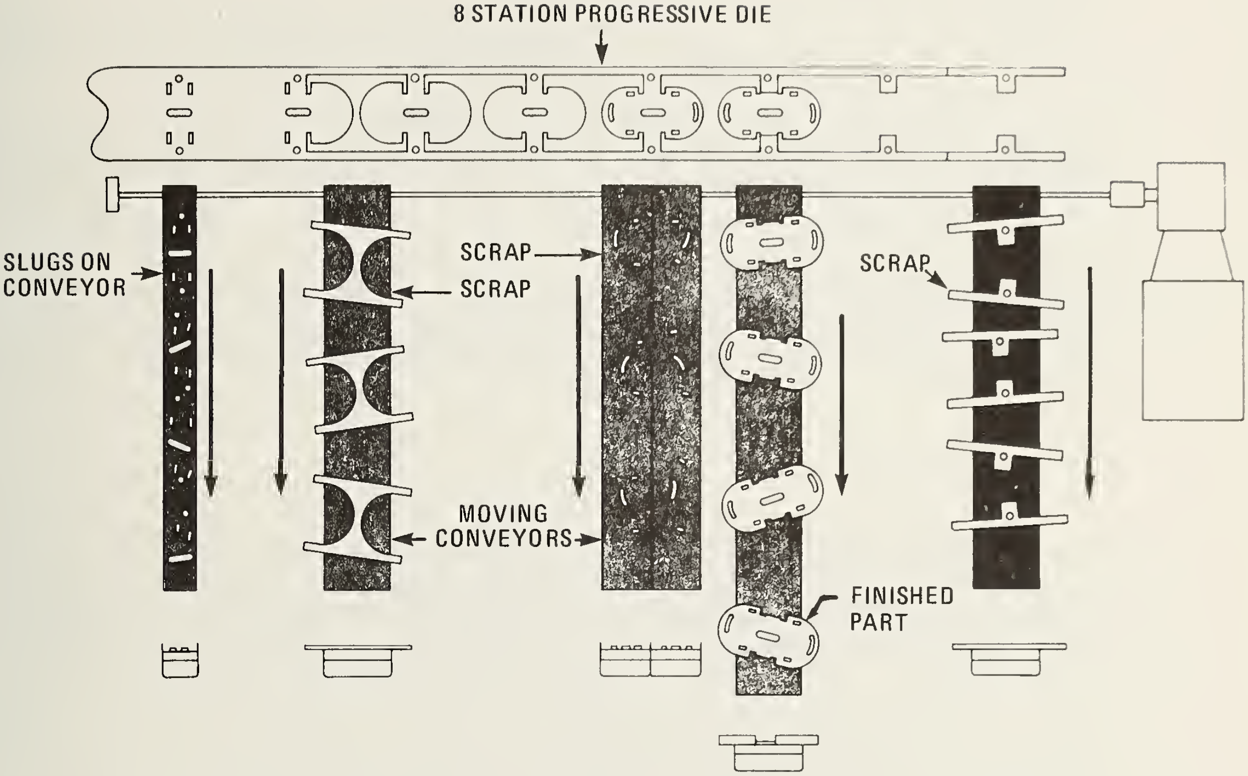
The coiled steel supplied to stamping plants usually comes with a light coating of oil. Often, if the metal has to be bent at a sharp angle, an additional lubricating compound is rolled or sprayed onto the metal before forming.

A recently developed type of mist dispenser permits highly selective applications of lubricant to critical areas of the die. Typical suppliers of lubricant applicators include Bijur and Jet Set. The price of a unit suitable for 60-inch wide material will range from $1,500 to $2,000.

* A comparator is an optical piece of equipment used for projecting the outline of a part on a screen to check its dimensions.

TABLE 1-4. AUTOMATION BETWEEN PRESSES AND AUXILIARY EQUIPMENT

Equipment	Manufacturer	Capacity	Lead Time	Price
Conveying Systems	Dorner Mfg. Corp. Prab Company			
Lubricant Applicators	Bijur Jet Set	60" wide stock		\$ 1,500 to \$ 2,000
Extraction Equipment	Sahlin I.S.I. Manufac.	14 to 18 stampings per minute		\$ 6,000 to \$25,000
Coil Loading Car	F.J. Littell	20,000 lb. 40,000 lb.	12 mos. 12 mos.	\$13,800 \$33,700



Source: Dorner

FIGURE 2-16. REMOVAL OF WORKPIECES AND SCRAP BY MEANS OF CONVEYORS

Extraction Equipment

Most modern press lines have automatic press loading and unloading systems. Unloading the workpiece from the press and placing it on the conveyors is accomplished by extractors or "iron hands" which reach into the press and pick up each piece. I.S.I. Manufacturing and Sahlin International both manufacture press unloading systems. I.S.I. makes a rack and pinion shuttle unit with a vertical lift or a cross shuttle bracket, for movement vertically or to the side. Vacuum actuators or grippers that come in several sizes are mounted on the shuttle unit. When the dies are changed, the unit may be moved out of the way, either vertically or to the side.

Sahlin International manufactures a high lift extractor with 6 inches of initial lift in the jaw assembly. Flat pads with vacuum jaws pick up stampings in the center and move them out of the press.

Stamping extraction systems such as the I.S.I. and the Sahlin equipment range in price from $6,000 to $25,000 per press. The spread reflects the number and size of motions required.

Coil Loading Car

Movement of the heavy coiled stock from the metal storage area to the press lines often requires special coil loading cars, a trackway for automatic movement of the cars and a single push-button control unit for controlling all operations of the cars. F.J. Littell manufactures a coil loading car capable of handling a 72 inch wide, 20,000 pound reel. The car is priced at $13,800. A 220 inch trackway for the car is priced at $6,260 and the push-button controls cost $2,770.

2.7 SIZE AND STRUCTURE OF THE STAMPING INDUSTRY

Like other manufacturing industries which serve the auto industry, the stamping industry is composed of two major types of operations:

- Contract operations, where the parts and components are made by independent companies and sold to the auto industry
- Captive operations, where the parts and components are made in-house by the auto company, usually by a separate division or plant of the company.

Each is discussed below.

2.7.1 Contract Operations

The contract stamping industry is a major supplier to the automotive industry. The exact size of the contract industry's contribution is difficult to measure since it is more often indirect than direct. For example, a maker of specialized stainless steel washers may sell his product to X company which sells subassemblies to Y company which makes windshield wipers for GM cars. However, it is estimated that of the 2,500-3,000 stampings used in an automobile approximately 2,000 are bought outside,* primarily the smaller stampings, by the auto manufacturers.

Size and Nature of the Contract Industry

The contract stamping industry includes about 3,000 individually owned businesses. Sales for the industry total about $14 billion annually. The median stamping company has 35 presses and 100 employees. Some, of course, are much larger; some are much smaller.

The industry tends to specialize. It may have expertise in high volume production of small precision parts; it may specialize in deep drawing; it may concentrate on assembly as well as stamping. To some extent the type of speciality is dictated by the equipment--and vice versa.

Geographic Focus

The industry is widely scattered. Where once it was concentrated in major industrial centers--Detroit; Cleveland; Chicago, etc., it has dispersed itself pretty much across the country. In some cases it has followed other industries--IBM, GE, etc. More often it has set up plants in areas where the climate, the tax incentives and, above all, a nonhostile labor attitude were considerations. Except for the extreme

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* The reasons why so many parts are purchased from outside vendors by the auto manufacturers are that (1) they can be made for less money by outside vendors, (2) the auto manufacturers can exercise more control over their vendors than they can over their internal manufacturing division and (3) floor space is usually tight and it is not often feasible for automotive plants to stock large inventories.

Northwest - Idaho, Montana and North Dakota, contract stamping industry services are available everywhere in the U.S.

Importance of Automotive Business

Of the 3,000 companies involved, a handful--perhaps 50--are 75 percent to 100 percent involved in the production of automotive stampings. They maintain close liaison and for practical purposes they are part of the industry. The companies for which they work consider them as adjuncts.

Some companies do not like to be reliant on any one market. These companies deliberately keep their automotive commitments to a 50 percent level or less. The breakdown given in Table 2-5 can be assumed to be reasonably accurate.

TABLE 2-5. NUMBER OF CONTRACT COMPANIES BY PERCENT OF AUTOMOTIVE BUSINESS

Percent Automotive Business	Number of Companies	Percent of Total	Cumulative Percent
75 to 100%	150	5%	5%
50 to 75	300	10	15
25 to 50	800	27	42
0 to 25	1,750	58	100
TOTAL	3,000	100%	-

Note that these figures refer to direct sales. It is impossible to "track" indirect sales.

The contract stamping industry has been steadily improving its position in the automotive industry over the last decade. In general, it is more efficient, has better equipment, less overhead, and pays lower wages than the automotive industries. The automotive industries use sophisticated "Make or Buy" analysis on new components and usually make the decision on a bottom line basis which favors outside contracting.

Over the decade ahead, the automotive industry will go outside for parts and components at an increasing rate. They are tending strongly to contract not only for stamping but for subassemblies; window and door latch assemblies, hood latches and springs, etc.

2.7.2 Captive Operations

Approximately 60 percent of all stampings in terms of weight are produced by the auto manufacturers themselves. These include the larger body and frame stampings. All four of the major domestic automobile manufacturers -- GM, Ford, Chrysler and AMC--own and operate plants which make these stampings.

2.8 CHARACTERISTICS OF A TYPICAL PLANT

The following sections describe a typical automotive stamping plant first in terms of the layout of the plant and sequence of operations through the plant which is essentially the same regardless of the type of operations (captive versus contracted) and second, in terms of capital (building, land and equipment), labor and energy requirements. To cover this second part, two separate plants are presented--a typical captive plant and a typical contract plant--to show the vast differences between these two types of operations.

2.8.1 Plant Layout

In terms of plant layout, modern stamping plants whether captive or contract tend to embody the best principles of industrial plant design. Where once the presses were jammed together wherever they would fit, with material supply and access to the press for die change and repair strictly a hit or miss proposition, they are now positioned in such a manner as to expedite material flow and reduce material handling to the lowest possible level.

Plant layout will vary but on average the stamping plant would employ its space as follows:

- Receiving and Material Storage 15%
- Offices, Cafeteria, Washrooms 20%
- Shipping 10%
- Tool Room and Die Storage 10%
- Press Room (including maintenance) 40%
- Compressor--Tumbling--Miscellaneous 5%

As shown in Figure 2-17, most plants are laid out on a straight line basis with the material storage area located in the rear and having direct access to the press room. The accepted practice is to line the presses up side by side and facing each other across an aisle wide enough to accommodate a forklift truck with special attachments to handle coil stock and dies.

Generous space between adjacent presses must be provided for uncoiling equipment, straighteners and feeds. Presses used are almost universally fed from left to right rather than from front to back. Manually fed presses, of course, are fed from the front.

In a plant using both automatic and manually fed equipment, the latter is usually grouped by itself. There are several reasons. The manually fed presses are provided with hoppers in which work in process is stored--this work in process is usually the output of the automatic presses which feed the hoppers by means of conveyors. Further, the automatic presses are very noisy--from 90 db to 100 db.

An automatic press produces two things--parts and scrap. The scrap includes the slugs produced when holes are pierced and the skeleton used to retain the part during processing. Normal practice is to eject the scrap out of the rear of the press into a container or onto a conveyor belt. The scrap, including the skeleton which is dropped into short lengths at the press, is collected at the press in drums.

The industry makes extensive use of conveyors and in some modern plants the scrap is deposited on conveyors running under the floor and collected in large special containers provided by the company's scrap dealer.

2.8.2 Sequence of Operations (Workflow)

As noted, material flow in the stamping plant is essentially straight line. It is affected strongly by the form in which the material is received and the manner in which it is processed.

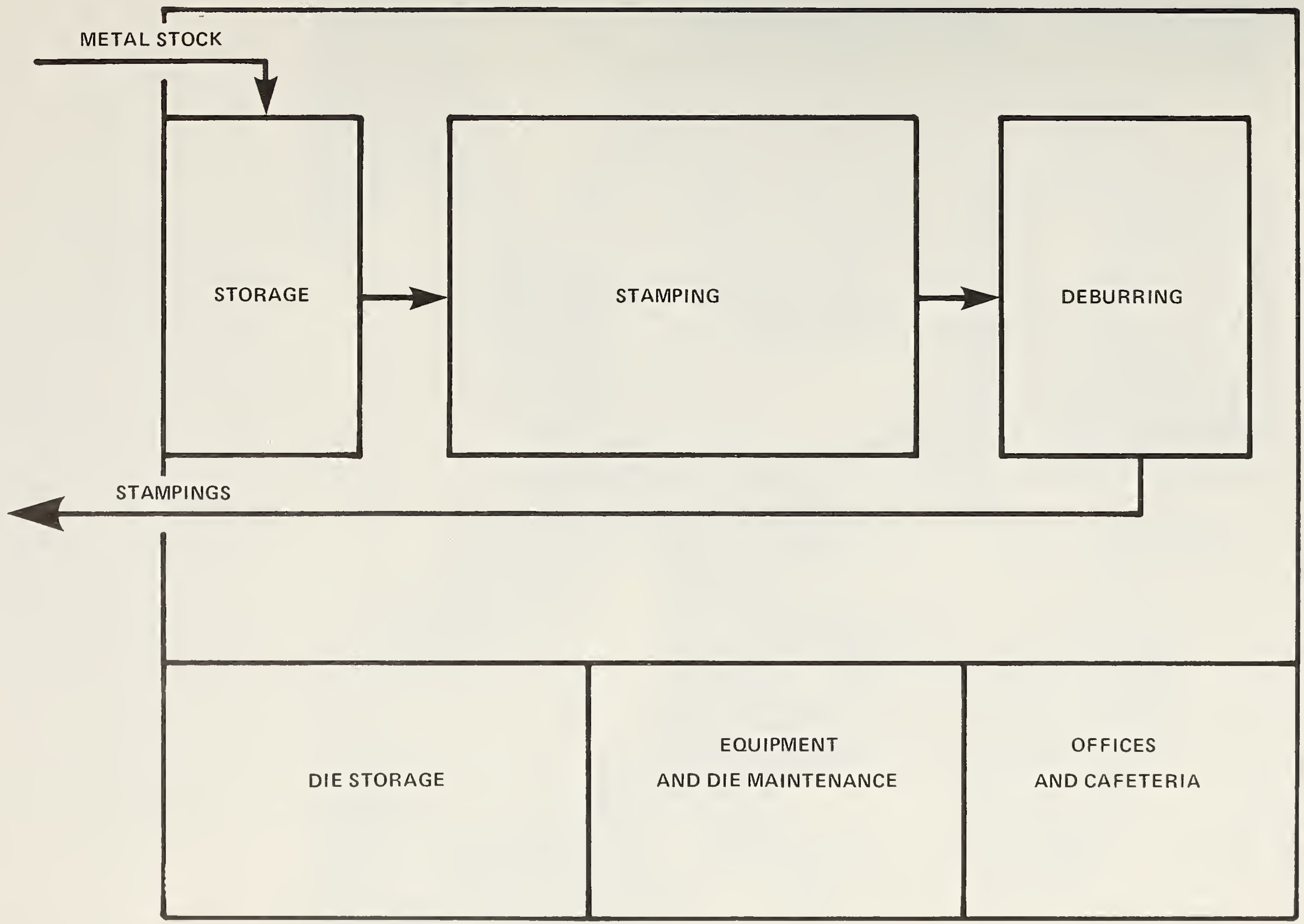

FIGURE 2-17. LAYOUT OF A
TYPICAL STAMPING PLANT

Materials Receiving and Storing

Materials are supplied in several forms:

- In the form of precut blanks. This is usually applicable to round and rectangular blanks. The blanking operation is performed by the metal center and carries a premium.

- In the form of large sheets which are sheared into strips of the desired width in-plant.

- In continuous coils which are automatically fed to the equipment. Because of the generally high volume of automotive stamping orders, this is by far the preponderant form and its use is rapidly increasing. OSHA has been a factor in this growth as has been a technological development called wire EDM which sharply lowers the cost of the tooling required to utilize coil material. The steel is inventoried and temporarily stored until required on the press lines. Figure 2-18 shows a number of these large coils waiting to be utilized.

Stamping

The next step in the sequence of operations is the actual stamping of the metal stock. Coils are delivered to the uncoiler by special forklift trucks, cranes, or coil cars and mounted on reels at the head of the press line. The steel is uncoiled, threaded through a straightener and automatically fed into the first press in the press line.

A typical line might include from five to seven presses in capacities from 1,000 to 2,000 tons.* The sequence of operations might include:

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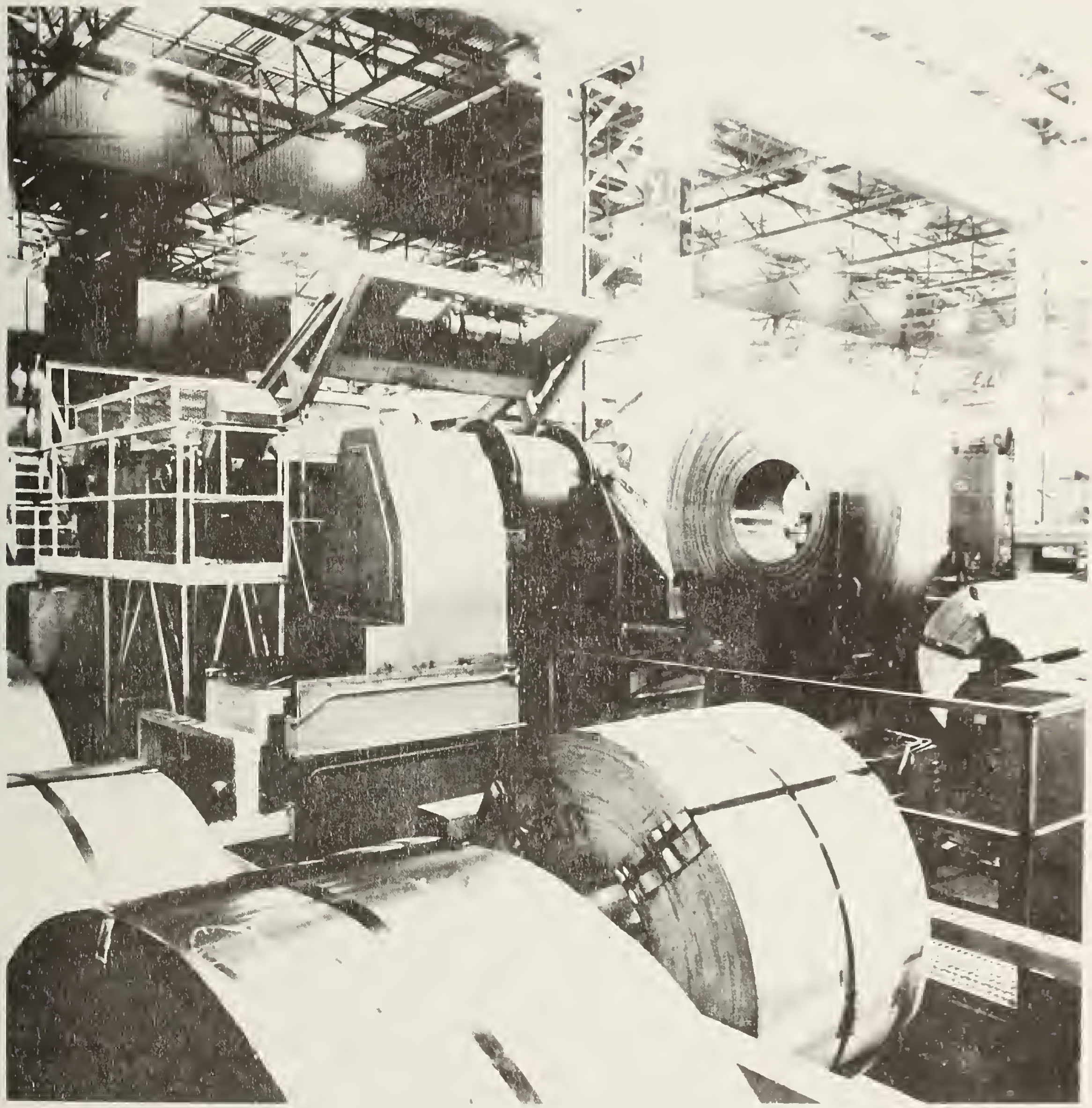
* In the production of smaller automotive components, it is customary to combine a number of operations in one tool; i.e., blanking, piercing, forming, drawing, etc. The most widely used tool is the progressive die. A typical progressive die will have about seven "stations" although some may have as many as 20. Some carbide dies with multiple stations may cost as much as $50,000 and up. When a progressive die is used, the blank is only partially cut. Enough of a "web" is left to retain the piece in the skeleton until the final operation when the skeleton is scrapped.



Source: U.S.I. Clearing

FIGURE 2-18. STEEL COILS IN
A STAMPING PLANT

- Blanking to produce the desired shape.
- Piercing to produce the desired holes and apertures.
- Forming to initiate the required third dimension.
- Forming to refine the desired shape.
- Sizing (coining) to insure accurate dimensions of the formed section. This is actually a final forming operation.
- Trimming to remove unwanted metal around the periphery of the part.

Usually there is some automation between the presser either in the form of conveyors or the widely used "iron hands." The latter are a simple form of robot with three axes of motion. Press lines of this type are extremely expensive as is the tooling and they require very large lot sizes if they are to be economical. Die change in a press line of this type is also difficult and time consuming and may require a full day or more as compared with the 15-minute die changeover typical of the light stamping industry. Some large presses are equipped with dual bolsters--the bolster is the bottom member to which the die is mounted. This makes it possible to preload a tool while another tool is still working.

Deburring and Finishing

As shown in Figure 2-17, the final step in the sequence of operation is deburring and finishing of the part. After the part is completed it may require washing but more often than not the lubricant left on the part after forming is allowed to remain as protection against rust. If smooth rounded edges are required, the part is "tumbled." This involves placing it in a revolving drum containing steel balls, abrasive stones or even walnut shells or corncobs depending on the finish desired. If the parts are large and unwieldy and cannot be tumble finished, the sharp edges called burrs are removed by abrasive methods.

Tumbling and washing (if required) are always "in-house" operations. This is not the case with heat treating or plating. About 8 percent of automotive stampings are plated or galvanized or, if aluminum, anodized. About 5 percent are heat treated to make them harder and more wear resistant. These processes are usually subcontracted out to specialist companies. It is important to note that control of and responsibility for the quality of these processes remains with the original vendor.

2.8.3 Capital, Labor and Energy Requirements for a Typical Plant

Each stamping plant has a unique layout and press inventory depending upon the types of stampings which are produced. Large captive stamping plants generally provide all of the major body stampings for several make/model lines. These plants usually have a wide selection of presses, ranging from 1,600 ton double action presses to small presses for making brackets and small parts.

Independent or contract stamping operations tend to be more highly specialized than the captive plants. The contractor will develop a high volume capability in a few select stampings (usually small trim, electrical or other accessory components) and thus offer these products at a low cost to the auto companies. Additional characteristics of each type of plant are described below.

Typical Captive Plant

Typically a captive automotive stamping plant would be a large facility capable of manufacturing most of the body stampings for 175,000 cars per year. Products of the plant would include roofs, hoods, doors, quarter panels, oil pans and all other major stampings and supporting brackets. The selection of equipment in the plant would include considerable automation between the presses to maintain high productivity and assure the safety of the workers. A layout for a typical captive plant is shown in Figure 2-19.

The plant may be housed in an industrial building with concrete foundation and cinder block or structural steel walls. In order that the overhead handling gear can be used to the fullest advantage, electrical conduit lines and air lines are typically buried in the floor. The estimated

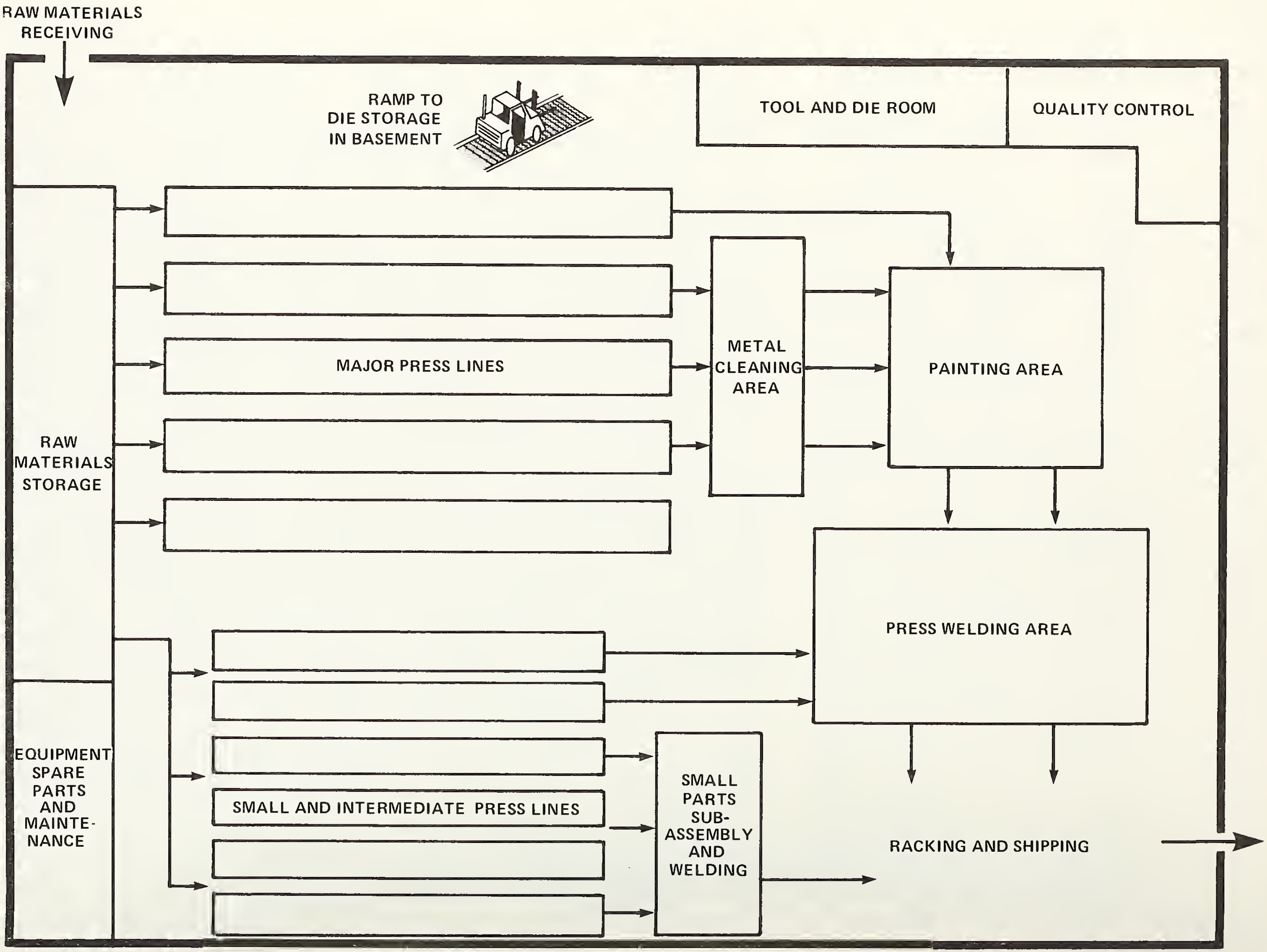


FIGURE 2-19. LAYOUT FOR A TYPICAL CAPTIVE PLANT

building size for a captive plant is 500,000 square feet. The building, parking lots and all auxiliary facilities may be located on 6 acres of land. Total capital requirements for the building and land are listed in Table 2-6.

TABLE 2-6. ESTIMATED BUILDING AND LAND REQUIREMENTS FOR A CAPTIVE STAMPING PLANT

Capital Requirements	Cost
Building	
(5,000 square feet @ $30 per square foot)	$1,500,000
Land	
(6 acres @ $20,000 per acre)	120,000
TOTAL	$1,620,000

The total cost of equipment required for a modern automated stamping plant is estimated at $65,665,000. A breakdown of the estimated equipment requirements by type of equipment, quantity and unit price is shown in Table 2-7. The largest equipment investment requirements are for the presses ($27,300,000) and the die inventory ($30,000,000). A large die inventory is required because of the broad range of body part styles and sizes over several vehicle models.

Labor requirements for a typical captive stamping plant includes sufficient foremen and press operators for two 8-hour shifts. Other jobs in the plant include press maintenance mechanics, diesetters, die maintenance workers, forklift operators, welders, inspectors and a maintenance crew to keep up the facility and grounds of the huge plant. Total labor requirements by type of skill are shown in Table 2-8.

TABLE 2-7. EQUIPMENT REQUIREMENTS FOR A TYPICAL CAPTIVE STAMPING PLANT

EQUIPMENT	QUANTITY	UNIT PRICE (THOUSAND)	TOTAL PRICE (THOUSAND)
COIL HANDLING			
Coil Racks	100	$ 11	$ 1,100
Uncoiler (20,000 pound reel)	6	50	300
Uncoiler (40,000 pound reel)	5	148	740
Straightener	11	35	385
Press Feed	6	55	330
PRESSES AND DIES			
Blanking Press (600 ton)	6	400	2,400
Double Action Press (1,400 ton)	5	1,000	5,000
Single Action Press (800 ton)	10	500	5,000
Trim Press (600 ton)	11	650	7,150
Single Action Press (400 ton)	11	350	3,850
Single Action Press (300 ton)	6	250	1,500
Single Action Press (200 ton)	12	200	2,400
Die Inventory			30,000
AUTOMATION BETWEEN PRESSES			
Extractors and Injectors	61	20	1,220
Conveyor Systems			200
CLEANING, FINISHING AND WELDING			
Cleaning, finishing equipment			150
Press Welders	5	500	2,500
MISCELLANEOUS			
Press Vibration Isolators	244	5	1,220
Quality Control Equipment			20
Fork Trucks	10	18	180
Pallets, Skids, Hoists and Other Material Handling Equipment			20
TOTAL			$65,665

TABLE 2-8. LABOR REQUIREMENTS FOR A TYPICAL CAPTIVE STAMPING PLANT

SKILL AREA	NUMBER
ADMINISTRATIVE:	
Plant Manager	1
Night Manager	1
Inventory Control and Purchasing	8
Secretary/Receptionist/Switchboard	2
Accounting	3
Maintenance Crew	10
PRODUCTION:	
Department Foremen/Supervisors/Lead Men	30
Press Operators and Trainees	122
Shipping/Receiving Clerks	4
Tool and Die Maintenance	18
Welders	8
Inspectors	12
Equipment Maintenance Mechanics	14
Fork Lift Operators	10
Die Setters	18
TOTAL	261

The principal utilities used in a captive stamping plant are electricity to operate the presses and air compressors, and natural gas to heat the plant. Compressed air is supplied to the presses on a continual basis for operation of the clutch mechanisms. A typical rate of compressed air consumption for a plant with 61 presses is 3,400 standard cubic feet per minute. Typical electricity consumption for a plant of the same size is 3,700 kilowatt voltage amps per hour.

Typical Contract Plant

This section discusses the capital, labor and energy requirements of a typical contract plant with 18 presses ranging from 35 tons to 50 tons. Such a plant would require at least three acres of ground in order to provide for employee parking, access to loading docks and possible future expansion.

The plant itself, assuming 18 presses, requires at least 25,000 square feet of floor space. Good quality construction of brick masonry costs about $20.00 per square foot in the Midwest area. (It is slightly lower in other parts of the country.) Money could be saved by using prefab metal construction but this is not generally acceptable for a stamping plant. It is wasteful of energy and not permitted by many zoning laws.

To staff a plant with 18 presses would require 36 press operators assuming a two-shift operation. This appears to be heavy since not all of the presses will be operating all of the time but the average absenteeism rate of 7 percent plus vacations, etc., make the figure realistic. As backup support the plant would have to employ three diesetters, two toolmakers to repair and sharpen tools, two material handling people and three maintenance men. Quality control would require an additional two personnel.

Indirect labor including management, engineering, office and sales personnel in a plant of this size would total 12 people. The total payroll, based on prevailing rates, would approximate $500,000. This figure presumes the usual employee benefits including medical plans, a pension program, etc.

Energy costs would include $15,000 for utilities and $18,000 for heating. Equipment costs, including the presses, a milling machine, a lathe and a grinder for the toolroom, air feeds and uncoilers for the presses plus a compressor and deburring equipment (tumbling barrels) and one fork truck equipped with coil handling equipment--this type of plant would not require an overhead crane--would range between $500,000 and $1.1 million. The lower figure assumes the use of utility type presses of the Benchmaster or Rouselle type, and the higher figure assumes high production equipment.

2.9 KEY ISSUES IN STAMPING

Of the key issues confronting the stamping industry today, the most significant are:

- OSHA Regulations
- Foreign Competition
- Competition From Plastics
- Liability and Workmen's Compensation
- Unavailability of Skilled Workers
- Design Changes and Weight Reduction

2.9.1 OSHA Regulations

The original OSHA standard for power presses was adapted from the ANSI B-1 standard and was widely criticized as being unworkable. Under industry pressures, the more unrealistic provisions were modified.

Over the last seven years, the stamping industry has spent about $1.2 billion dollars in compliance measures - installing air clutches, brake monitors, guards, sensing devices, improved controls, acoustic enclosures, vibration movements, etc.

Whether this investment has decreased the number of injuries is debatable. OSHA figures are not specific and GAO figures would indicate no significant change in either direction. There can be no doubt, however, that the meeting of OSHA requirements has led to an overall upgrading of equipment and a measurable improvement in productivity on the order of 5 percent across the industry. This is primarily because older presses, which could not economically be brought into compliance, have been phased out.

The OSHA noise exposure standard of 90 db for eight hours has worked hardships. A proposed OSHA standard which is expected to call for an 85 db level is also generally regarded as unworkable.

Currently, most OSHA citations in the stamping industry are for noise violations. The industry has taken the stand that personal hearing protection is the only effective solution and, in general, the courts have supported this stand.

2.9.2 Foreign Competition

Foreign competition has affected the stamping industry in direct relationship to the number of foreign cars that are imported and that otherwise would have been produced in this country.

There has been little effect on a one-on-one basis except in the case of fasteners and some fractional horsepower electric motors. In other words, the automotive industries do not buy stampings abroad although they do buy stamping from Canadian sources.

At least two foreign car producers have set up U.S. manufacturing facilities. Because U.S. labor rates are lower than those of Japan, Germany and several other countries and because of the declining value of the dollar, it is believed that this trend will continue and that it will be to the benefit of the domestic stamping industry.

2.9.3 Competition From Plastics

The stamping industry has faced competition from plastics for many years. With the need for lightweight components and the development of high strength engineering plastics such as PPG's AZDEL and Allied Chemical's STX, competition will continue to be strong.

However, these plastics are petroleum based and their rising cost is rapidly eroding their economic advantage so that their only real advantage is their light weight.

In general, the production of plastic parts in larger sizes is extremely slow as compared with metal forming processes. (For this reason, STX is often formed on metal forming presses rather than by sheet molding processes.)

There will be a continuing encroachment by plastics on traditional metal stamping applications but it will be very slow, very selective and by no means catastrophic. And in some applications the trend has reversed, primarily for reasons of cost, esthetics and reliability.

2.9.4 Liability and Workmen's Compensation

There are scattered incidents where metal stampers have been named as third-party dependants in liability actions. These are rare incidents, however, and are not an indication of a trend.

The proliferation of liability actions has had an effect on the stamping industry, however. Increasingly the automotive industries are requiring rigorous quality control and the documentation thereof. In general the automotive industries have accepted the additional costs.

The costs of workmen's compensation insurance have tripled over the last five years. There are indications that the additional costs are totally unjustified. No conjecture can be made at this time as to future implications because bills before the House and the Senate, which are generally expected to be enacted, will sharply alter the picture.

2.9.5 Unavailability of Skilled People

The single most serious problem affecting the stamping industry today is the lack of skilled personnel, particularly tool and die makers.

The industry graduates about 2500 journeymen from registered apprenticeship programs each year as against an annual requirement of 4600, based on Labor Department figures. The actual shortfall is much higher in the opinion of knowledgeable people in the industry. To compound this problem, more than half of the tool and die work force is over 50 years old and will be retiring over the next seven years.

The shortage is even more surprising in view of the fact that a Class A tool and die maker can expect to earn more than $20,000 per year.

There are many reasons ranging from the erosion of the work ethic to the failure of the educational establishment to recognize the opportunities the stamping industry offers.

The industry, together with the tool and die industry and the Bureau of Apprentice Training (Department of Labor) has undertaken a crash program to encourage young people to enter the industry; however, the problem is grave and will hamper the industry for the foreseeable future. It will only be partially alleviated by developments in technology such as NC, CNC, and Wire EDM.

2.9.6 Design Changes and Weight Reduction

From time to time over the last 50 years it has been predicted that design changes would effect the anatomy of the stamping industry both internally and externally. The change in design from riveted to welded construction of body frames 30 years ago is often cited as an example.

The A. O. Smith Company had built the most dedicated, highly automated stamping and assembly plant in the world. It is true that the line was shut down forever at about the same time as the advent of welded body and side frames, but it was really coincidental. The line was closed down because the major auto builders had started to introduce multiple models. This made it economically unfeasible to maintain a monolithic line.

A. O. Smith is still the largest manufacturer of auto and truck chassis and frames. The equipment and processes used in their manufacture have not changed significantly. The real change has been along the lines of decentralization and more rapid die changeover.

The same parameters apply to the unibody concept. This concept is widely misunderstood, perhaps because of the manner in which it was introduced by some of its early advocates, notably Citroen and Saab. It is often confused with monocoque construction in which, like an egg, the strength of the unit relies on its external skin continuity.

Because of the necessary apertures in an automobile--hood, windows, doors, firewall, etc; true monocoque construction cannot be applied to an automobile.

The term, unibody, is somewhat of a misnomer. It means that various components are welded and brazed into an assembly rather than bolted and riveted. For the foreseeable future cars will continue to use frame numbers. Front drive cars will require additional cross-frame members since they must now support the differential and what used to be the drive train.

In view of the extremely high injury rate in the so-called subcompact and minicompact cars, it is probable that auto makers will be required to improve the impact resistance of these models. This can best be done by increasing their structural rigidity. Since the weight disadvantage would be intolerable if they took the approach of using a heavier "skin" it is probable that the use of additional structural numbers will be the alternative.

An analogy can be found in residential construction which is really not all that different. Some years ago, several states departed from the traditional 16-inch on center framing design in favor of 24-inch centers. The result was disastrous and they were forced to return to the old standards.

The frame is the skeleton of an automobile and it cannot be reduced beyond a finite minimum. That minimum has been reached and we can anticipate a reversal, i.e., increasing use of structural members for reasons of safety.

Faced with the problem of weight reduction, the automobile makers have turned to the HSLA (high strength low alloy) steels. The theory is that if you use a steel with a tensile strength of 75,000 psi to replace a carbon steel with a tensile strength of 50,000 psi, you can use thinner material.

The theory, in fact, has proved to be tenable although not without problems. The HSLA steels are difficult to form because of their strength and they tend to crack if the necessary deformation is severe. Several auto builders have backed off on the HSLA steels and returned to the conventional materials.

This is a temporary retreat--a pause while the steelmakers improve their product and the suppliers of heavy stampings develop their technology. The HSLA steels are a formidable weapon in the war against weight and their use in heavy stampings will continue to widen.

The use of titanium, graphite composites and other sophisticated materials has been suggested as a weight reduction measure. The use of these materials would present severe problems to the stamping industry since they cannot be formed on conventional equipment.

The costs would be prohibited and these materials are not foreseen as a threat during the next decade.

The stamping industry has had a growth rate (dollar adjusted) of 4 percent per year for the last years. There seems to be no reason to expect a major shift, upward or downward, over the next decade.

The industry has reacted strongly and quickly to petroleum price increases by switching from petroleum lubricants to synthetics and various soap and borax solutions. This has had an unanticipated benefit--improved performance and the elimination of waste disposal problems.

3. PLASTIC FORMING

3.1 GENERAL

In its broadest sense, the term "plastic forming" denotes a process whereby a desired shape is imparted to plastics through the carefully planned application of pressure and/or heat. With the trend toward use of lighterweight materials in automobiles, the forming of plastics into such parts as bumpers, wheels and certain body parts is becoming increasingly more important. In 1977, use of plastics in cars was over five percent of total U.S. consumption. By 1985 and certainly by 1990, one can be reasonably assured that this percentage will be significantly greater.

3.2 STEPS IN THE PRODUCTION OF PLASTIC

The production of plastic parts of the type used in automobiles requires two basic steps: resin production and plastic processing. Resin production involves the basic conversion of plastics from basic feedstocks to plastic materials (resins) in the form of granules, pellets, or powders. This step also usually involves compounding or formulating the base plastic into the finished plastic material by adding various chemicals. The method for making the resins is very complex and is beyound the scope of this report. Processing, on the other hand, refers to the steps required to turn the plastic material into secondary products (sheet, casings, hoses, coated fabrics, fasia, etc.). It is the processing, or more specifically, the forning of plastic into various automotive parts and components which is the subject of this report.

An overview of the basic steps involved in the processing of plastic resins into finished automotive products is shown in Figure 3-1. The process is relatively straighforward. In most cases, the plastic resins, in the form of powder, granules or sheet, are input directly into the forming machine without any preprocessing. The principal exception is when the resin is received in the form of sheets. In this case, the sheet must first be cut to the approximate size of the part to be made before it is introduced into the machine. During the forming operation, pressure and/or heat is applied to the resin material. If a thermoset plastic resin is being formed, then the heat and pressure serves to both form the plastic material into the desired shape as well as to harden it. If, on the other hand, a

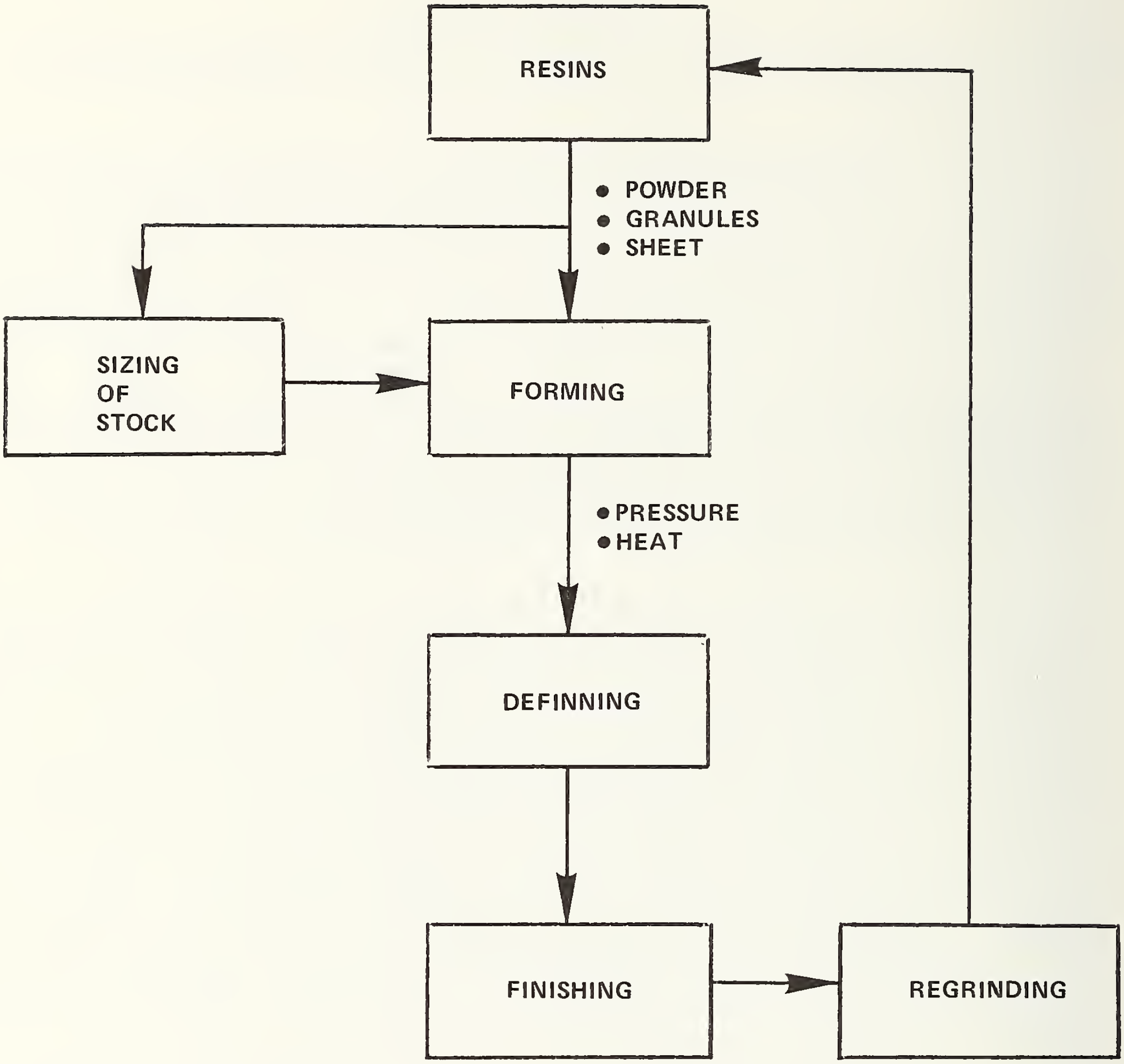


FIGURE 3-1. BASIC STEPS IN PLASTIC PROCESSING

thermoplastic material is used, the heat/pressure is used only to form the material. Hardening is achieved by cooling the plastic while it is still in the machine.*

The output of the forming process is a nearly finished automotive component. In many cases, the part resulting from the forming process still has sprues, gates and/or flash (i.e., excessive material on it which must be removed). This is accomplished through a process called definning where the excess material is removed using saws, shears, and/or grinders. If a thermoplastic material was used to make the part, the excess material which has been removed is often reground and cycled back through the forming process. As shown in the figure, the final operation performed on the product is a finishing operation, where the part is either primed for painting, painted and/or chrome-plated.

3.3 OVERVIEW OF PLASTIC FORMING OPERATIONS

An overview of the various opertions or techniques used to form plastic resin is shown in Figure 3-2. The forming processes that are most important to the auto industry are shown by the shaded boxes in the diagram and are injection molding, compression moldng, and reaction injection molding. Blow molding, transfer molding, calendaring and extrusion are also used in the auto industry but to a lesser extent.

The following are brief definitions of the plastic operations shown in Figure 3-2:

- Blow Molding. A method of fabrication in which a warm plastic parison (hollow tub) is placed between the two halves of a mold (cavity) and forced to assume the shape of that mold cavity by use of air pressure. The air pressure is introduced through the inside of the parison and thereby forces the plastic against the surface of the mold that defines the shape of the product.

- Calendering. The preparation of sheets of material by pressure between two or more counter-rotating rolls. The machine which performs the operation is a calendar.

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* Thermoplastics are those plastics that can be repeatedly softened by heating and hardened by cooling. Thermoset plastics are those plastics which, once heated or "cured", become substantially infusible and insolvable and may not again be softened.

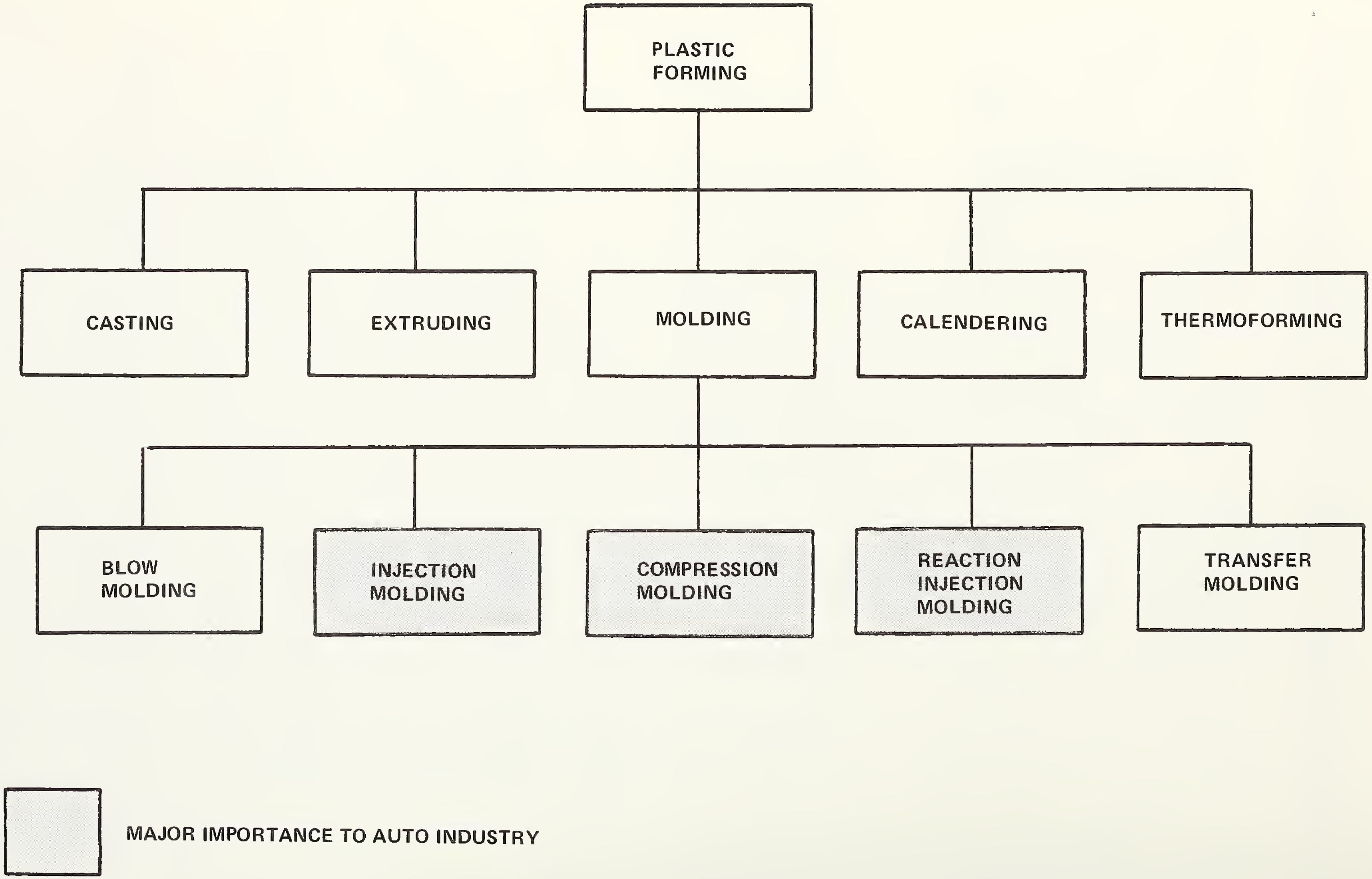


FIGURE 3-2. OVERVIEW OF PLASTIC FORMING OPERATIONS

- Compression Molding. A technique of thermoset molding in which the molding compound (generally preheated) is placed in the heated open mold cavity, mold is closed under pressure (usually in a hydraulic press), causing the material to flow and completely fill the cavity, pressure being held until the material has cured.

- Extrusion. The compacting of a plastic material and the forcing of it through an oriface in more or less continuous fashion.

- Injection Molding. A molding procedure whereby a heat-softened plastic material is forced from a cylinder into a cavity which gives the article the desired shape. Used with both thermoplastic and thermosetting materials.

- Reaction Injection Molding (RIM). A process that involves the high-pressure impingement mixing of two (or more) reactive liquid components; after mixing, the liquid stream is injected into a closed mold at low pressure. The finished parts can be cellular or solid elastomers, with a wide range of hardness and modules. Also known as high-pressure impingement mixing. (HPIM). Used especially with urethanes.

- Thermoforming. Any process of forming thermoplastic sheet which consists of heating the sheet and pulling it down onto a mold surface.

- Transfer Molding. A method of molding thermosetting materials, in which the plastic is first softened by heat and pressure in a transfer chamber, then forced by high pressure through suitable sprues, runners, and gates into a closed mold for final curing.

3.4 TYPE OF PLASTICS USED IN CARS

The most important automotive plastics at present are polyurethane, reinforced polyester, polypropylene, polyvinyl chloride, and ABS. As automobiles are downsized, however, other plastics such as polyethylene and engineering plastics, a group of plastics noted for their high strength and ability to be used in engineering applications, are likely to become important. A brief description of each of these plastics is presented below.

- Reinforced Polyester. Reinforced polyester refers to a composite of thermosetting polyester plastic and, in most cases, glass reinforcing materials called fiberglass. Automotive uses include front fascia, spoilers, grille opening panels, fender skirts, and side rails. Reinforced plastic parts often come as mixed components such as sheet molding compound (SMC), a roll of thick sheet, or bulk molding compound (BMC), a slab of extruded log or rope.

- Polypropylene. Polypropylene is a thermosplastic found in many under-the-hood parts such as ducts, battery cases and fan shrouds. The plastic can also be extruded into fibers, used in automotive carpeting.

- Polyvinyl Chloride. Polyvinyl chloride (PVC), or vinyl, has exceptional chemical, weathering and abrasion resistance. The plastic is often processed by calendering and used for automotive upholstery. PVC is also used for vinyl roofs and for certain molded parts.

- ABS. ABS is known as both a commodity plastic and an engineering plastic depending on the specific formulation. In automobiles it is used in grilles, lamp housings and instrument panels.

- Engineering Plastics. The engineering plastics are generally low-volume, high-priced plastics with relatively few suppliers. The transportation industry accounts for over 25 percent of the consumption of these materials. The major automotive engineering plastics are nylon, polycarbonates (PC), polyphenylene oxide (PPO) and polybutylene terephthalate (PBT).

    - Nylon is a strong tough plastic and is usually injection molded for vehicle parts such as fender extensions of master brake reservoirs.

    - Polycarbonates are tough, rigid and easily fabricated. However, they have poor resistance to marring, abrasion and solvents. The plastic is used in automotive front-end panels, rear lenses, and headlamp covers.

- Polybutylene terephthalate, a thermoplastic polyester is very strong and has good electrical properties. It is used for exterior and interior automotive applications such as electronic ignition components and backup lights.

- Polyphenylene oxide has high impact strength and is easily processed by injection molding. It is used in wheel covers, windshield wiper assemblies, and side window frames.

3.5 INJECTION MOLDING

The basic concept of injection molding revolves around the ability of a thermoplastic material to be softened by heat and to harden when cooled. In most injection molding operations, granular material (the plastic resin) is fed into one end of the cylinder (usually through a feeding device known as a hopper), heated, softened, and forced through a nozzle (where it is still in the form of a melt) into a relatively cool mold held closed under pressure. Here, the melt cools and hardens (cures) until fully set up. The mold then opens and the molded part is removed.

The injection molding process makes possible the production of highly finished and detailed plastics at very high rates. Injection molding is used for thermoplastics, polypropylene, polyethylene, and others. It is estimated that the 1985 car will include 300-400 pounds of plastic, much of it injection molded.

3.5.1 Major Types of Injection Molding

Injection molding is best characterized by:

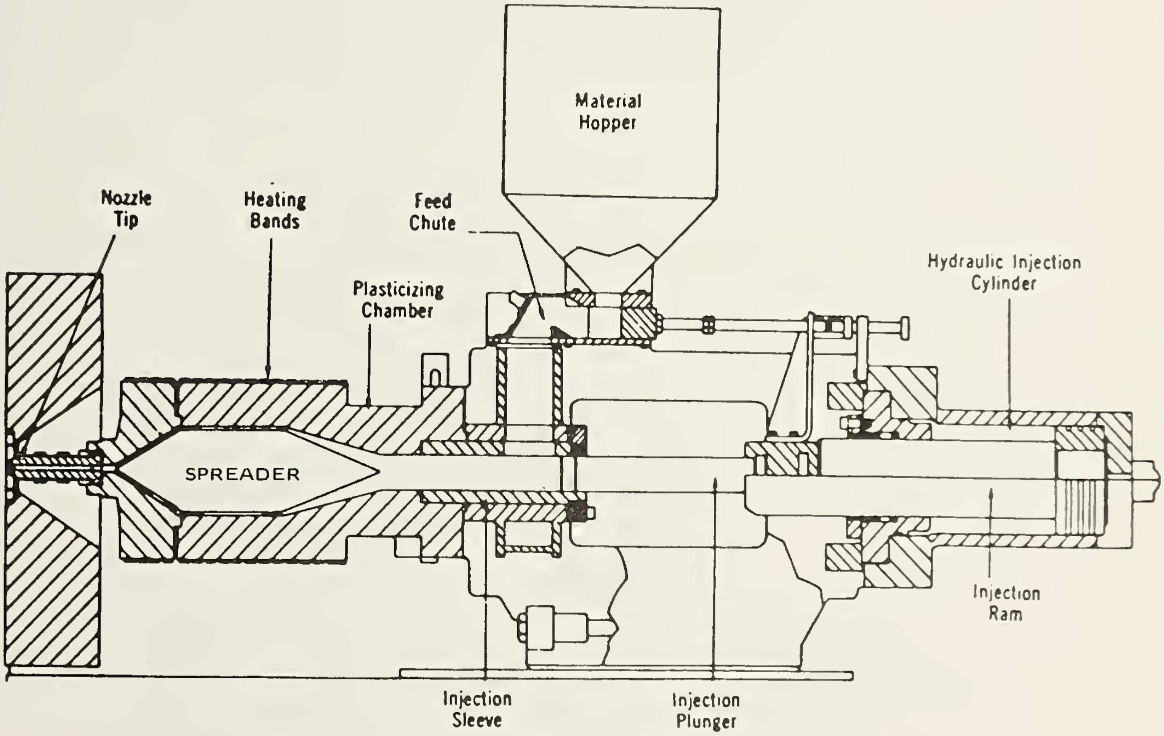
- The injection unit or the way in which the melt is plasticized (softened) and forced into the mold
- The clamping unit or the system for opening the mold and closing it under pressure
- The type of mold used
- The machine controls
- The type of plastic materials used.

Each is described below.

Types of Injection Units

Injection molding machines fall into categories delineated by the type of injection unit used. The categories include single stage plungers, two-stage plungers, two-stage screw injection cylinders, and in-line reciprocating screw injection plungers. A brief description of each type of injection unit is provided below.

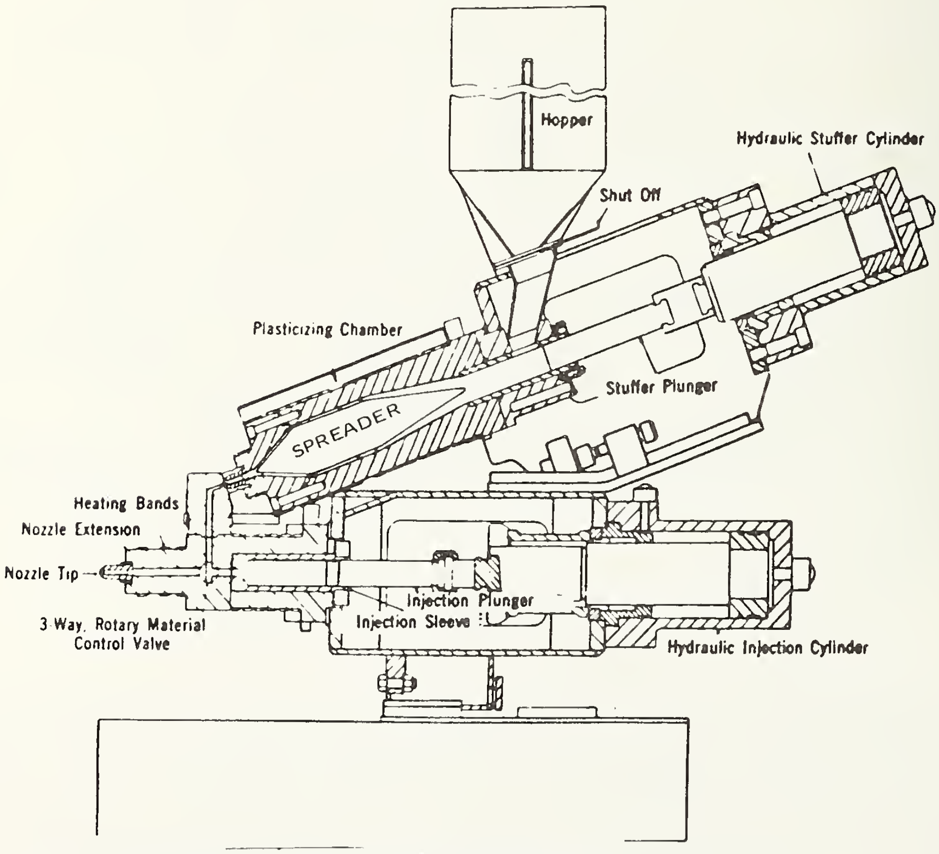
- Single Stage Plunger. A typical conventional single stage plunger is schematically shown in Figure 3-3. It consists of a barrel heated with electrical resistance heater panels in which is located a fixed spreader or torpedo. During operation, the feed hopper feeds granular molding material into the injection cylinder using some kind of measuring device to meter the amount fed. The forward motion of the injection plunger forces the granules along the cylinder and around a spreader. As the granules move forward they are melted by the heating bands surrounding the spreader. The granules are then fed through the nozzle, a tapered sprue hole and runners into the cavities of the mold which is held tightly clamped until the granules have solidified.



Source: SPI, Plastics, Engineering Handbook.

FIGURE 3-3. SINGLE STAGE PLUNGER UNIT

- Two-Stage Plunger. Figure 3-4 shows a two-stage plunger type unit. As shown in the figure, this type of equipment involves two plunger units one on top of the other. The one plunger unit is used to plasticize (melt) the material and feed to the second unit. The second plunger unit operates as a shooting plunger and pushes the plasticized material into the mold. It should be noted that the first stage cylinder (also known as a pre-plasticizer) is identical with the plunger unit cylinder described previously. In operation, the preplasticized cylinder forwards melted plastics through the open valve, between it and the shooting cylinder. The shooting plunger, which at this point is forward, is forced backward as the cylinder is filled. It retracts until it hits the stop, whereupon the valve closes. When the shooting cylinder plunger is made to go forward by hydraulic pressure on the piston, the plastic mass flows through the nozzle into the mold.



Source: SPI, Plastics Engineering Handbook.

FIGURE 3-4. TWO-STAGE PLUNGER UNIT

- Two-Stage Screw Injection Cylinder. The two-stage screw injection machine is identical to the machine just described except that a screw extruder is substituted for the plunger-type injection cylinder (see Figure 3-5). In this machine, the action of the screw served to work and melt (plasticize) the resin and feed it into the second plunger unit where the injection ram forces it forward into the mold. The major advantage of this type of unit lies in the improved homogeneity of the plastic mass delivered by the screw to the shooting cylinder.

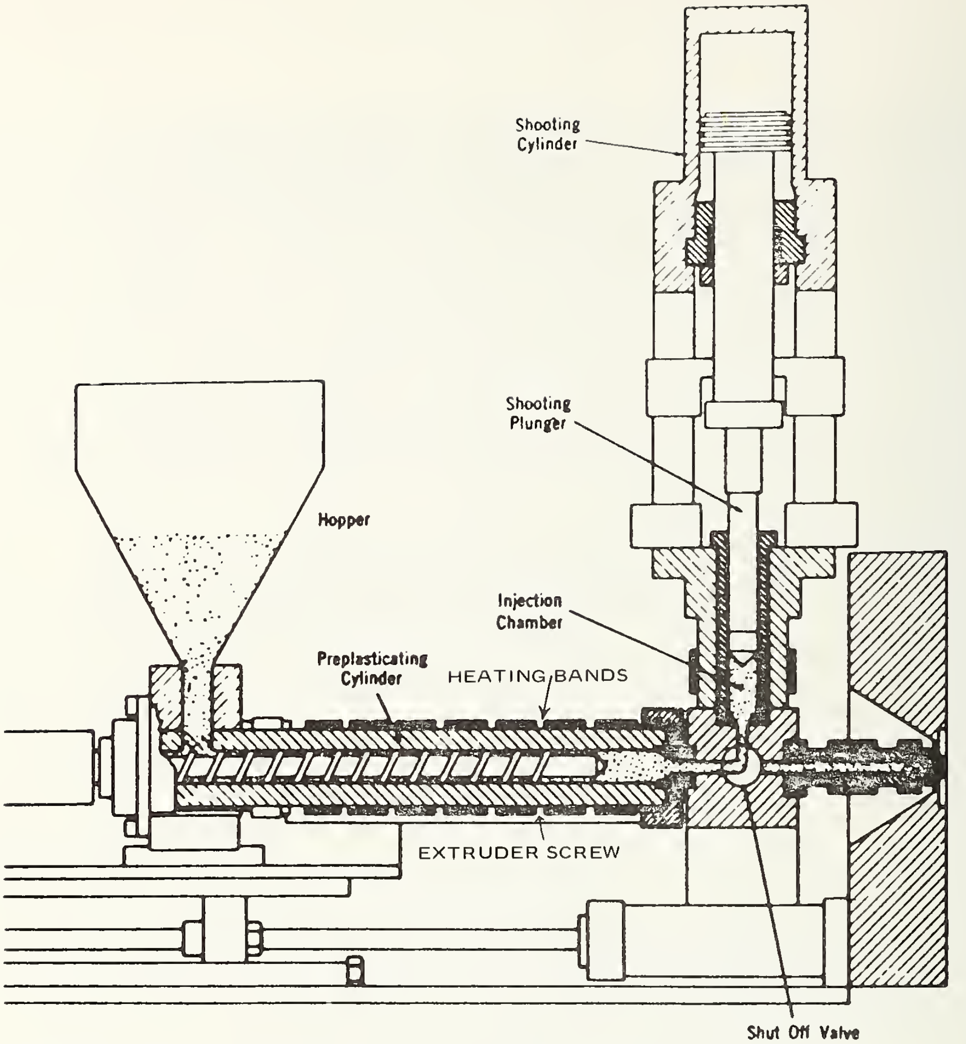
- Reciprocating Screw Injection Cylinder. The newest and most popular machine sold today is the in-line reciprocating screw injection machine shown in Figure 3-6. This machine, like the previous one, uses a rotating screw which moves back and forth within the heating cylinder. As the screw rotates, the granules are conveyed forward and melted. The melt flows from the last flight of the screw through the nonreturn valve. As the material comes off the end of the screw, the screw moves back to permit the plastic material to accumulate. At the proper time, the screw is forced forward, acting as a plunger and propelling the softened material through the nozzle and sprue into the mold cavities. The size of the charge is regulated by measuring the back travel of the screw. The primary advantage of this machine over the others discussed lies in the uniformity of the plasticity obtained from the screw which produces higher quality moldings at lower temperatures and apparent pressures.

Types of Clamping Units

Mold clamping, i.e., the holding of mold halves closed during injection and opening after solidification, on most present-day machines is usually one of two types:

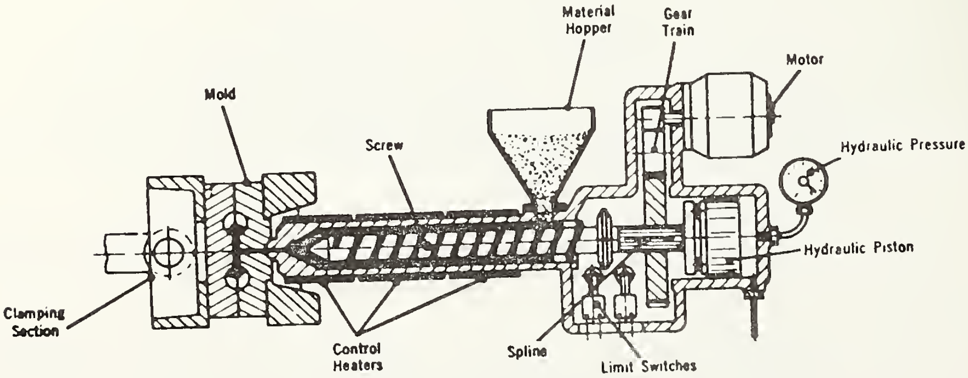
- Hydraulic clamps, in which a hydraulic cylinder operates directly on the moveable parts of the mold to open and close it

- Mechanical or toggle clamps in which the hydraulic cylinder operates through a toggle linkage to open and close the mold halves.



Source: SPI, Plastics Engineering Handbook.

FIGURE 3-5. TWO-STAGE SCREW INJECTION UNIT



Source: SPI, Plastics Engineering Handbook.

FIGURE 3-6. IN-LINE RECIPROCATING SCREW UNIT

Diagrams of these two types of clamps are shown in Figures 3-7 and 3-8, respectively.

Most clamps in use today are horizontal, with injection taking place through the center of the stationary platen. But for special jobs, vertical clamp presses are available, in which the injection mechanism is horizontal and injection takes place at the die parting line.

Types of Molds

The heart of the molding process is the mold. The primary purposes of the mold are to:

- Determine the shape of the part
- Conduct the material from the heating cylinder to the cavity
- Vent the entrapped air
- Cool the part
- Eject or strip the parts without marks or damage.

Thus, the quality of the part and its cost to manufacture are largely dependent on the mold design, construction and excellence of workmanship. In describing a mold, the criteria shown in Table 3-1 is usually used. Thus, a typical mold might be described as a four cavity, machined steel, chrome-plated, hot runner, stripper-plate tumbler mold.

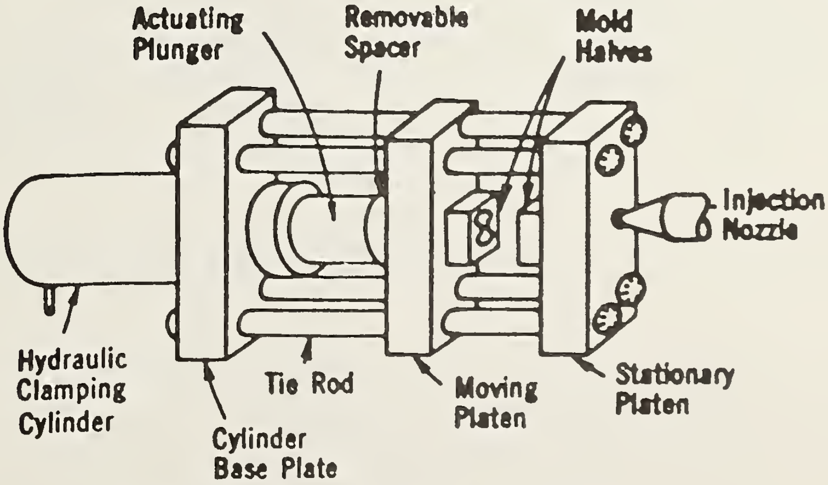


FIGURE 3-7. HYDRAULIC CLAMP

TABLE 3-1. CRITERIA FOR MOLD DESIGN

Number of cavities

Material
- Steel
- Stainless steel
- Prehardened steel
- Hardened steel
- Beryllium copper
- Chrome plated
- Aluminum
- Epoxy-steel

Parting line
- Regular
- Irregular
- Two-plate mold
- Three-plate mold

Method of manufacture
- Machined
- Hobbed
- Cast
- Pressure cast
- Electroplated
- EDM
  (spark erosion)

Runner system
- Hot runner
- Insulated runner

Gating
- Edge
- Restricted
  (pin point)
- Submarine
- Sprue
- Ring
- Diaphragm
- Tab
- Flash
- Fan
- Multiple

Ejection
- Knockout pins
- Stripper ring
- Stripper plate
- Unscrewing
- Cam
- Removable insert
- Hydraulic core pull
- Pneumatic core pull

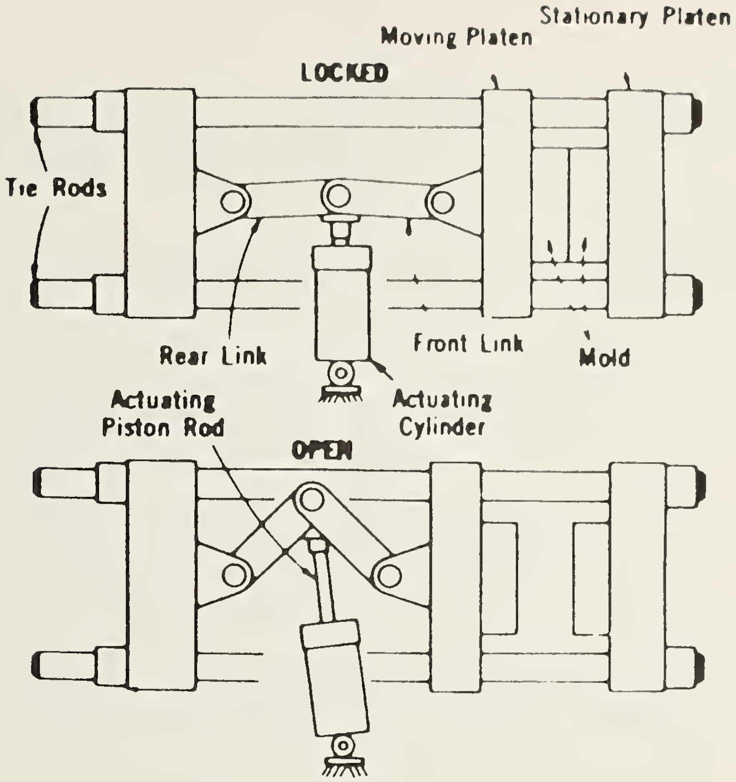


FIGURE 3-8. EXAMPLE OF A TOGGLE CLAMP

Machine Controls

One of the most active areas of development in injection molding machine design is in machine controls. The injection process deals with time, pressure, and temperature. To achieve consistent quality, each of these parameters must be controlled accurately to fill the mold with exactly the same amount of polymer during each cycle. To accomplish this, equipment is now available which will automatically make the necessary adjustments as variations occur.

The following are descriptions of machine control systems which are commercially available for controlling injection molding machines:

- Monitoring Systems. These systems monitor high and/or low set points of specific conditions relative to pressure, temperature, displacement and force. The systems use time and distance relationships to produce an indicative reaction from the monitor. If reaction is consistent, parts are assumed to be the same. If reaction is inconsistent, i.e., a deviation occurs, an alarm buzzes or lights flash. This is a signal to the machine operator that some corrective action is necessary.

- Feedback Systems. These systems also serve as a monitor. They differ from monitoring, however, in that they have the capability of energizing mechanisms that will change variables (i.e., feed information back to the machine to raise or lower temperatures, increase or decrease pressures, etc.). These systems operate by monitoring/ sensing injection velocity, injection pressure, cavity pressure and/or melt temperature. Using these devices will automatically maintain processing operations within a fixed level of variance.

- Computer-Controlled Systems. Computer controlled systems use feedback loops, monitoring devices, etc., for instantaneous self correction of all processing variables. Machine cycles and processing parameters for a given part can thus be stored on tape or other electronic data storage device and simply plugged into the control cabinet of a computer-run machine whenever that particular part is to be molded. In essence, the computer will automatically direct the setting-up of the machine.

Types of Plastics

Injection molding can be used for molding both thermoplastic and thermosetting resins. In making automotive parts and components, however, it is used solely for molding thermoplastic resins such as polypropylene, ABS, and polyethelene.

3.5.2 Advantages/Disadvantages of Injection Molding

Compared to compression molding, the advantages of injection molding are that:

- The process is much faster. This is because the mold does not have to be alternately heated and cooled as in compression molding.

- Mold costs are lower.* This is because fewer cavities are necessary to maintain equivalent product by injection molding.

- Articles of difficult shapes and of thin walls are successfully produced by injection molding. Wall thicknesses are also less in injection molding.

- Metal inserts, such as bearings, contacts or screws, can be applied in the mold and cost integrally with the product.

- Material loss is low, as sprues and gates can be reused.

The primary disadvantage of injection molding comes in the molding of thermosets and fiber reinforced plastics where there exist problems with the structural soundness of parts. Abrasion problems on machines also exist.

3.5.3 Automotive Applications

Automotive applications of injection molding include radiator grills, glove box doors, headlight bezels, fender caps, tire valve caps and wheel covers. These and other injection molded components are shown in Figure 3-9.

3.5.4 Types of Equipment Required

The principal types of equipment required for injection molding are as follows:

- Granulator—grinds runners, sprues and rejected plastic parts into granules for reprocessing.

- Dryer—removes moisture from the thermoplastic resins before processing.

- Air Veyor—transports raw materials to various destinations in the plant by means of air pressure.

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* Molding costs as high as $50,000, however, are not uncommon.

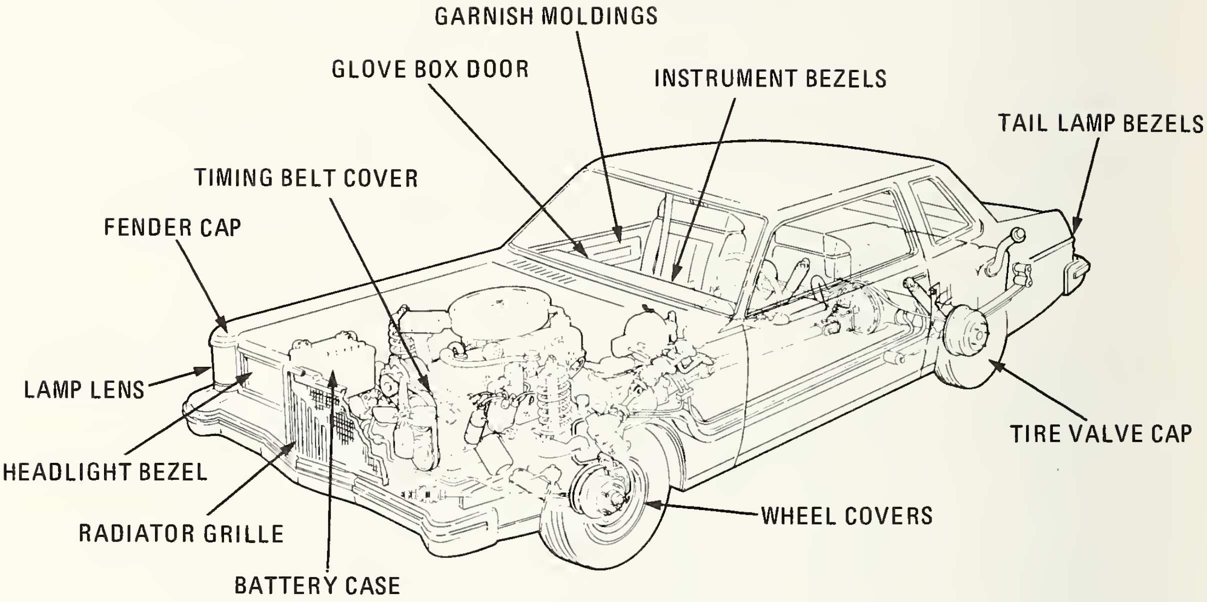


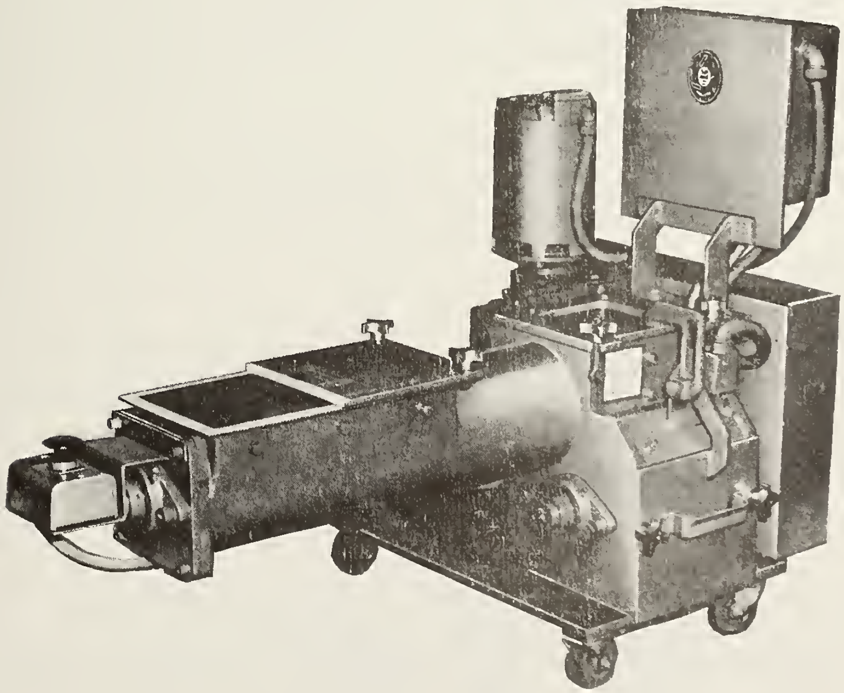
FIGURE 3-9. INJECTION MOLDED PARTS

- Hoppers—feeds the molding material into the injection molding machine at a controlled rate.
- Injection Molding Machines—plasticizes the molding material and forces it into the injection chamber.
- Molds—the tool used to form the shape of the injection molded part.
- Abrasive Finishing Equipment—used to remove gate stumps and rough spots from the finished injection moldings.

Each type of equipment is discussed below. Detailed cost and manufacturer information is provided in Table 3-2.

Granulator

A granulator is a special type of grinder that takes runners, sprues and other rejects from the injection molding process and grinds them into granules of the desired size for reprocessing. Granulators are usually rated by the number of pounds they are capable of grinding per hour. In most plants the granulating equipment is placed close to the injection molding machine. The machine operator gathers the sprues and runners and deposits them directly into the hopper of the granulator so that the regranulated material can be added to the new resins on a continuous basis. Granulators are make by Sterling, Cumberland and Polymer Machinery among other manufacturers. A machine capable of processing 1,000 pounds per hour is priced at $10,500 and one which processes 2,000 pounds per hour ranges in cost from $16,000 to $20,000. The typical lead time on a granulator is approximately 4 months. Figure 3-10 shows a typical granulator.



Source: Ball Jewell

FIGURE 3-10. GRANULATOR

TABLE 3-2. TYPES OF EQUIPMENT REQUIRED FOR INJECTION MOLDING

Equipment	Manufacturers	Capacity	Maximum Injection (ounces)	Lead Time	Price
Granulator	Sterling Company	1,000 lbs/hr		4 months	$10,500
	Cumberland	2,000 lbs/hr			$16,000-$20,000
	Polymer Machinery	4,000 lbs/hr		6 months	$40,000
Dryer	Novatec Whitlock Bry-Air	10,000 lbs/hr		3-4 months	$22,500
Air Veyor	Novatec	10,000 lbs/hr		1-2 months	$800
	Premier Pneumatics	16,000 lbs/hr		1-2 months	$800
Hopper and Floor Stand	Novatec	20,000 lbs/hr			$6,700
Injection Molding Machine	HPM Cincinnati Milacron Reed	250 tons	20	2 months	$83,000
		375 tons	32	2 months	$108,000
		500 tons	48	2 months	$138,000
		700 tons	110	5 months	$191,000
		1,000 tons	165	5 months	$280,000
Molds	Athols Liberty Hoover Universal				$10,000-$100,000
Abrasive Finishing and Deflashing Equipment	Air Products and Chemicals Universal Dynamics Wheelabrator-Frye	4,000 lbs/hr			$150,000

Dryer

Surface moisture is removed from plastics before they are injection molded to ensure that the correct surface and strength characteristics of the plastic products are not jeopardized by condensation. Most plastic dryers use a molecular sieve desiccant through which air is passed for dehumidification. The sieve traps moisture molecules but allows air molecules to pass. Then the dry air is heated to a predetermined temperature and delivered to the plastics material. The dry air picks up moisture from the plastics and is carried back into the dryer for dehumidifying and reheating. Dryers are normally attached to the hopper.

Dryers are manufactured by Novatec, Whitlock, Premier Pneumatics and a number of other companies. A dryer capable of handling 10,000 pounds per hour costs $22,500. Typical ordering time for this equipment is 3 to 4 months.

Air Veyor

Air veyors or air blower/vacuum systems are used to transport the raw materials and pellets to different destinations in the injection molding plant (e.g., silo, storage bin, hopper, etc.). These air conveying systems are most advantageous for large flow rates of materials required throughout the plant. Air conveying systems may use compressed air, blown air or a vacuum system for conveying the raw materials.

Air veyors are manufactured by Novatec and Premier Pneumatics among others. A system capable of handling $10,000 pounds per hour is priced at $800.

Hopper

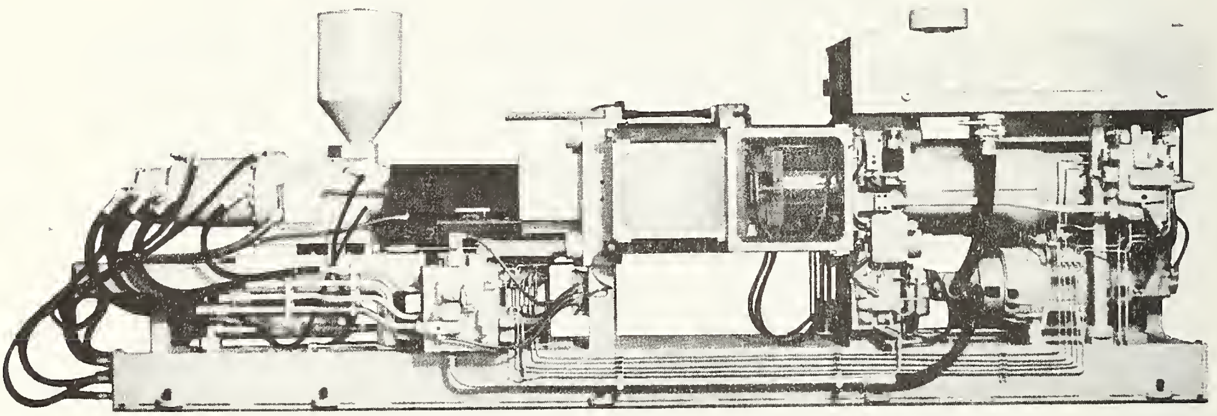
The hopper is the feed reservoir into which the molding granules are loaded and from which they fall into the molding machine through a metering device. In many cases, the hopper is combined with a drying device to heat and dry the granules before they are fed into the injection molding machine. Hoppers are generally mounted on a separate floor stand.

Hoppers are manufactured by Novatec, Leach Manufacturing Company, and Foremost Machine Builders among others. A hopper capable of handling 20,000 pounds per hour is priced at $6,700.

Injection Molding Machines

Reciprocating screw machines are the most widely used type of injection molding machine. In this machine, a reciprocating screw moves back and forth within the heating cylinder to help soften the plastic and force it along the cylinder and into the mold. A low speed, high torque hydraulic motor usually is used to turn the screw.

Injection molding machines are manufactured by HPM, Cincinnati Milacron, Reed, Newbury Industries and Gloucester Engineering Company. A small machine capable of injecting 20 ounces of plastic with 250 tons of clamping pressure costs approximately $83,000. A moderate sized machine capable of injecting 48 ounces of material with 500 tons of pressure is priced at $171,000 and a large machine which injects 165 ounces with 1,000 tons of pressure is priced at $280,000. Figure 3-11 shows an injection molding machine.



Source: Cincinnati Milacron

FIGURE 3-11. INJECTION MOLDING MACHINE

Molds

The injection mold determines the size, shape, dimensions, finish, and often the physical properties of the finished product. The most common material used for molds for plastics is steel, although in recent years, molds cast from beryllium copper, aluminum or Kirksite have been used. Fabrication of steel molds is done in a tool room where the steel is machined to make cavities and cores. Following machining, the mold may be chrome or nickel-plated and polished.

Injection molding plants may have in-house mold shops or buy molds from outside suppliers, or both. Independent mold manufacturers include Athols, Liberty and Hoover Universal. Molds range in price from $10,000 to $100,000 depending on the complexity of the design and the dimensional accuracy required.

Abrasive Finishing and Deflashing Equipment

Many plastic products require some degree of machining and finishing after they have been processed and before they are ready for shipping. Injection moldings may have rough spots left where the gates were broken off. Other imperfections may include scratches, dull spots, or slight ridges where the mold sections joined. Stumps of gates and other imperfections may be removed by tumbling, filing, sanding, buffing, or grinding. A blast machine is one type of equipment used for this purpose. Nonabrasive media such as walnut shells, corn cobs, or plastic pellets are placed in a stream of air projected at high velocity by a rotating bladed wheel or a pressure blast gun. The machines generally are batch type tumbling systems fed by conveyors.

Abrasive finishing and deflashing equipment is manufactured by Air Products and Chemicals, Universal Dynamics, and Wheelabrator-Frye. A typical machine, capable of handling 4,000 pounds per hour, is priced at $150,000.

3.5.5 Size and Structure of the Industry

Approximately 5,500 million pounds or 70 percent of all molded plastics materials are processed by the injection molding process.* Approximately 14 percent of these injection molded plastic components are consumed by the transportation industry in general, with polypropylene and the engineering plastics being the principal plastics consumed for transportation parts.

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* Source: Kline's Guide to the Plastics Industry, 1978.

Of the estimated 6,100 processing locations for injection molded plastics, over half are in-house molders of finished plastic products for nonplastic uses, such as the automobile. Based on the value of plastics consumed, General Motors and Ford are the first and third largest injection molders, with Tupperware (Dart) ranked second. Plastics consumption for injection molding of auto parts by General Motors, Ford and AMC are summarized in Table 3-3.

TABLE 3-3. INJECTION MOLDING PLASTICS CONSUMPTION BY GM, FORD AND AMC

Company	Consumption (Millions)	Principal Polymer
General Motors (11 plants)	$145	Polypropylene, ABS
Ford Motor Company (2 plants)	$60	ABS
American Motors	$18	Polypropylene, Polyethylene

Source: Kline's Guide to the Plastics Industry, 1978.

3.5.6 Characteristics of a Typical Plant

The following sections describe the layout, materials flow, and capital, labor, and energy requirements for an injection molding plant which processes approximately 65 million pounds of injection molded automotive parts per year. The plant is typical of large injection molding plants, with a building area of 254,000 square feet and a total work force of 715. Total equipment costs are estimated at $18 million, and total resin requirements are estimated at 240,000 pounds per day.

Plant Layout

A schematic diagram of the plant layout is shown in Figure 3-12. The total plant area (254,000 square feet) provides approximately 60,000 square feet for the injection molding machines, 45,000 square feet for the maintenance area and tool room and 34,000 square feet for the assembly area. The estimated sizes of other work areas are shown in Table 3-4.

TABLE 3-4. DISTRIBUTION OF PLANT AREA AMONG MAJOR ACTIVITIES

Activity/Function	Area (square feet)
Raw Material Storage	25,000
Injection Molding	60,000
Scrap Cutting	6,000
Finishing/Plating	34,000
Assembly	34,000
Stamping, Machining, Wiring	20,000
Regrinding	5,000
Storage of Finished Products	25,000
Maintenance/Tool Room	45,000
Total	254,000

A major consideration in the plant layout is the reduction of all unnecessary materials handling by efficient use of conveying, sorting, and bulk handling systems. The design of the overall raw materials handling system can have a major impact on the ability of the plant to achieve low manufacturing costs and an orderly flow of materials. Single purpose aisles and large storage areas help to reduce congestion.

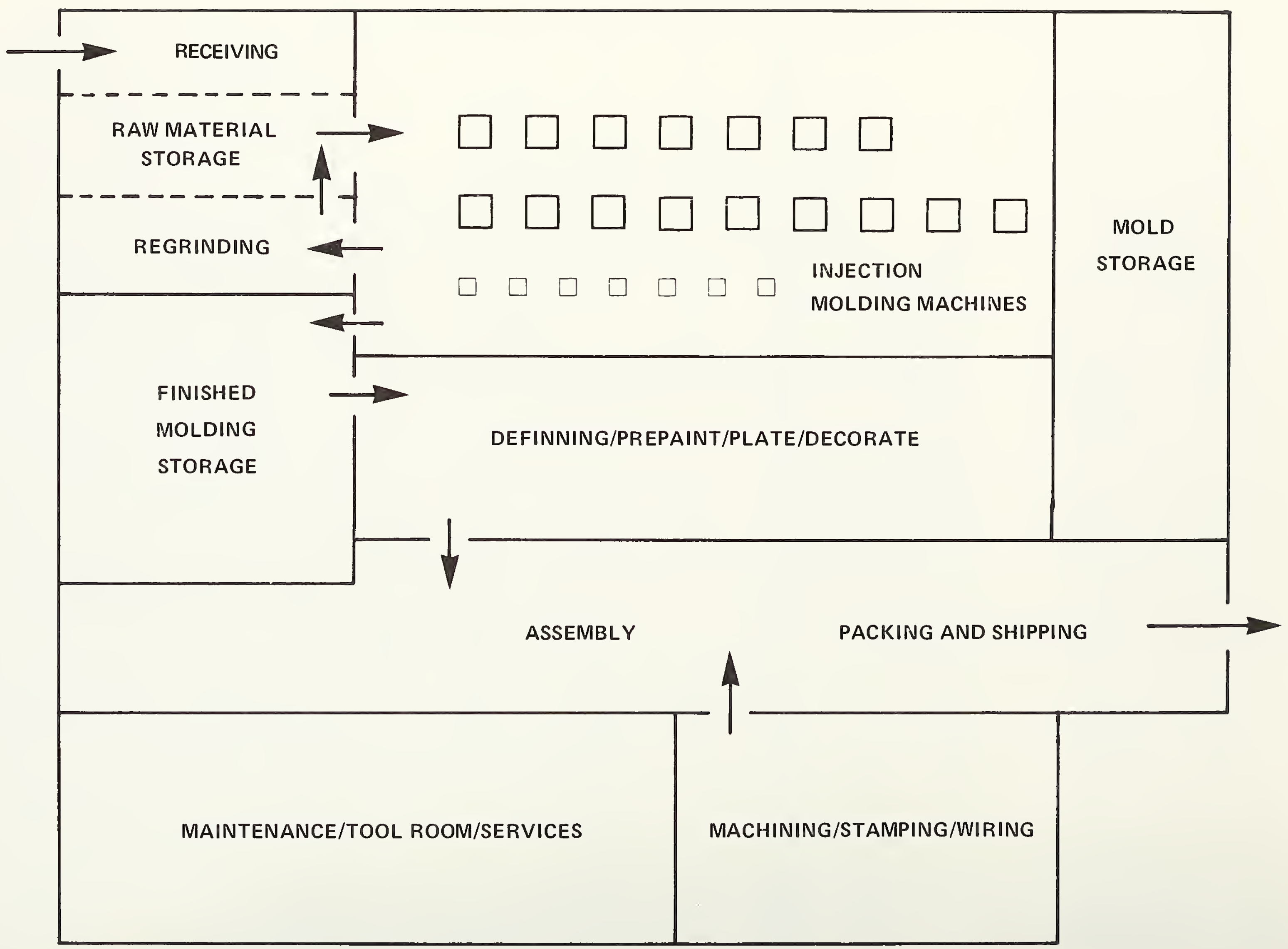


FIGURE 3-12. INJECTION MOLDING PLANT LAYOUT

Materials Flow

Resin, the principal material used in injection molding, is received at the plant in granules and placed in the raw materials storage area until required, as illustrated in Figure 3-12. As needed, the air conveyor system sucks the granules into the central vacuum system and distributes them to the injection molding machines. The granules are fed into hopper-dryers where they are blended and dried before entering the injection cylinders.

Once the molded plastic parts are ejected from the molding machine, sprues, gates, and other scrap pieces are removed by scrap cutters. All scrap is removed to the raw materials area for regrinding, while the molded plastic parts are cleaned and polished to remove rough edges and flash. A tumbling or blasting machine may be used for this purpose.

The final step in the flow of the injection moldings is the assembly process. Here the product, battery cases, glove box doors, tire valve caps, and others, are assembled and packaged for final shipping. Small components needed for the assembly process are stamped, machined, and/or wired directly in the plant. All products are packed and shipped out, usually by truck or rail car.

Capital Requirements

Total building and land requirements for the plant are shown in Table 3-5. The estimated cost for a building to house the injection molding plant is $12,700,000 for a building area of 254,000 square feet. An estimated land area of 15 acres is needed to accommodate possible future plant expansions, delivery of raw materials to the plant by truck or rail car, parking for employees, and outdoor silos for storage. The property should have adequate supplies of power, water, and air to supply all plant requirements, including lighting, ventilation, air-conditioning, compressed air supply, water treatment and an electrical substation.

TABLE 3-5. BUILDING AND LAND REQUIREMENTS FOR AN INJECTION MOLDING PLANT

Capital Requirement	Cost
Building (254,000 sq. ft. @ $50 per sq. ft.)	$12,700,000
Land (15 acres @ $20,000 per acre)	300,000
Total	$13,000,000

The estimated investment for equipment is $18 million, as shown in the itemized list of equipment in Table 3-5. The plant is fully equipped with 36 injection molding machines, including 10 high tonnage, 16 medium tonnage, and 20 low tonnage machines. Sufficient auxiliary equipment is provided for the complete manufacturing of finished injection moldings. The auxiliary equipment includes cleaning, painting, finishing, and assembly facilities. In addition, a machining, stamping, and wiring area is provided in the plant for the fabrication of small parts.

Labor Requirements

A labor force of 715 is estimated to be required for the injection molding plant described above. A typical breakdown of labor categories is shown in Table 3-6. Key personnel in the plant include the mold and equipment maintenance workers who are responsible for the safe handling, storage, and installation of the molds and continuous maintenance of the injection molding machines.

TABLE 3-6. ESTIMATED EQUIPMENT REQUIREMENTS FOR AN INJECTION MOLDING PLANT

Equipment	Quantity	Unit Price (Thousands)	Total Price (Thousands)
Injection Molding Machines:			
1,000 ton, 165 Ounce Injection Capacity	10	$280	$2,800
500 ton, 48 Ounce Injection Capacity	16	171	1,700
250 ton, 20 Ounce Injection Capacity	20	83.2	1,600
Mold Inventory			2,200
Granulator (4,500 pounds/hour)			50
Dryer (20,000 pounds/hour)			50
Air Veyor (16,000 pounds/hour)			1
Blasting Equipment			150
Cleaning Equipment			360
Painting/Plating Equipment			3,500
Tool Room and Laboratory			750
Machining, Stamping, Wiring Equipment			1,500
Assembly Equipment			1,600
Material Handling, Maintenance, Packing Equipment			1,700
Total			$18,000

TABLE 3-7. ESTIMATED LABOR REQUIREMENTS OF AN INJECTION MOLDING PLANT

Activity/Department	Number
Management	10
Production Supervision	20
Injection Molding Machine Operators	150
Cleaning/Definning	75
Painting/Decorating	30
Machining/Stamping, Wiring	100
Assembly/Packing	250
Tool Room and Equipment Maintenance	30
Materials Receiving/ Laboratory	50
Total	715

Energy Requirements

The estimated electric power requirements for an injection molding plant are listed in Table 3-7. Most of the equipment in the plant is electric, including the injection molding machines, dryers, granulators, and all painting and assembly equipment. The estimates of electricity requirements for the injection molding machines assume a 70 percent rate of equipment availability (30 percent of equipment at any time may be inoperative). The total amount of electricity use (11,000 kw per hour) would be reduced by heating the plant with natural gas.

TABLE 3-8. ENERGY REQUIREMENTS FOR A TYPICAL INJECTION MOLDING PLANT

Equipment/Function	Power Requirements (kw per hour)
Injection Molding Machines:	
7 Machines @ 151 kw	1,057
14 Machines @ 106 kw	1,484
18 Machines @ 80 kw	1,440
Other Electric Equipment (i.e., granulators, dryers, air veyors, painting and assembly equipment)	1,000
Heat and Light	6,000
Total	11,000

3.5.7 Key Issues

Key issues relating to the injection molding process are the development of material handling capabilities for large parts and improvement of the structural soundnesses of injection moldings.

Material Handling

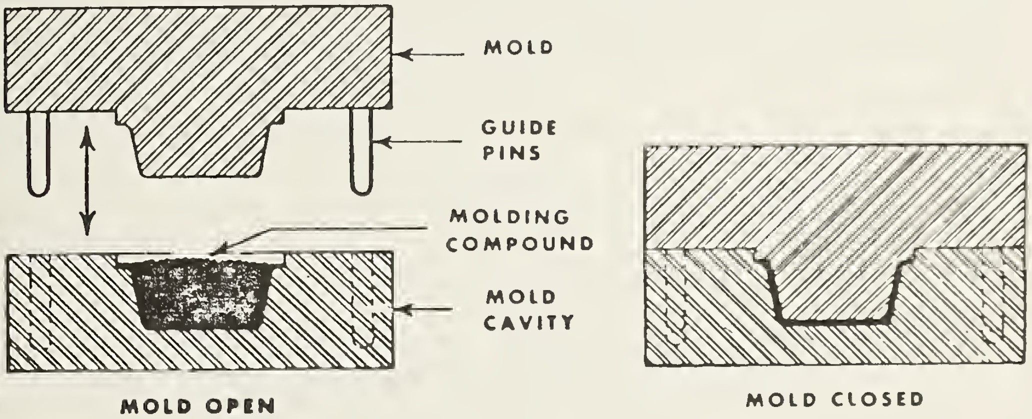
Since injection molded thermoplastics are generally warm and compliant when they are removed from the press, mechanical press unloaders are currently not capable of handling many injection moldings without causing imperfections in the molding surface. Thus, press unloading, particularly of large parts, is labor intensive and somewhat slowed by the need for manual handling. Equipment suppliers are faced with the challenge of designing mechanical press unloaders capable of extracting the moldings and stacking them without pinching or scarring the surface. Although injection molding is a faster process than other plastic forming processes such as compression molding, there is still a need to shorten processing time. It is hoped that innovations in mechanical unloading equipment will cut some of the handling time out of the current process.

Structural Soundness

There is great potential for the widespread use of injection moldings in load bearing components such as doors, hoods and quarter panels, but these applications will not be realized until the automotive industry and the public are convinced of the strength of the plastic parts. Injection moldings have not yet demonstrated the structural soundness necessary for these components and automotive engineers are hesitant to introduce injection moldings in body designs. While there is an urgent need to lighten the auto, more engineering data must be developed which will certify that injection molded body parts can withstand the necessary physical strains under all possible conditions before they replace steel stampings in auto bodies.

3.6 COMPRESSION MOLDING

Compression molding is used to form plastic components through the application of heat and pressure in a closed mold. It is used almost exclusively for shaping thermoset plastics. The plastic molding material, usually in powder or granule form, is loaded into a mold cavity. The mold is closed, squeezing the molding material throughout the cavity. In most cases, the application of heat triggers a chemical reaction in the plastic compound that permanently hardens the material in the shape of the mold.* The compression technique molding typically uses hydraulic presses to force the sections of the mold together. A basic two-part compression molding process is illustrated in Figure 3-13.



Source: SPI, Plastic Engineering Handbook

FIGURE 3-13. BASIC COMPRESSION MOLDING PROCESS

In the automotive industry, compression molding is most commonly used with reinforced polyester compounds. These are compounds that combine thermosetting polyester plastic and, in most cases, glass filament reinforcing materials. They are strong and have exceptional strength to weight. The

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* In other cases, the application of the catalyst alone causes the chemical reaction.

most commonly used reinforcement materials usually come in rolls of thick sheet called sheet molding compound (SMC). Their automotive applications include front fascia, spoilers, grille opening panels, fender caps, and other nonstructural trim and decorative parts.

3.6.1 Major Types of Compression Molding

Different types of compression molding are distinguished by:

- The type of mold used
- The type of press used
- The type of molding material used.

Molding processes may also vary with the design of the final product. Important variables include the thickness of the part, the presence or absence of metal inserts, and the required degree of tolerance.

Type of Molds

Compression molds fall into three general categories: hand molds, semi-automatic molds and fully automatic molds. Each is described below.

- Hand Molds. These are molds which must be manually removed from the press, taken apart to remove the molded article, and assembled again for the next molding cycle. They are normally used for experimental or small product runs, or for molding highly complicated articles.

- Semi-Automatic Molds. Semi-automatic molds are mounted on the hydraulic press, and the operation of the press opens and closes the mold and ejects the finished piece from the molding cavity. This type of mold is most often used in applications that require multiple cavities or for articles that are too large or too deep for hand molding.

- Fully Automatic Molds. Fully automatic molds are operated with a completely automatic press. The complete cycle of operation, from the loading of the molding compound to the unloading of the finished article, is carried out automatically.

Fully automatic molds frequently contain multiple cavities. Although they represent a larger investment, fully automatic molds and presses achieve a higher rate of production and greater uniformity while requiring significantly lower labor expenditures.

Regardless of the type of mold, most molds are made from high grade steel so that they can be hardened and polished.

Types of Presses

From an operational standpoint, compression presses may be separated into two groups, the self-contained type and those operated by remote power (system type). The former are complete units and do not require any auxiliary equipment to make them function. That is, they come equipped with an individual pump and motor from which is derived the power to either open or close the moveable platens. In contrast, the system type press requires a power house, i.e., accumulator, compressor, piping system and boiler to be able to operate on a production basis. Both types of presses, however, serve the same function--to force and hold the sections of the mold together.

In general, self-contained type presses are more expensive than system type presses because the motors, pumps and controls are component parts of the press. However, because they include their own power source, they are more flexible than system type presses. Thus, self-contained presses are used more commonly in small plants with limited requirements, while system type presses are usually found in large installations where many batteries of presses are required to turn out a large volume of work.

Presses come either hydraulically or mechanically operated (hydraulically operated being the most popular) as well as in a broad range of sizes. They also come hand operated, semi-automated and fully automated. Fully automatic compression molding involves automatic sequencing of necessary functions performed in making finished molded articles from granulated or nodular thermosetting molding compounds. Essentially speaking, it involves a compression molding press equipped with a mold and additional equipment designed to:

- Store a quantity of molding compound
- Meter volumetrically or gravimetrically, exact changes of compound
- Deposit these charges into appropriate mold cavities
- Remove the finished article from the mold material following each cycle
- Remove any flash or granular molding material not ejected with the finished article.

Once an automatic press has been placed in operation, it can run unattended except for periodic recharging of the storage container (hopper) and removal of finished parts plus occasional maintenance and minor adjustments. One prevalent automatic molding design is the rotary press where as many as 30 molds are arranged in a circle around a traveling mechanism. The mechanism moves continuously from mold to mold activating each individually.*

Type of Material

A wide variety of thermoset plastics are shaped by compression molding. All of the plastics are chemical compounds made by processing a mixture of heat-reactive resins with reinforcements, fillers, pigments, dyestuffs, lubricants, etc. The molding compounds are usually in powder, granulated or modular form.

The plastic used most frequently for compression molded articles is phenol-formaldehyde, generally called phenolic molding compound. Other resin systems include melamine-formaldehyde, alkyds and polyesters, diallyl phthalate, epoxy and silicone. Common reinforcements are glass and synthetic fibers. Fillers consist of silicon, wood flour, or combinations of these.

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* Automated machines such as these, however, are not commonly found in the automotive industry.

When heat is applied to thermoset plastics, the materials first become liquid and then undergo an irreversible chemical reaction called "cure" or "polymerization." Polymerization is generally a time-temperature relationship requiring shorter cure times when higher temperatures are used. Typical pressure, temperature, and time values for a phenolic wall socket in semi-automatic compression molding might be 3000 psi, 300°F, and 1-1/2 min.

Depending on the type of molding material and the final product, some compression molding applications involve preforming and preheating of the molding compound.* Preforming insures accuracy in the volume of the compound load placed in each cavity. It also facilitates proper distribution and flow of resin and accurate placement of reinforcement material in asymmetrical product shapes. Preheating reduces the cure time necessary to harden the compound. Best results are obtained with electric preheaters that heat the compound internally and avoid the possibility of prematurely hardening the surface of the molding material.

3.6.2 Advantages and Disadvantages of Compression Molding

Some of the advantages of compression molding for thermoset plastics are as follows:

- Significantly less waste of material in comparison to other molding processes
- Internal stress in the molded article minimized
- Utilization of a maximum number of cavities in a given mold
- Readily adaptable to automatic loading and unloading
- Useful for thin wall parts
- Best suited for reinforced plastics
- More economical than transfer or injection molding for parts weighing more than 3 pounds

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* Preforming and preheating of materials are also not common in the automotive industry.

- Suitable for large parts

- Molds generally less expensive than injection types.

Some of the disadvantages of compression molding for thermoset plastics are as follows:

- Not suitable for very intricately designed articles

- Special confinement and positioning considerations for polyester compounds

- Requires cleaning of mating parts of molds between compressions

- Requires generous ejector areas to avoid fracturing of articles on release from molds

- May be unsatisfactory for production of articles having extremely close dimensional tolerances.

3.6.3 Automotive Applications

Automotive applications of compression molding include the following:

- Front fascias
- Spoilers
- Grille opening panels
- Fender caps
- Trim.

These and other automotive components are shown in Figures 3-14, 3-15 and 3-16.

3.6.4 Equipment Required

With the types of compression presses available today, (i.e., self-contained presses), very little additional equipment is needed to make compression molded plastic parts. The only other equipment necessary (besides the molds themselves) would be:

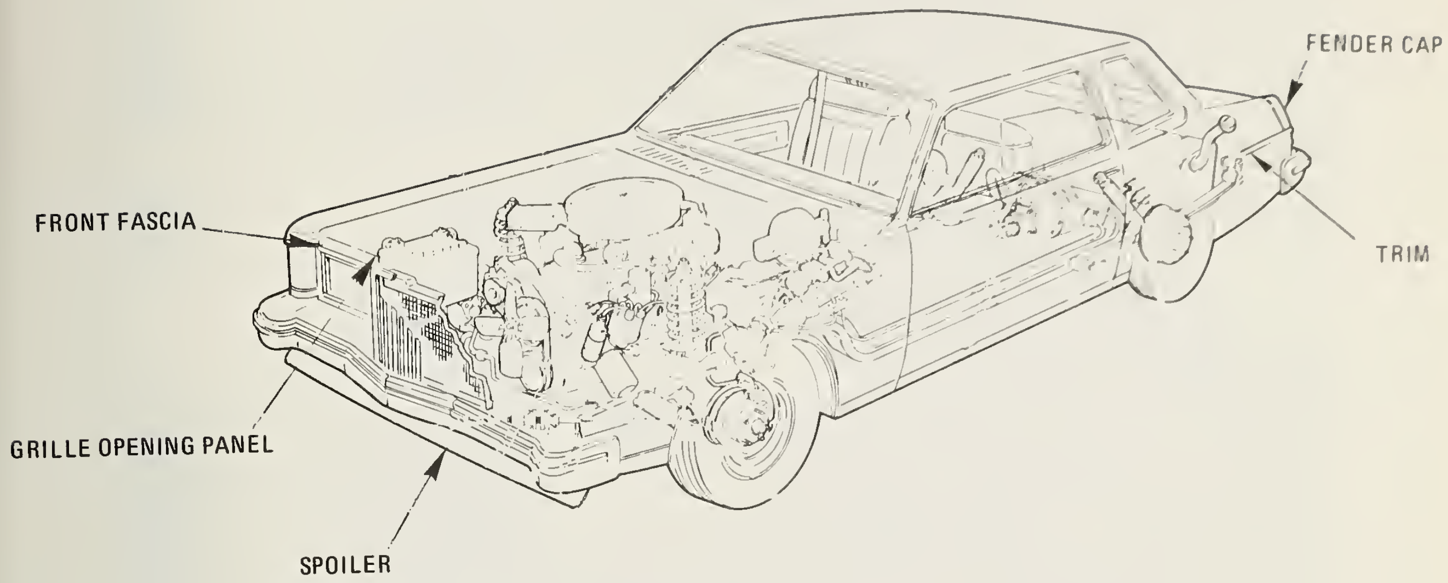

FIGURE 3-14. COMPRESSION MOLDED AUTOMOTIVE COMPONENTS

- Equipment needed to cut the preformed or SMC material before introduction into the mold cavity
- Equipment for removing the excess plastic material, i.e., flash, from the molded product, i.e., deflashing or trimming machine
- Paint and primer spraying equipment
- Other equipment such as air compressors to support the deflashing machines, material handling equipment (racks, cranes, forklift trucks), resin storage equipment and inspection equipment.

Information on the cost, suppliers, capacity, cycle and lead time for selected examples of this equipment is summarized in Table 3-9. As described in the previous section, there exists automated equipment which essentially combines most of the above equipment into one unit. This equipment, however, is not usually employed in the automotive industry. A compression molding machine in operation is shown in Figure 3-17.

TABLE 3-9. MANUFACTURER AND PRICE INFORMATION FOR SELECTED COMPRESSION MOLDING EQUIPMENT

Equipment	Manufacturers	Capacity	Lead Time	Cycle Time	Price
Compression Molding Machines	Wabash Metal Company	1,000 Tons			$100,000
	Reliable Plastic Machinery	400 Tons			80,000
	Dake Corporation	100 Tons			70,000
Molds	Atlas Machine & Tool	3 Lbs.	6 Months		40,300
	Atols Tool & Mold	10 Lbs.	7-8 Months		85,460
	Damascas Tool Company				
Deflashing Machine	Dynablast	3 Lb. Part	2 Months	5/Minute	38,000
	D-M-E Company	15 Lb. Part	2 Months	1/Minute	38,000
	Wheelabrator-Frye				

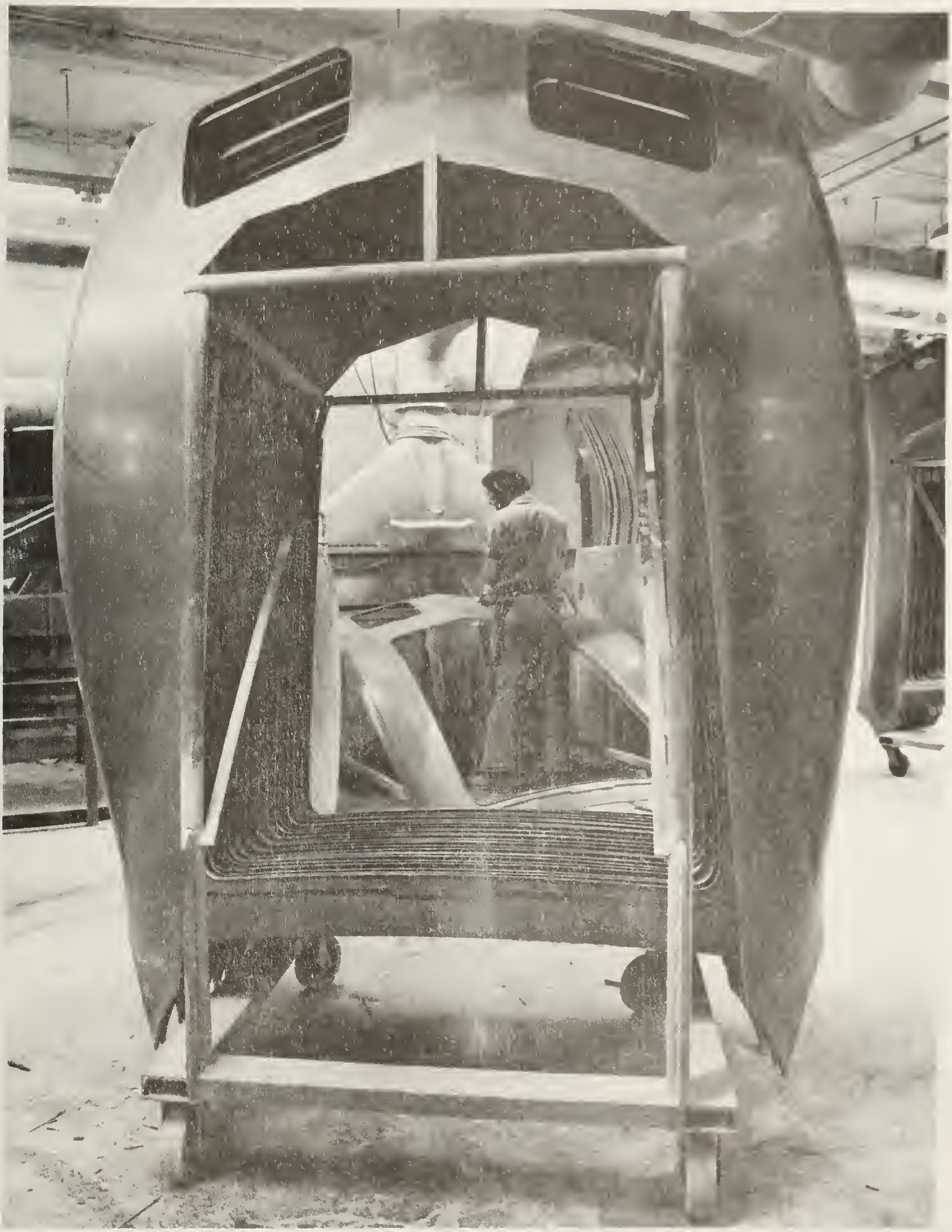

FIGURE 3-15. GLASS
REINFORCED BODY PART FOR CORVETTE

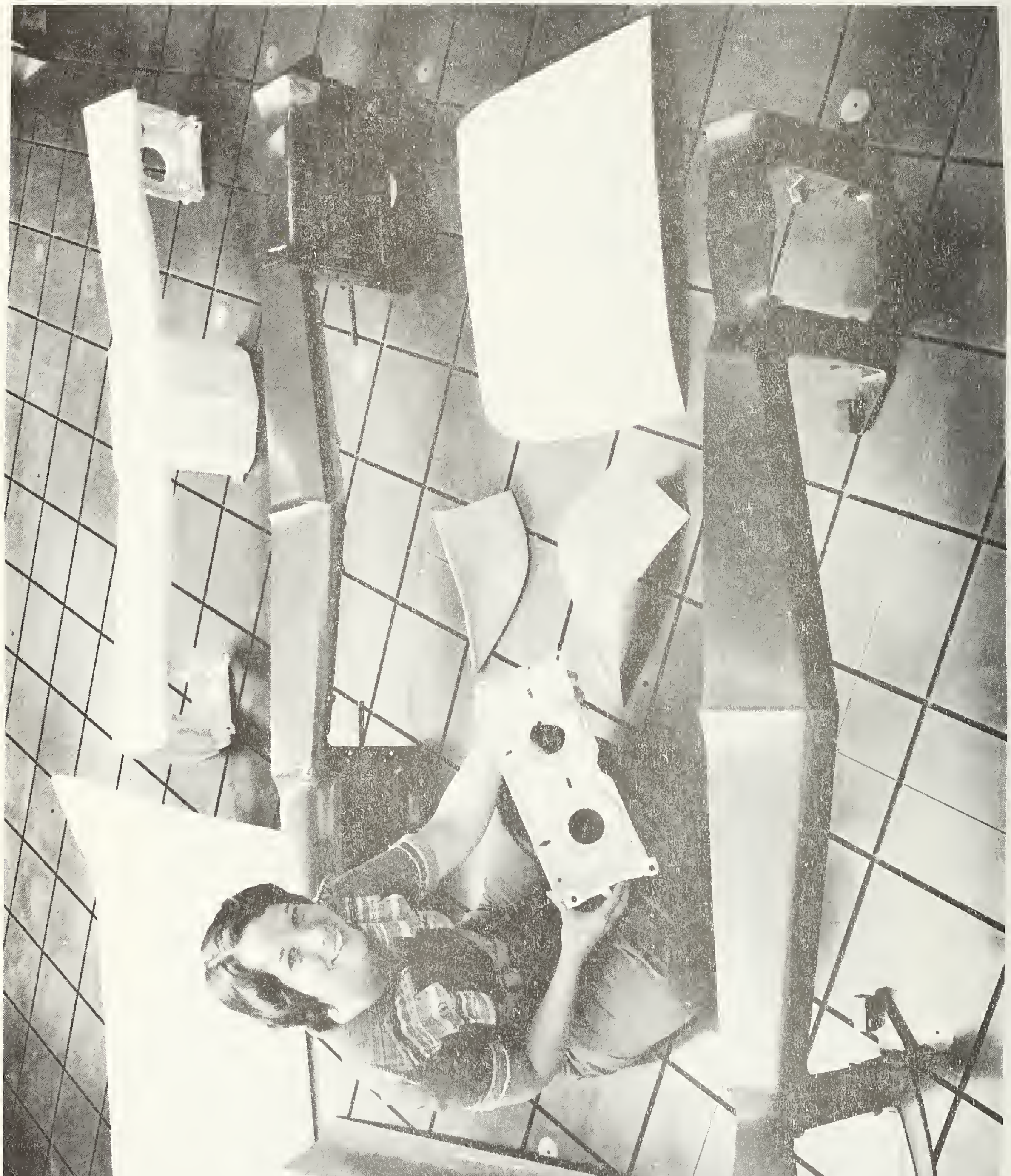

FIGURE 3-16. COMPRESSION MOLDED AUTO PARTS

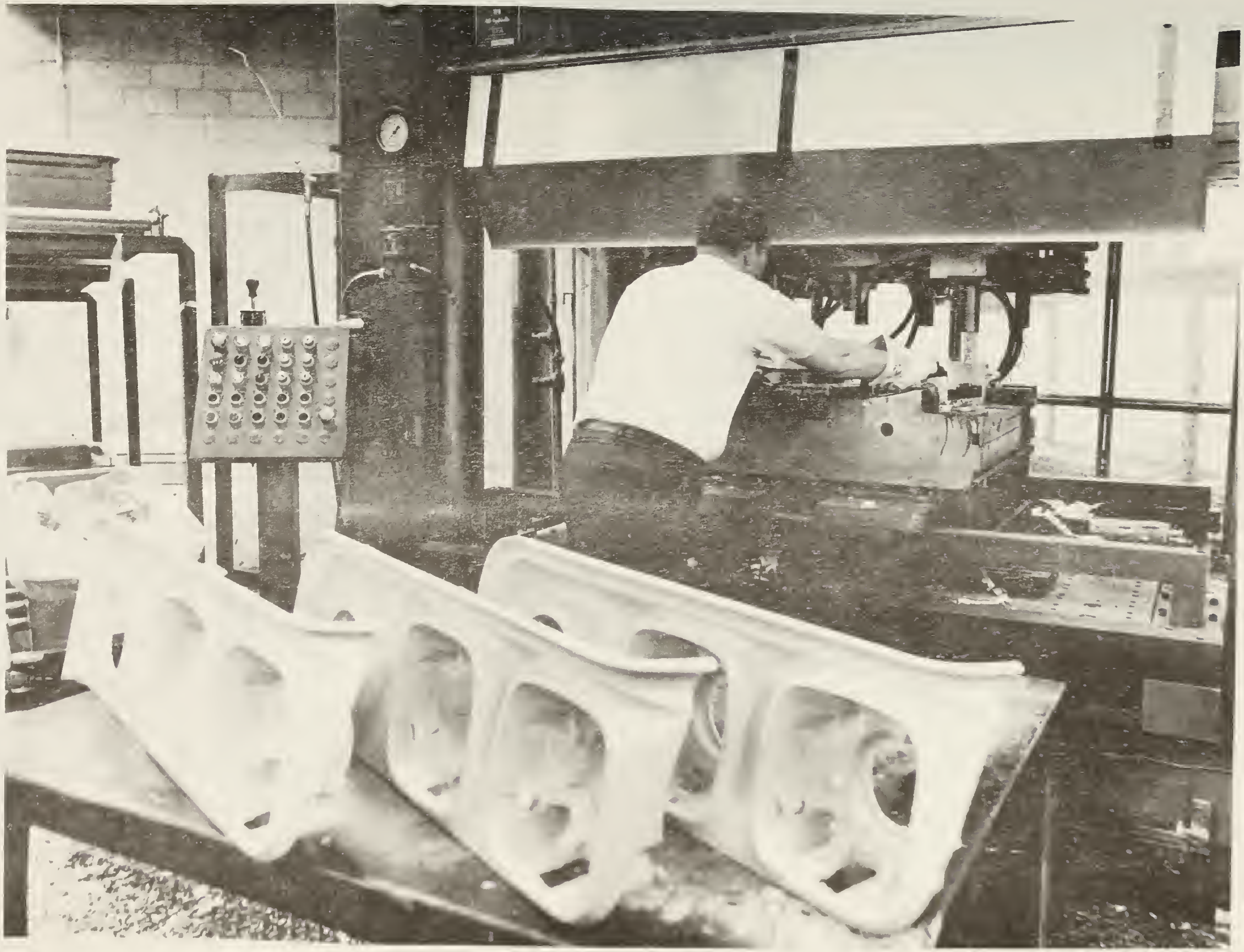

FIGURE 3-17. COMPRESSOR MOLDING
MACHINE IN OPERATION

3.6.5 Size and Structure of the Industry

Compression molding is the most popular method of processing thermosetting materials and is used to manufacture many products in addition to automotive components, such as golf balls, phonograph records and outboard motor housings. In the passenger car alone, compression molded plastics make up 44 percent of total plastics consumption. The types of plastics used for automotive components are listed in Table 3-10, along with the total number of pounds used in passenger cars for the years 1972, 1974 and 1976. As shown in the table, the thermosetting plastics which are increasing in use is glass reinforced polyester.

TABLE 3-10. CONSUMPTION OF THERMOSETTING PLASTICS IN PASSENGER CARS

Material	Consumption (Million Pounds) 1972	1974	1976
Cellulosics	17	19	15
Phenolic	55	51	46
Glass Reinforced Polyester	140	154	220

Source: Kline's Guide to the Plastics Industry, 1978.

The total number of compression molding facilities in the United States is 2,550. Because of the loose organization of the industry, statistics are not available which define the percentage of these facilities which supply the automotive industry.

3.6.6 Characteristics of a Typical Compression Molding Plant

This section describes the plant layout, work flow and capital and labor requirements of a compression molding plant assumed to consume approximately 60 million pounds of molding compound per year (30 million pounds of resin plus 30 million pounds of glass). This total amount is equivalent to a daily consumption of 100,000 pounds of each material.

Plant Layout

Figure 3-18 shows a typical compression molding plant layout. As shown, the plant includes areas for receiving and storing raw materials, preparing the molding compound (either bulk or sheet), a room for the molding machines and a storage area for completed moldings. Additional areas in the plant are provided for cleaning and inspection of the compression moldings, final painting (if needed), packing, shipping and equipment maintenance and laboratory facilities. The estimated allocation of space to each of these activities is summarized in Table 3-11.

TABLE 3-11. DISTRIBUTION OF AREA AMONG PLANT ACTIVITIES

Activity/Function	Area (Sq. Ft.)
Material Receiving, Storing and Handling	150,000
Premixing and Preparation of Molding Compound	5,000
Molding Machines	90,000
Cleaning/Inspection	45,000
Priming/Painting	25,000
Equipment Maintenance and Laboratory	5,000
Aisles	80,000
TOTAL	400,000

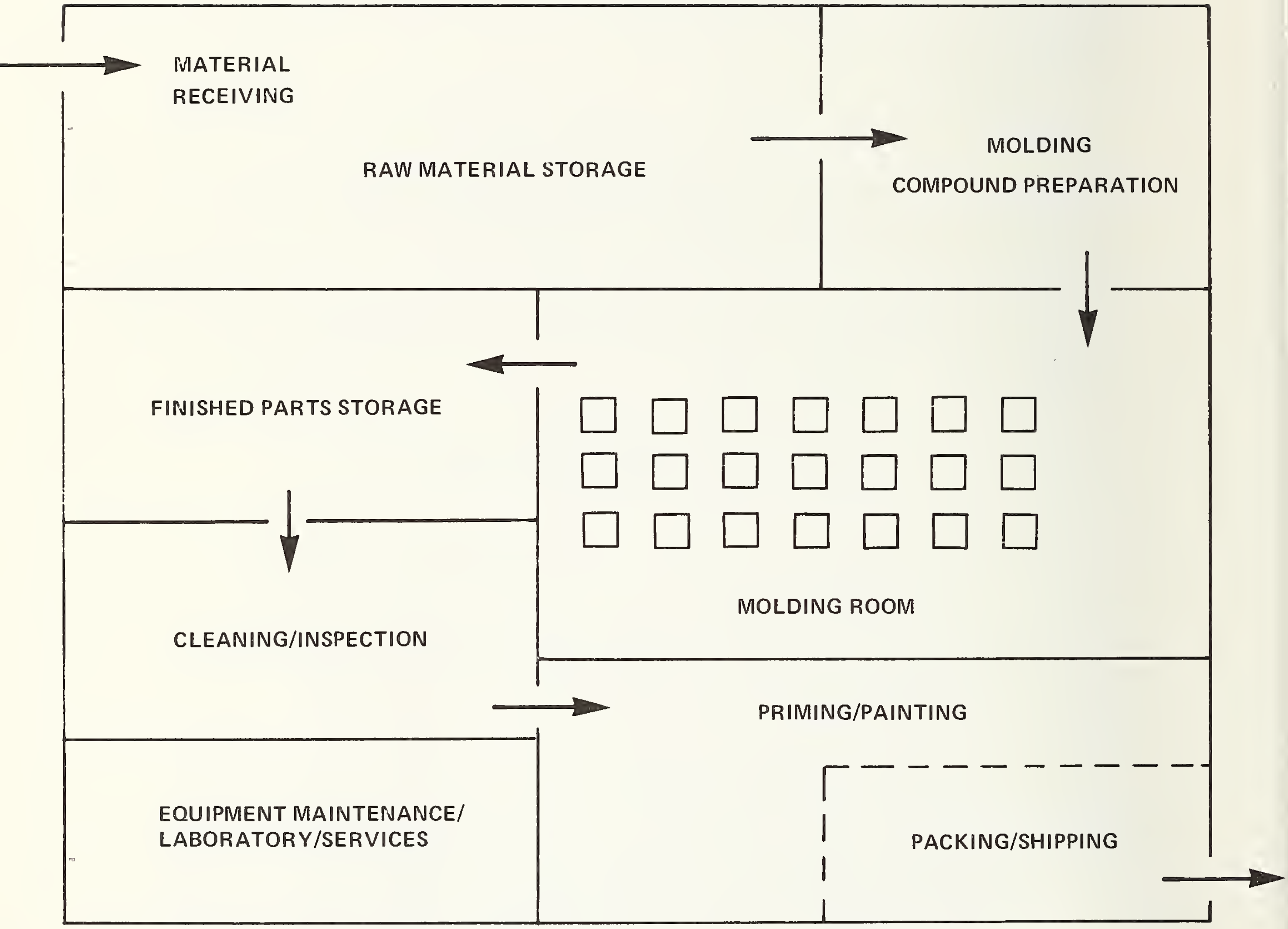

FIGURE 3-18. TYPICAL COMPRESSION MOLDING PLANT LAYOUT

Materials Flow

The first step in the materials flow is the preparation of the molding compound from the thermosetting polyester, catalysts and reinforcements. A measured amount of the compound is placed in the lower half of each compression mold along with an appropriate amount of thermosetting polyester and catalysts. When SMC is used, the individual mats are first cut into the desired size and then positioned in the mold along with the resins. Where required, the molding compound is next preheated up to the temperature where it is plastic and will flow easily as the mold closes. This mass is then heated under pressure in the mold until polymerization occurs and the material becomes a dense solid.

The resulting form is ejected from the machine and flash is removed by deflashing or trimming equipment. The completed compression moldings are temporarily shelved in a storage area until they are completely cured. They are then cleaned, inspected and finished with a primer or paint as needed. Finished parts are packed and shipped from the plant by truck or rail car.

Capital Requirements

Total estimated capital requirements for the typical compression molding plant are $42,930,000. A building to house the plant is estimated to require 400,000 square feet for a building cost of $20 million. Twelve acres of land add another $360,000. Total building and land requirements are shown in Table 3-12.

TABLE 3-12. ESTIMATED BUILDING AND LAND REQUIREMENTS FOR A COMPRESSION MOLDING PLANT

Capital Requirement	Cost (Thousands)
Building (400,000 square feet @ $50/sq. ft.)	$ 20,000
Land (12 acres @ $30,000/acre)	360
TOTAL	$ 20,360

The compression molding machines are the largest single equipment expense. A total of 105 machines, ranging from 250 to 1,000 tons of pressure are estimated to cost $8.6 million. The necessary mold inventory is estimated at $7 million and deflashing and priming/painting equipment is estimated at $4.4 million. The total equipment costs, shown in Table 3-13, are estimated at $21.9 million.

TABLE 3-13. EQUIPMENT REQUIREMENTS FOR A COMPRESSION MOLDING PLANT

Equipment	Quantity	Unit Price (Thousands)	Total Price (Thousands)
Molding Machines			
1,000 Ton	5	$ 100	$ 500
400 Ton	50	85	4,550
100 Ton	50	70	3,550
Mold Inventory			7,000
Cutting Equipment			100
Deflashing Equipment	65	38	2,470
Cleaning/Inspection Equipment			1,000
Priming/Painting Equipment			2,000
Miscellaneous Support Equipment Including Air Compressors, Material Handling, Racks, Crane, etc.			700
TOTAL			$21,870

Labor Requirements

Total labor requirements for the compression molding plant are estimated to be 347 employees, including production workers and management. Nearly half of the production workers are required to operate or provide support for the injection molding machines, and 75 workers are needed for cleaning of the completed plastic parts. Table 3-14 lists the total labor requirements for each of the major plant activities.

TABLE 3-14. ESTIMATED LABOR REQUIREMENTS FOR A COMPRESSION MOLDING PLANT

Activity/Function	Number
Plant Management and Administration	10
Injection Molding Area	150
Blending/Performing Mold Compounds	20
Cleaning	75
Paint	30
Equipment and Building Maintenance	50
Foremen, Supervisors	12
TOTAL	347

3.6.7 Key Issues

There are three important issues or trends currently in the compression molding field. These include:

- Improved equipment to meet the needs of high-volume SMC automotive production
- The conversion of many large compression molded parts to injection molding of glass-fiber-reinforced polyster.
- The need to reduce the cycle time for compression molding SMC.

3.6.8 Improved Equipment

A basic trend in thermoset processing is toward more precise control and increased automation to improve productivity. In compression molding, the increased use of glass reinforced parts by the auto industry has helped to a large extent to generate interest in improving the compression molding process. Newly-designed add-on equipment includes SMC resin-mixing systems, programmable SMC preform cutters, press loaders/unloaders, and trimming and deflashing equipment.* Also, compression presses are being equipped with more sophisticated machine-control systems. These improvements should make compression and transfer molding more viable for mass production use.

3.6.9 Converstion to Injection Molding

Thermoset injection molding has recently been gaining popularity as a replacement for compression molding, and reaction injection molding has also negatively impacted the compression molding process. The fast cycle times of injection molding and the low equipment cost of R/M have sometimes made these processes economically justifiable. Many makes of large automotive parts have switched from compression molding to injection molding of glass-fiber-reinforced polyster. Reduction in post-mold finishing and scrap loss is also a major attraction to prospective switchers to injection molding.

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* Modern Plastics, April 1929, page 62.

However, compression molding will still remain important in certain applications (such as those requiring a special orientation of reinforcements in the molded part) and may continue to be the choice of independent producers since it requires less capital investment than for injection molding. Compression molding may also continue to be the preferred method for molding large glass-reinforced auto parts, such as hoods or deck lids.

3.6.10 The Need to Reduce Cycle Time

In many cases, a compression molding press will do the same work as a number of steel stamping and forming presses. According to Owens-Corning, in order to SMC to compete with steel in auto body parts, the cycle times for compression molding must be brought down to two minutes. This would make the production of fiberglass-reinforced hoods, desk lids and doors economically justifiable.

In order to reduce cycle time, Owens-Corning is undertaking a major research effort to develop fast cure SMC systems. In addition, the company feels the time consumed in heating the charge in the mold can be dramatically reduced by preheating outside the press.

3.7 REACTION INJECTION MOLDING

Reaction injection molding (RIM) is a process for molding polyurethane elastomers or foams into end-products with solid integral skins and cellular cores. Two or more streams of highly reactive liquid components are impinged together under high pressure in a mixing chamber. The resulting mixture is then injected, under low pressure, into a mold where the component materials react until the mixture has formed into a solid finished product.

Reaction injection molding is today primarily used for molding large polyurethane automotive parts such as bumpers and front fascia. The technique is new but is gaining rapid acceptance in the industry because it considerably reduces the capital and operating costs for making large plastic parts. The acceptance of RIM has been accelerated by regulations concerning the durability of automobile front and rear ends under low speed impact. These regulations have led to increased use of "soft" front ends, using plastic materials such as RIM-molded polyurethane.

3.7.1 Major Types of Reaction Injection Molding

The major types of reaction injection molding can be distinguished by

- Materials used
- Equipment arrangement
- Mixing pressure

Materials Used

The plastic most commonly molded by RIM is polyurethane, formed by combining an isocyanate with a polyol. The mixture and types of the isocyanates and polyols determine the properties of the urethane. Some of the major groupings of RIM urethane applications segregated by type of urethane foams used are as follows:

- High density, integral-skin foams used for TV cabinets, electronics consoles, engine housings, building construction parts, and sports equipment

- Semi-rigid elastomers used in automobile bumpers and fascia, solid tires, rollers, and belts

- Low density insulation foams used in refrigerator and freezer cabinets.

In the auto industry presently the major type of urethane used is the semi-rigid form. However, high modulus urethanes reinforced with glass are being actively explored by auto manufacturers for use in automotive fenders, side panels, hoods and trunk lids. Thus reinforced rigid urethane foam is being considered as a lightweight replacement for metal parts. The success of this change depends on the perfection of the technology of making reinforced urethane parts by reaction injection holding.

Several nonpolyurethane resin sytems are now available for RIM and there is now considerable interest in using these new systems.

Equipment Arrangement

The formation of urethane involves a reaction between polyols and isocyanates. The basic equipment for RIM processing includes material tanks for storing, heating, and recirculating the reactive liquids; high output pumps for delivering the liquids; mixing heads with adjustable opposing orifices for liquid streams; molds made from steel, aluminum, or nonferrous alloys; clamps for holding the molds; and a molding press.

The heart of the system is the mixing head. The impingement mixing chamber is very small - 1 to 5 cu cm - and impingement pressures run between 1500 and 3000 psi. Once the mixed components are injected into the mold, usually at pressures below 60 psi, they begin to react immediately.

Over the past four years molding cycle times have fallen from around six minutes to under two minutes on many volume applications. Thus there now exist two major types of RIM installations. Many of the first installations used "multiple clamp" arrangements where a urethane unit with material tanks and pumps would inject urethane into as many as twelve different "clamp" units. The clamp units would contain the clamps and hydraulics for holding the molds and the molds themselves. Multi-station sequence control and distribution systems were required.

Another type of installation is now available. This type of operation uses individual self-contained reaction injection molding machines very similar in concept to injection molding machines.

Mixing Pressure

The term RIM now usually refers to a urethane process where the polyols and the isocyanates are mixed by high pressure impingement of the two liquids. Earlier methodologies for molding rigid urethanes used low pressure pumps and mechanical mixing systems. The new high pressure RIM system has many advantages as listed below.

- The mixing head is self-cleaning so that a solvent flush, which is required in low pressure molding, is not needed.
- Outputs are higher since there is no mechanical mixing. Thus faster reacting urethane mixes can be used.
- Mold cycle time is reduced because reaction time is faster and the material cures more rapidly.
- Less air is trapped in the reaction mixture so that the parts have improved appearances with less surface defects.

3.7.2 Advantages and Disadvantages of Reaction Injection Molding

Reaction injection molding has some significant advantages over other molding processes, particularly injection molding. They include the following:

- Per part cost 20 to 30 per cent lower than alternative methods
- Mold injection pressures of 50 to 100 psi, compared to pressures as high as 4000 psi for injection molding precesses
- Lower process temperatures, averaging 70° to 80° F for the liquid reactants and 120° to 160° F for the mold
- Less of the floor space required for injection molding processes

- One-fiftieth of the energy required for other plastic-forming processes.

For large automotive parts, reaction injection molding requires less capital investment and less operating energy usage than injection molding. Injection molding requires high tonnage presses (3000 tons) to mold large parts whereas with RIM a 100 ton press is adequate.

A special class of problems has arisen in reaction injection molding when manufacturers have attempted to use the process for producing rigid reinforced urethanes. They are being addressed but continue to require special consideration. They include the following:

- Regular maintenance of the mixing head required to prevent erosion of mixing-head hydraulic pistons by reinforcing agents

- Avoidance of elbows and sharp turns in material lines necessary to prevent settling of filler fibers

- Negative effect on part impact strength when reinforcing fiber is added to urethane.

3.7.3 Automotive Applications of Reaction Injection Molding

RIM is presently used for automotive front fascia, and bumpers. Soft bumpers or front ends are now on such cars at Ford's Thunderbird and Mustang; GM's Pontiac Firebird, Chevrolet Camaro and Pontiac Phoenix; and Chrysler's Omni/Horizon. In 1980, approximately 24 percent of new car front ends will have soft urethane components, and RIM is expected to process some 30,000 tons of unreinforced elastomer for the '80 model year .

Potential uses for reinforced reaction injection molding (RRIM) include many body parts. Present and potential uses of RIM parts are shown in Figure 3-19. In 1980 reinforced RIM will be used to make 5000 fenders on Oldsmobile's Omega X-body. Actual examples of RIM parts are shown in Figure 3-20.

1. Modern Plastics, October, 1979, p. 40.

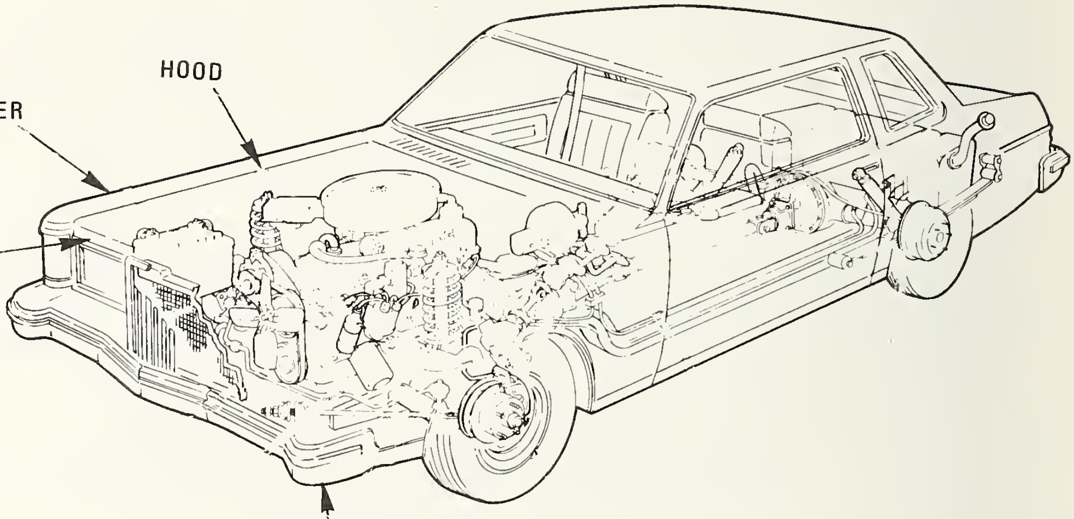


FIGURE 3-19. PRESENT AND FUTURE USES OF RIM PARTS ON A CAR

3.7.4 Equipment Required

Principal categories of equipment used to manufacture RIM parts are:

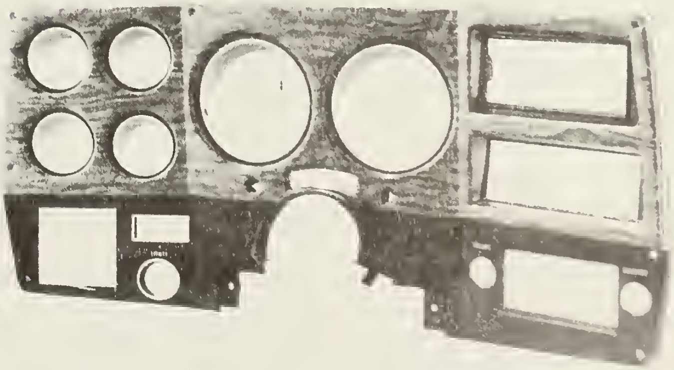
- RIM molding machinery
- Ovens
- Molds

Equipment specifications, lead times, and costs along with principal equipment manufacturers are shown in Table 3-15. Below is a brief description of the various major pieces of equipment.

RIM Machinery

During operation of RIM equipment the two urethane components continuously recirculate through the system. Thus, in some operations a recirculator is a necessary part of the RIM molding system. The two high pressure pumps in the system must be capable of filling the mold completely in 2 to 3 seconds, which entails throughputs

Fascia



Instrument Panel

FIGURE 3-20. EXAMPLES OF RIM PARTS

TABLE 3-15. EQUIPMENT: REACTION INJECTION MOLDING

Type	Company	Capacity	Cycle Time	Lead Time	Price
Reaction injection molding machine	Cincinnati Milacron, Admiral Equipment, Battenfield Corp.	90 ton 54" daylight Maximum shot weight 50 lb.	2 min.	8 mos.	$170,000
		72" daylight	2 min.	8 mos.	$190,000
Recirculating Machinery	Cincinnati Milacron	Feeds 6 to 8 RIM machines		6 mos.	$ 36,100
		Feeds 1 reinforced RIM Machine			$ 52,000
Post-Cure Oven	Cincinnati Industrial Koch, Goerge, Sand, Inc.	120x32x10 ft.	1200 parts per hour	20 wks.	$100,000*
		66x23x13 ft.			$ 62,000
		68x25x14 ft.			$ 80,000
Molds	Athols, Chicago A-1 Tool Corp.	Large bumpers smaller		6 mos.	$100,000 $60,000

* Add 50 percent for installation

as high as 650 lb/min and pressure to 3000 psi.

In cases where a RIM pump unit serves many clamp units, many high pressure lines are required and sequencing controls and valves are needed. To save space, the pump unit can be placed above the presses. When the pump and clamp units are mounted together, the unit can serve as a complete RIM system, much as with injection molding machinery. Examples of RIM equipment are shown in Figure 3-21.

Ovens

Ovens are used to finish cure the urethane-molded parts after they come out of the molding machines. The parts are usually moved through the oven by a conveyor that can make many passes back and forth. The size of the oven required depends upon the temperature the parts are to be kept at, the specific thermal properties of the parts, and the number of parts to be processed each hour. Usually an operation requires a single oven which must be custom made to the particular requirements of the plant.

Molds

Techniques for making molds for RIM are quite different than for normal injection molding. Mold making companies are still learning the subtleties of the process. Although lower pressures could result in the use of lighter, less expensive molds, requirements for durability have tended to keep steel molds common. Each RIM machine requires a mold and the molds generally last the lifetime of the run of the part.

3.7.5 Size and Structure of the Industry

Since RIM technology is so new, its use is not widespread and a few companies dominate the industry. Within the auto industry both Ford and GM have RIM facilities. GM's facilities include 18 large machines and are connected with Guide in Anderson, Indiana. Ford has a captive plant in Utica. Outside the automotive manufacturers, Davidson Rubber, part of Ex-Cell-O Corporation, is the leading RIM manufacturer. Davidson will supply 45 percent of all soft bumpers used in 1980 model cars, with the car companies manufacturing about

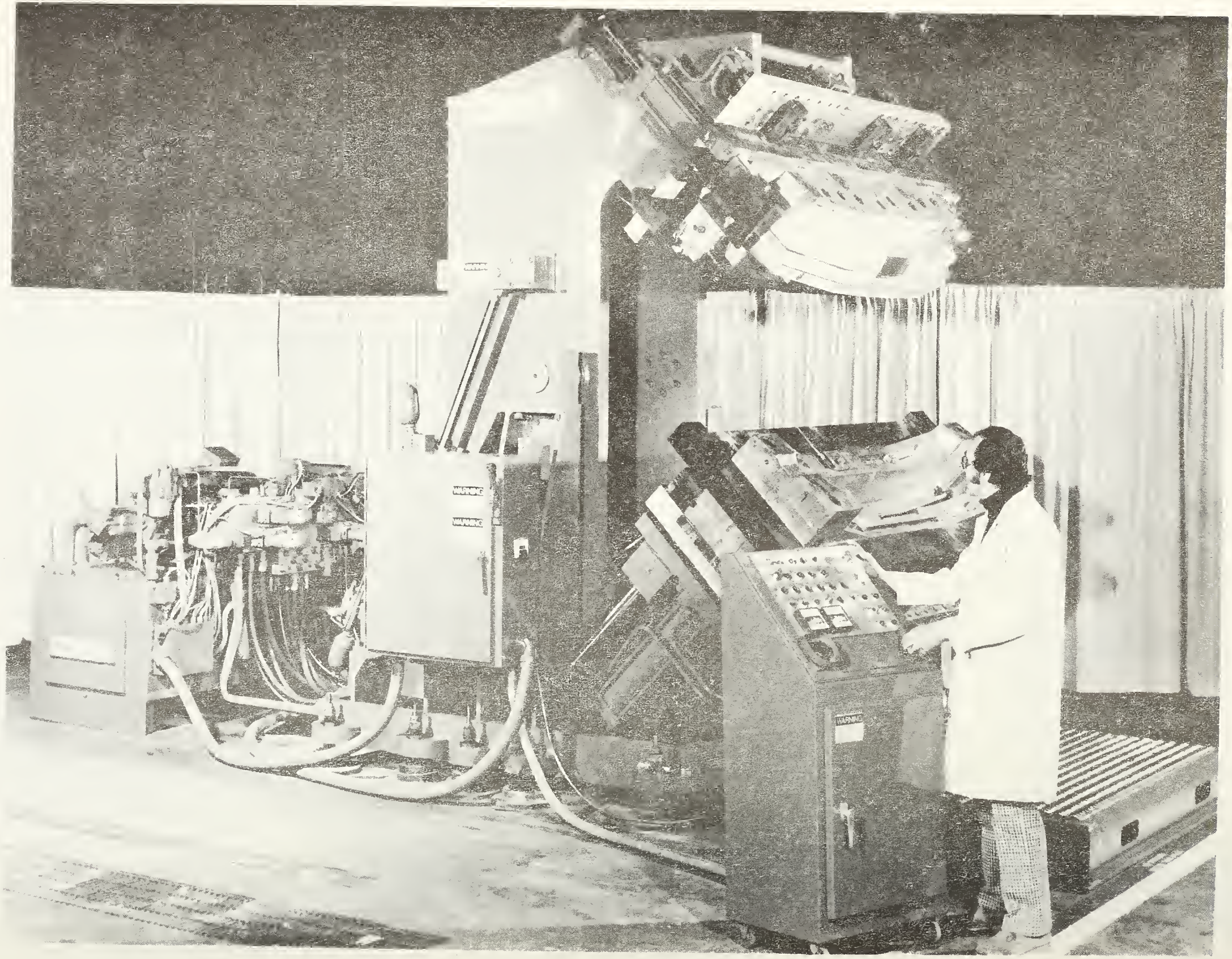


FIGURE 3-21. RIM MACHINERY FOR MAKING BUMPERS

42 percent. Davidson's share will amount to about $65 million worth of business and includes soft bumpers on such cars as the Mustang, Camaro, and Omni. Davidson's main RIM plants are in Farmington, New Hampshire and Americas, Georgia. Another important independent RIM company is C & F Stamping, Grand Rapids, Michigan. The company is producing a reinforced RIM spoiler as a customizing accessory to Pontiac's 1980 Sunbird Formula subcompact.

3.7.6 Typical Plant

Currently, RIM plants that supply the auto industry have a wide range of sizes and equipment. A typical large producer could have perhaps 30 molding machines in a plant. Plants that make large RIM parts tend not to use other kinds of plastic molding processes. A typical automotive production plant layout would have many parts in common with an injection molding plant, such as a painting and an assembly area. Below is a description of a hypothetical RIM plant using 30 machines and producing about 30 million pounds of plastic products per year.

Plant Layout

Figure 3-22 shows a diagram of the typical plant. The major areas of the plant include:

- The molding area
- The post-cure area
- Painting area
- Assembly area
- Machinings/stampings area.

Table 3-16 lists the area of each of the main parts of the plant. The molding machines take up less area per machine than do injection molding machines. The other major difference between this type of plant and a regular injection molding plant is that considerable area must be set aside for the ovens.

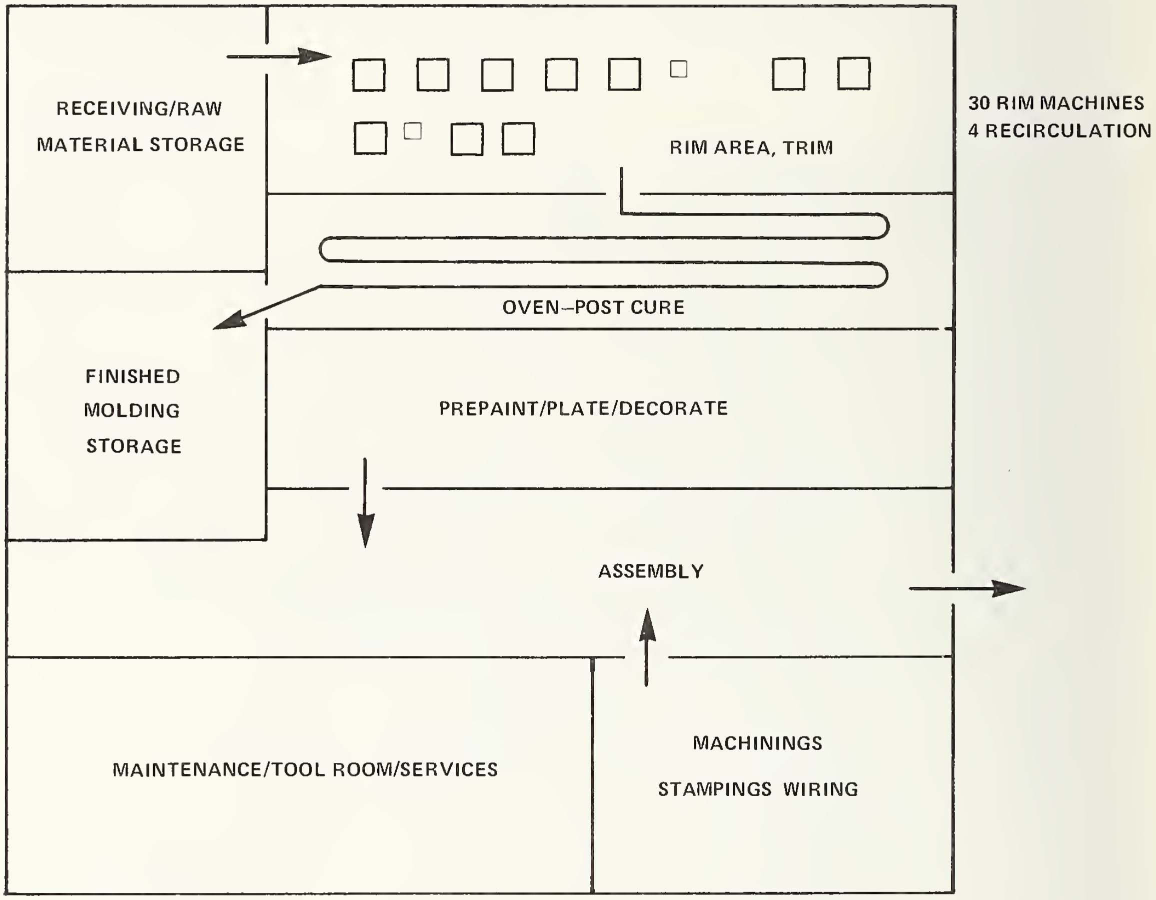


FIGURE 3-22. RIM PLANT LAYOUT

TABLE 3-16. SIZE OF THE RIM PLANT

RIM injection area	22,000 sq. ft.
Oven area	10,000
Finished molding storage	12,000
Finish, paint, plate area	17,000
Small part preparation	10,000
Raw material storage	12,000
Maintenance/tool room	22,000
	111,000 sq. ft.

Several of the major areas of the plant are described below.

- The Molding Area. The model plant is designed with 30 complete reaction injection molding machines. Each of the machines contains a pumping unit and a clamping unit. Every six machines also requires a recirculating unit. In this area the polyols and isocyanates are pumped to each machine and the reaction injection molded parts are made. In each two minute cycle an operator must spray the mold to prevent the molded part from sticking. One or two operators may be used at each machine. After the part is removed from the mold, sprues are taken off and flash is trimmed. This is done by hand. Around each RIM machine is a booth connected to a circulation system. This is required to take care of the fumes from the mold release spray.

- Post-Cure Area. Overhead conveyors carry the molded parts to the oven. The parts are carried in pre-forms that lend support to the still fragile pieces. The parts travel through the oven for an hour at 250°. They are then fully cured and ready for further operations. In the model plant a 120 ft. x 32 ft. x 10 ft. oven is used and the parts make 8 complete passes in the heated area.

- Painting, Assembly, and Stamping Areas. Once the part is fully cured, painting and assembly operations should basically be similar to those functions in an injection molding plant. Bumpers are often assembled in the plastic molding plant before they are shipped.

Materials Flow

The principal materials handled in the plant are the polyols and isocyanates. These are usually used in about a one to one ratio by weight. The scrap rate in RIM molding is very low generally under 5 percent. However, the scrap can usually not be reused and must be discarded.

The polyols and isocyanates are received in liquid form and mixed in the RIM machines where they become plastic parts. The plastic parts travel on conveyors to and through the ovens. Finally the parts go through painting and then the assembly area for final unit assembly.

During this process other materials flow through the plant. Paint, plating and decorating materials are introduced in the painting area. Steel and wire are introduced into the machining/stampings where they are made into parts that are then used in the assembly area.

In the 30 million pound per year model plant the typical major materials use would be as follows

- Polyols - 60,000 pounds/day
- Isocyanates - 60,000 pounds/day.

Capital Requirements

To develop capital requirements we will again assume an output of around 30 million pounds per year. This corresponds roughly to a plant with 30 machines, 70 percent of which are continuously operational.

- Building and Land Requirements. Previous calculations have indicated this plant will require about 11,000 sq. ft. of floor space. The building does not have to be too elaborate so a cost of $50 per sq. ft. is reasonable. Thus, the building would cost roughly $5.5 million. (See Table 3-17).

TABLE 3-17. BUILDING AND LAND REQUIREMENTS

Building (110,000 sq. ft. @ $50 per sq. ft.)	$5.5 million
Land (9 acres @ $20,000/acre)	.18 million
Total	$5.7 million

- Equipment Requirements. Equipment requirements are detailed in Table 3-18. The major expenditures are for RIM machines, molds and painting equipment. The total cost is $13.7 million. Cost for painting and assembly equipment can only be estimated roughly because these figures are very sensitive to the type of part being manufactured. The price for the RIM machines assumes a 90 ton clamp force.

TABLE 3-18. COST OF EQUIPMENT FOR RIM PLANT

Item	Size	Quantity	Unit Price	Total Price
RIM Machines	90 ton 54" daylight	30	$170,000	$5.8 million
Molds	Large	30	100,000	3 million
Recirculation Machine	Non-filled serve 6-8 machines	5	36,000	.18 million
Oven	12 x 32 x 10 ft.	1	160,000	.16 million
Materials Handling & Support				.1 million
Booths & Circulation				.2 million
Cleaning				.18 million
Painting				1-3 million
Tool Room				.5 million
Machining, Stamping, Wiring Equipment				.75 million
Assembly				.8 million
				$13.7 million

1. Includes installation and conveyor system.

Labor Requirements

A RIM plant of the size being discussed would tend to employ 300-500 people. A detailed breakdown of likely employment in each section of the plant is given in Table 3-19.

TABLE 3-19. LABOR REQUIREMENTS FOR THE TWO-SHIFT RIM PLANT

Area	Number of People
Molding	150
Ovens	6
Cleaning	36
Painting and Decorating	15
Machining, Stamping, Wiring	50
Assembly	125
Maintenance and Tool Room	15
Supervision	10
Management	5
Total	412

Energy Requirements

The 90 ton RIM machines are rated at 60 horsepower. While this power is not consistently used, power is also required for heating and cooling elements and control panels. Thus 60 horsepower is used as a realistic upper bound on energy use. With 30 machines, 1,800 horsepower is used or 1,350 kw. Other major power requirements are for painting, post cure, and illumination. Energy estimates are shown in Table 3-20. No estimate is given for power usage for heat since the value varies considerably with plant location. However, in the North, heating costs of ten run at about 60 percent of the total energy costs of a manufacturing facility.

TABLE 3-20. ENERGY REQUIREMENTS

RIM	1,350	Kw
Painting	300	
Post Cure	60	
Illumination	250	

3.7.7 Key Issues

Reaction injection molded technology has already been widely accepted for molding soft urethane bumpers and front fascia. Davidson predicts that by 1986 50 percent of new cars will feature soft front-end systems. RIM cycle times have been considerably reduced in recent years and the process has become more economically viable.

The major issues still confronting RIM concern its application as a reinforced molding technology. Techniques need to be perfected for using fibers longer than 1/8 inch, rather than the 1/16 in now commonly used, while still preventing abrasive wear of the mixing heads.

The RIM industry is also looking for a good internal mold release agent which would not interfere with paint adhesion to the molded part. This would greatly speed up both RIM and RRIM output rates.

It is generally felt that large growth in RIM use will require the perfection of reinforced RIM technology.

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