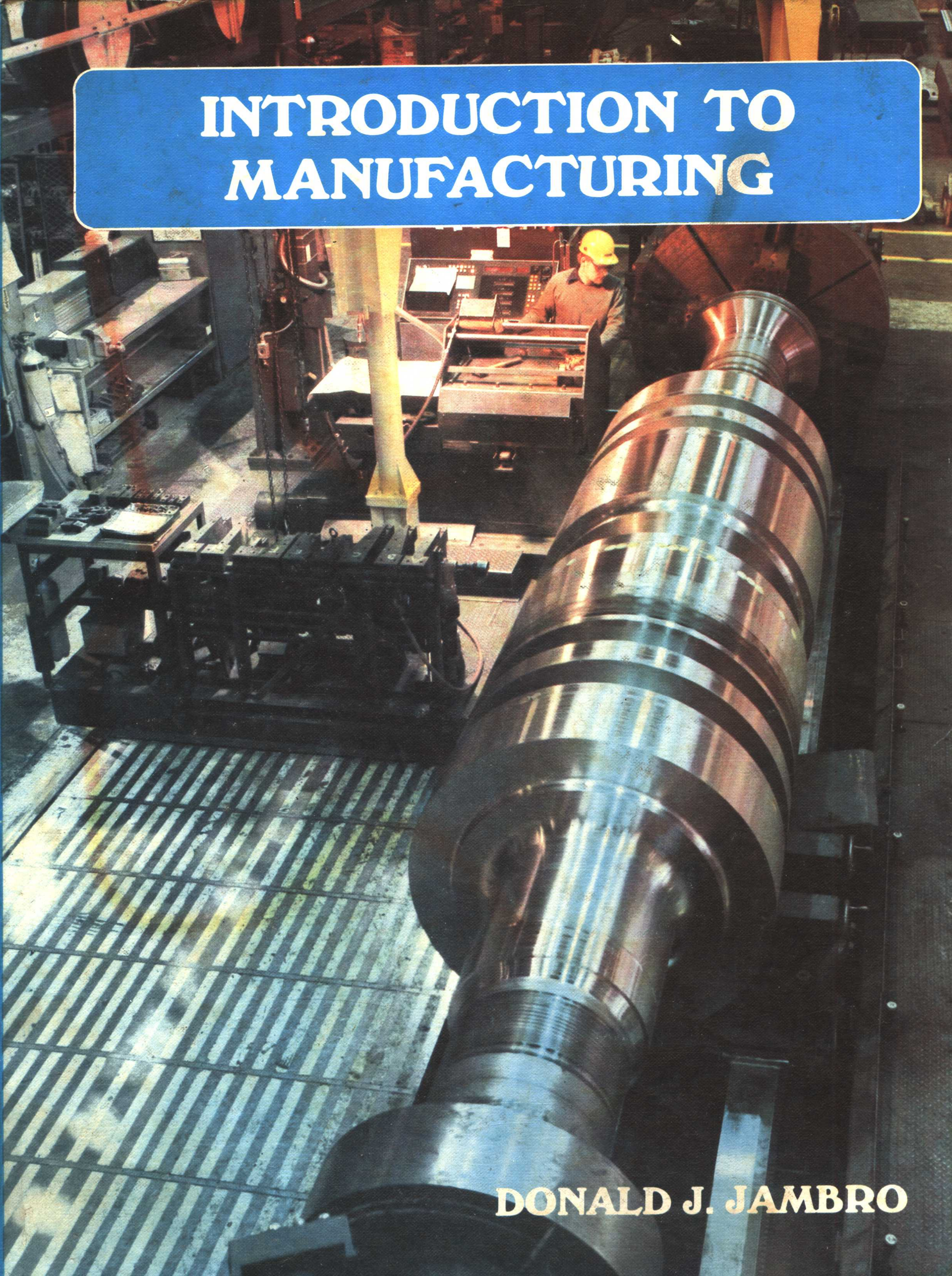
INTRODUCTION TO MANUFACTURING



DONALD J. JAMBRO

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Preface

Manufacturing is a large, complex industry. Approximately one out of every four people are employed directly in manufacturing. Many others are employed in careers related to manufacturing such as maintenance and repair of manufactured products and the marketing of manufactured products. A recent study by the United States Department of Labor indicates that almost 20 million people are employed by manufacturing industries.

Introduction to Manufacturing discusses the many processes and careers associated with the manufacturing industries. The textbook gives students the opportunity to become involved in activities directly related to the processes by which a company converts raw materials into finished products. Career information is infused throughout the text. The knowledge and experiences gained will assist students in selecting and preparing for a career in manufacturing.

The textbook presents a logical sequence of topics leading to the organization of a company and the production of a product. The first part of the text deals with the development of manufacturing industries, careers, and the materials used for manufacturing. The various industrial processes used to manufacture a product are then presented. Later units cover product development, organizing a company, setting up a production line and then the product run.

Each unit begins with broad objectives stated in measurable terms. Each student knows what to expect from the unit. Highly illustrated information is then presented. Following the information, highly motivative hands-on activities are outlined. The instructor can use one or all of the suggested activities.

Review questions are included at the end of each unit. These questions can be used by the student as a means of self-evaluation or used by the instructor for evaluation of what the student has learned.

Note that in all units, metric equivalents are stated along with English measurements. These are not precise equivalents, nor are they necessarily American standards. These equivalents are approximations of the actual value and are included to help the student begin to think in metric terms. If the teacher or student desires, these metric values can be used instead of the English values to complete all activities in the text.

ABOUT THE AUTHOR

Donald Jambro is an Industrial Arts Curriculum Leader and instructor at the Secondary School level. He is a member of numerous professional organizations including the American Industrial Arts Association and the Society of Plastics Engineers. Donald Jambro holds a Bachelor's and Master's in Industrial Education and a C.A.S. in Educational Administration. He has authored a number of textbooks and audiovisual materials for secondary industrial arts programs.

Contents

Unit 1

Development of Manufacturing

OBJECTIVES

After completing this unit, the student will be able to:

- outline the development of manufacturing.
- list several principles of manufacturing.
- list several key people who contributed to the development of manufacturing.
- outline why mass production is essential.

Since the beginning of time, human needs and wants have continually increased. In order to meet these growing needs and wants, tools were developed.

The earliest needs of humans were based on survival. Without the ability to get food, clothing, and shelter, people would die. Hunters soon learned that hunting with spears, axes, or bows and arrows was much better than hunting with their bare hands. People began to control their environment through the tools and weapons they developed. Today, the process of converting raw materials into products is called *manufacturing*. The products are usually made in large quantities by machines. The development from the simple tools for survival to today's complex manufacturing processes involved several steps and the ideas of many people.

THE INDUSTRIAL REVOLUTION

As society's needs increased, techniques were developed for producing large quantities of items quickly and inexpensively. Thus, the *industrial revolution* began in Europe and Great Britain toward the end of the 1700's. It signified the movement from making products by hand in the home to making products by machines in factories. The steam engine, invented by James Watt, further improved factory production. The steam engine replaced the musclepower and waterpower that had been needed to run machines, Figure 1-1.

DUPLICATION OF PARTS

Mass production is the system used to make interchangeable parts by dividing the labor among many people, Figure 1-2. Eli Whitney, most well-known as the inventor of the cotton gin, made many contributions in the area of mass production.

After the American Revolution, there were few guns to protect the new country. In 1798, Eli Whitney proposed to manufacture 10,000 muskets in a period of two years.

Whitney spent the first year *tooling-up* or getting ready for production. He had to develop new processes and machines to mass-produce the guns. He used the division of labor theory – one person did one machine operation. To mass-produce a product in quantity requires accurately made, standardized parts. To insure accurate, standardized parts, Whitney used jigs and fixtures. Without jigs and fixtures, accurate size parts would be impossible. A *fixture* holds a part in the proper position for machining. A *jig* holds a part and guides the tool for cutting or drilling. A drill jig is shown in Figure 1-3. Whitney's new production system could be applied to the mass production of any product.

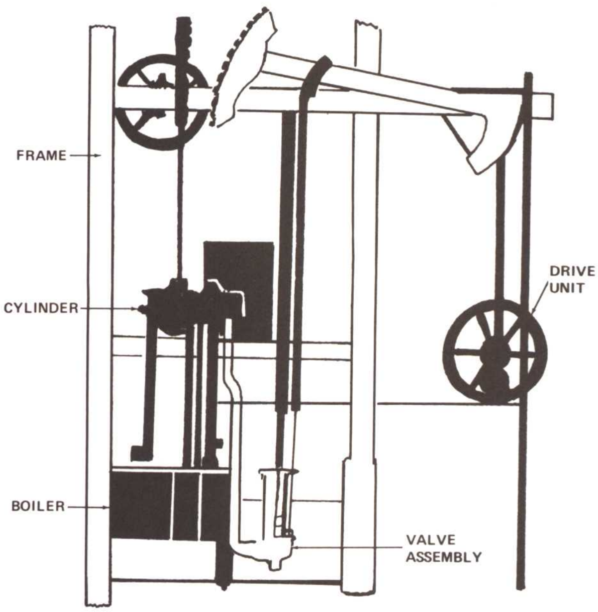


Fig. 1-1 Watt's steam engine replaced the work force and waterpower needed to run machines. (*T.A. Jambro*)

Fig. 1-2 Interchangeable parts made the automobile engine and thousands of other products possible. (*General Motors*)

Whitney's principles of mass production were:

- Each machine can be set up to do a specific machine operation on many parts.
- Parts can be quickly assembled into the finished product.
- Parts can be accurately machined.
- The system requires less skill on the part of the workers.
- There is a great time savings in the production of parts.
- Each part will be an accurate reproduction of similar parts and can be interchanged, thus reducing assembly costs.
- The system reduces costs and increases efficiency.
- Tooling-up requires time and a risk on the part of the manufacturer.

DEVELOPMENT OF MACHINES

When a product is made by hand, it is difficult and time consuming to make any two things exactly the same. Therefore, to produce any product with a high degree of accuracy, machines must be used. Although many machines have been developed, only some of the most important ones will be discussed.

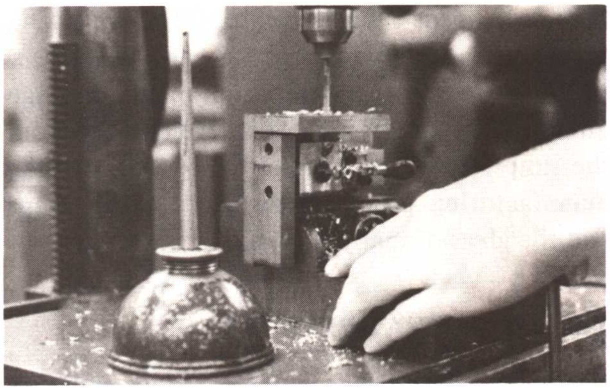


Fig. 1-3 A drill jig is used to accurately locate a hole in a large number of parts that are the same.

One of the first important inventions was John Gutenberg's movable type in 1450, Figure 1-4. Before this invention, an entire page of a book was printed from a carved block of wood. Gutenberg's system involved single letters on metal. These letters were hand set to form a printed page. The letters could be reused many times. The press was a screw which applied pressure to a page laid over the inked type. His invention gave way to the mass printing of books. In 1886, Ottmar Mergenthaler developed a complex machine that could automatically set an entire line of type. The operator struck keys similar to the keys on a typewriter.

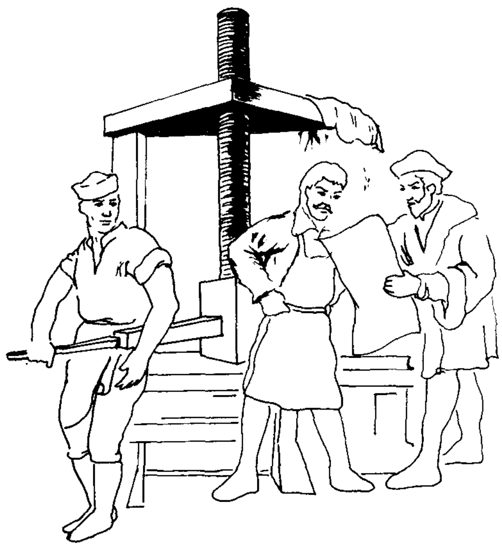


Fig. 1-4 John Gutenberg invented movable type to print a page in his screw-type press. His invention led to the mass printing of books. (*T.A. Jambro*)

In 1740, the French developed a screw-cutting lathe for duplicating watch parts, Figure 1-5. James Watt developed the steam engine in 1769 to power machines. Oliver Evans developed power conveyors to move materials in 1783. Joseph Clements built the first machine to plane off metal surfaces in 1825. In 1839, the Glovet brothers built a machine to cut the teeth of gears using a template. Elias Howe invented a sewing machine in 1845. The machine was faster than five workers.

It took Eli Whitney only two weeks to invent a machine to separate seeds from cotton, Figure 1-6. Whitney's cotton gin did the work of fifty people. Thomas Blanchard developed a lathe that could turn out irregular-shaped gun

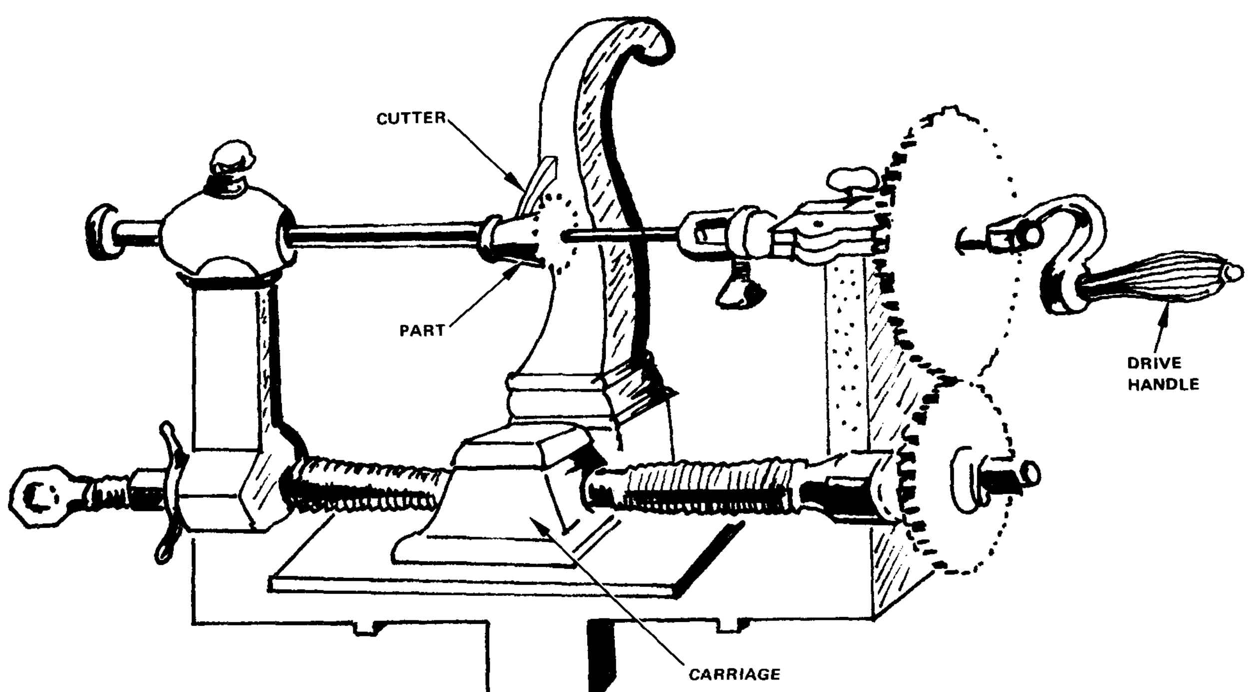


Fig. 1-5 The first screw-cutting lathe was developed by the French for duplicating watch parts. (*T.A. Jambro*)

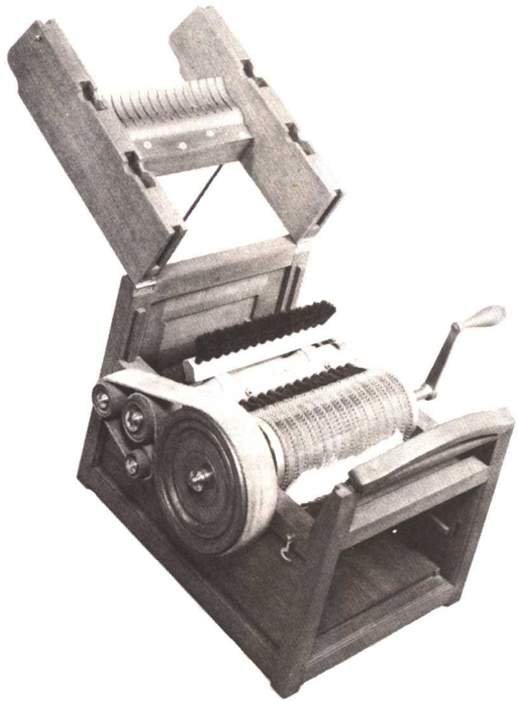


Fig. 1-6 Eli Whitney's cotton gin did the work of fifty people. The machine was used to separate the seeds from cotton. (*DoAll Company*)

stocks. Lawrence and Robbins invented a turret lathe. It held a number of tools that were used in succession to machine a part.

DEVELOPMENT OF MEASURING TOOLS

James Watt, realizing the need for accuracy, developed the first micrometer for precision measurements. Figure 1-7 shows several types of micrometers. A much more accurate micrometer was developed by a Frenchman named Palmer. Following the Civil War, Brown, Sharpe, Pratt, and Whitney refined the development of gages to check the accuracy of machined parts, Figure 1-8. Joseph Witworth, an Englishman, developed a system of standard screw threads.

In 1885, Carl Johansson developed gage blocks that were accurate within four millionths of an inch. In the United States, The National Bureau of Standards was established in 1901. The bureau has the responsibility to maintain standards for weights and measurements. Many standards were established to help manufacturers make interchangeable parts.

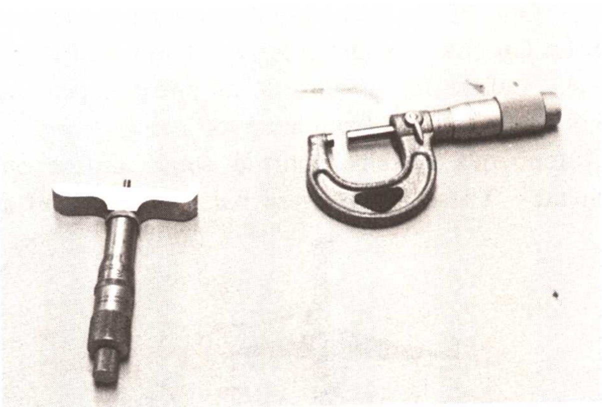


Fig. 1-7 Modern day measuring instruments, left to right: depth micrometer and 0-1" micrometer

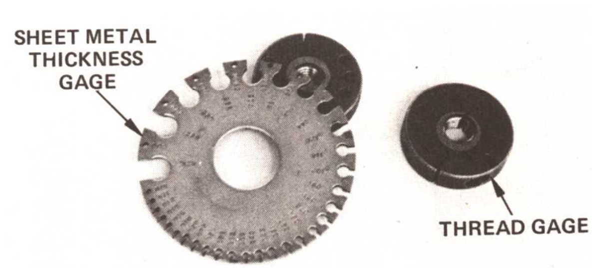


Fig. 1-8 Modern day gages are used to check the accuracy of materials and machined parts.

DEVELOPMENT OF THE ASSEMBLY LINE

The development of the assembly line process was the contribution of many inventors. Henry Ford was one of the first to combine his ideas with those of other inventors to mass produce a product. Ford was concerned with making cars at a lower cost. To do this, the cars had to be produced at a faster rate. Machines had to be built that could duplicate accurate parts. The machines he developed only required an unskilled worker to put in the material and push a button. The machine did the operation. Ford set up his assembly line to bring the parts to the workers at the right height and speed. He used Frederick Taylor's time and motion studies as a basis for the speed of moving parts. Workers had exactly enough time for each step without one second left over. Ford's concept of the moving assembly line produced a completed Model T every 10 seconds in 1914. A modern production line is shown in Figure 1-9.

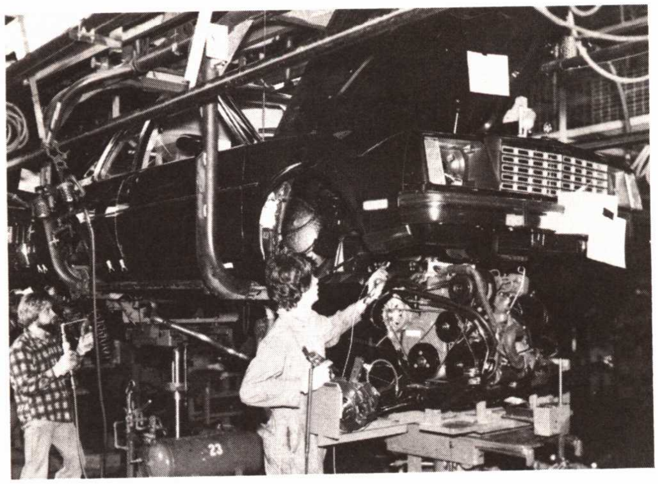


Fig. 1-9 Today's car assembly line is based on Ford's manufacturing principles. (*General Motors*)

The manufacturing principles that Ford used were:

- Accurate duplication of parts makes interchangeable parts possible.
- Each worker has a specific job to perform.
- Wasted motion and wasted time are eliminated.
- Conveyors bring parts and assemblies to and from workers.
- Tools, equipment, and workers are placed in the order of the operations needed for assembly.
- Travel distances for parts and subassemblies are kept as short as possible.

Due to Ford's production ideas, prices could be cut and a better car could be made. Workers' wages could be increased and the company made a profit. The working day was cut from nine to eight hours. Workers had money in their pockets for their needs as well as leisure time for relaxation. They even earned enough money to buy a Model T.

ACTIVITIES

A. MANUFACTURING HISTORY

Write a short essay (100 words or less) on the history of manufacturing.

B. PRINCIPLES OF MANUFACTURING

List 10 principles of manufacturing as developed by Whitney and Ford.

C. MANUFACTURING INDUSTRIES

Visit a local manufacturing plant to see what and how the principles of manufacturing are applied.

D. MANUFACTURING PIONEERS

1. Name two pioneers in the field of manufacturing and explain what each contributed to manufacturing.
2. Describe in your own words why products are manufactured.

E. PRODUCT SIMULATION

Equipment and Materials

Ditto paper, 8 1/2" x 11" (216 mm x 280 mm)
Scissors
Rubber cement
Drafting scale
T square
45° triangle
30°-60° triangle

Procedure

The class will be divided into two equal groups. Both groups are to make paper envelopes large enough to hold a 3" x 6" (76 mm x 152 mm) card. Each envelope should be made of the least amount of paper possible. One group will mass produce envelopes as a team of workers. The other group will custom build envelopes individually.

Mass Production Group

1. Assign specific jobs for production
   a. Cut out envelope shapes from ditto paper, using Figure 1-10 as a guide. Be sure a 3" x 6" (76 mm x 152 mm) card will fit in.
   b. Fold.
   c. Glue flaps.

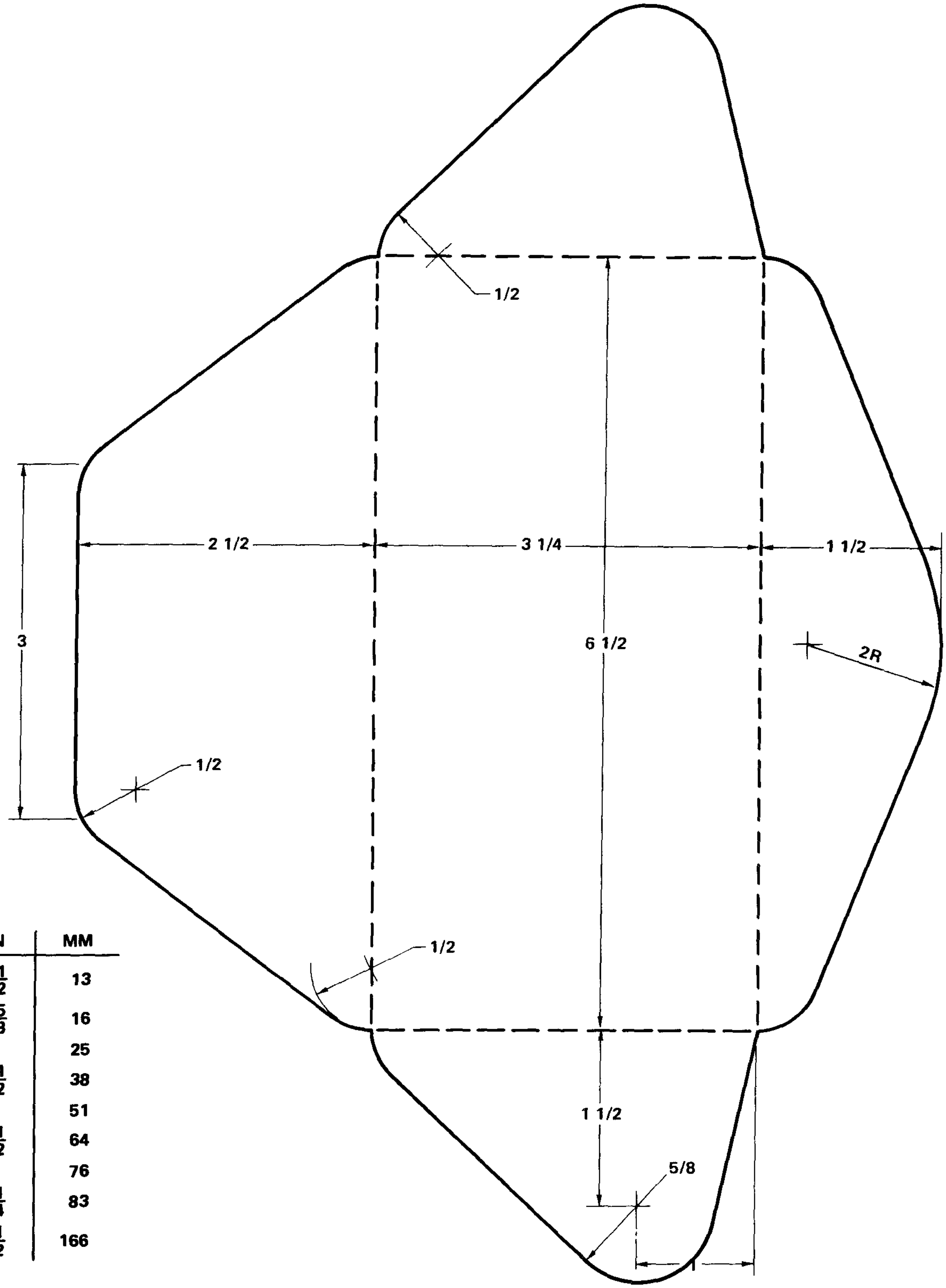
Custom Building Group

Each student must:
1. Draw out a design for an envelope.
2. Check to be sure a 3" x 6" (76 mm x 152 mm) card will fit into the envelope.
3. Check for efficient use of paper.
4. Cut out the design.
5. Glue together.

Each group should work for 20 minutes. When time is over, compare the number of envelopes produced by each group. How do the quality and appearance of the products compare? When is custom building needed?

REVIEW

1. What is the name of the movement toward the use of machines that began in Great Britain and Europe in the late 1700's?
2. Who is the person credited with developing the concept of duplication of parts in the United States?
3. Who invented movable type in 1450?
4. What nation developed the screw-cutting lathe for duplicating watch parts?
5. Who invented the sewing machine in 1845?
6. Who developed the cotton gin?
7. What was the name of the machine developed by James Watt to replace manpower?
8. Why was the National Bureau of Standards established?
9. Who set up the modern assembly line?
10. What are the clamping devices for holding and machining parts called?



IN	MM
$\frac{1}{2}$	13
$\frac{5}{8}$	16
1	25
$1\frac{1}{2}$	38
2	51
$2\frac{1}{2}$	64
3	76
$3\frac{1}{4}$	83
$6\frac{1}{2}$	166

Fig. 1-10 The mass production group will use this design for envelope production. (*Brad Thode*)

Unit 2

Careers in Manufacturing

OBJECTIVES

After completing this unit, the student will be able to:

- distinguish between the production of goods and service industries.
- define six job classifications for employees in manufacturing industries.
- list at least six sources for obtaining career information.
- demonstrate the use of the *Dictionary of Occupational Titles* or the *Occupational Outlook Handbook* to explore a specific career.

The demand for workers in any occupation depends on consumer needs. For example, if all people decided to do their own baking, there would be no need for bakers. Many factors that affect the demand for workers change over a period of time. Because such changes are predictable, the growth or decline in occupations can be predicted.

LABOR FORCE

The labor force has increased sharply from the mid 1960's because of the increased number of women entering the labor market. In 1976, there were about 88 million people in the labor force. That number is expected to reach about 104 million by 1985, Figure 2-1.

America's industry can be divided into two large groups – *service industries* and *goods-producing industries*. Most workers are employed in such service industries as transportation, government, education, health, maintenance, banking, trade, and insurance.

Goods-producing industries include farming, mining, construction, and manufacturing. The goods-producing industries account for about 32 percent of the country's labor force, Figure 2-2.

The number of people employed in the service industries is expected to grow faster than the number of people employed in the goods-

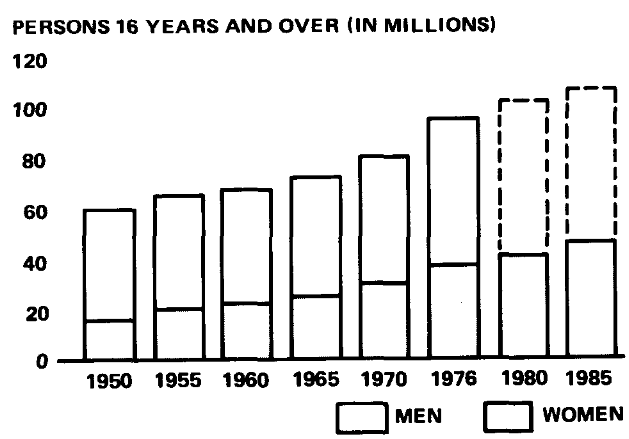


Fig. 2-1 The chart shows the labor force growth from 1950-76 and projected 1980 and 1985 growth. (*U.S. Government*)

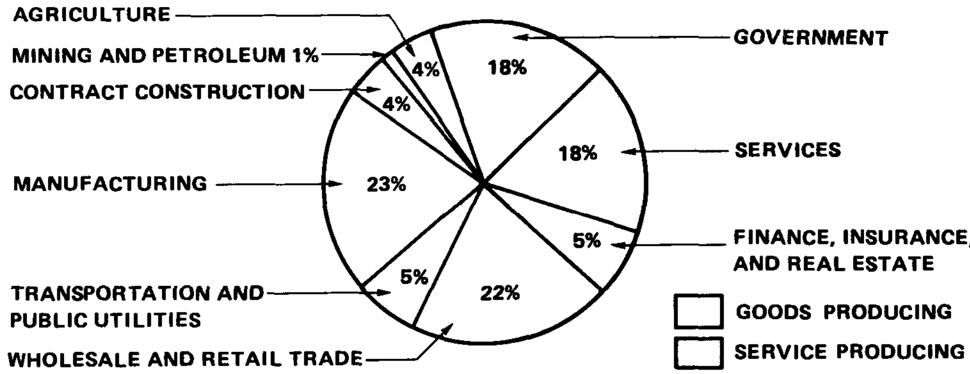


Fig. 2-2 Almost one-third of the total labor force works in goods-producing industries. (*U.S. Government*)

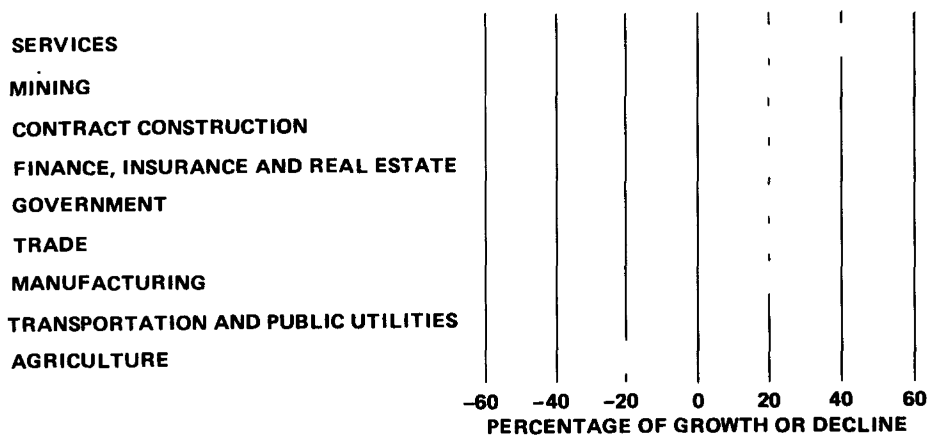


Fig. 2-3 Employment growth varies widely from industry to industry. (*U.S. Government*)

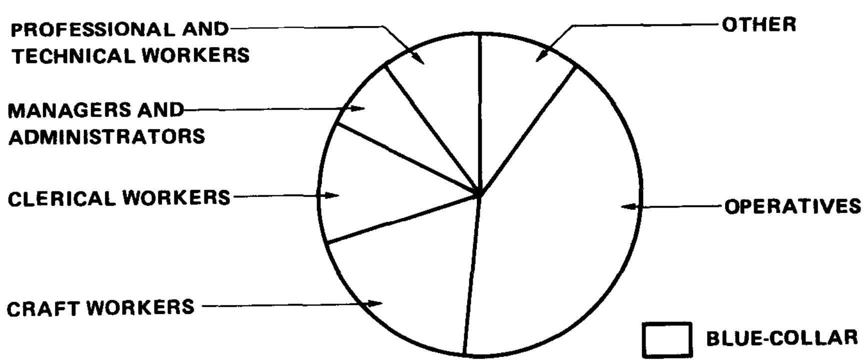


Fig. 2-4 Seven out of every ten employees in the manufacturing industry are blue-collar workers. (*U.S. Government*)

producing industries. By 1985, employment in the service industries is expected to increase by about 40 percent. Employment in the goods-producing industries is expected to increase about 17 percent by the same year. The goods-producing industries' employment growth is expected to be less because new technology, improved machinery, and automated production reduce the need for workers, Figure 2-3.

Generally, occupations are divided into *blue-collar* and *white-collar* jobs. Most employees are blue-collar workers, Figure 2-4. Blue-collar jobs are craft (highly skilled), operative (skilled), and laborer (unskilled) jobs. White-collar jobs include

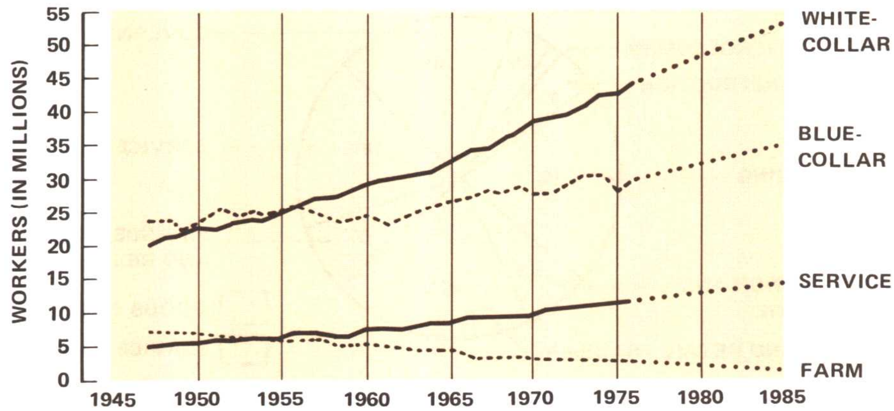


Fig. 2-5 The shift toward white-collar occupations is expected to continue. (*U.S. Government*)

managerial, professional, technical, sales, and clerical positions. The number of white-collar jobs has increased since the mid 1950's. This increase is expected to continue. The number of blue-collar jobs have increased slowly. The number of farm workers has been decreasing, Figure 2-5. Fewer farmers are needed to produce the same amount of food because of improved techniques and technology.

EDUCATION

Education is very important in order to get meaningful employment. Having a high school or college degree dces not always guarantee employment, however. Training along with education will usually determine employment opportunities. A high school education has become a standard in obtaining employment. The majority of employers will not consider applicants for a job unless they have a high school diploma or a graduate equivalent degree. The average number of years of education for the labor force is approximately 13 years. As education increases, the chance of unemployment decreases, Figure 2-6.

Generally, the more education, the higher the individual's income, Figure 2-7. However, many jobs that require only a high school education can pay as much as or more than some jobs requiring a college education. For example, many jobs in the building trades pay higher wages than many jobs that require a college degree.

A typical career ladder for a plastics manufacturing company is shown in Figure 2-8. The bottom rung contains the job that requires the least amount of education, training, and skill from the worker. It also pays the lowest salary. The higher the job is on the ladder, the greater

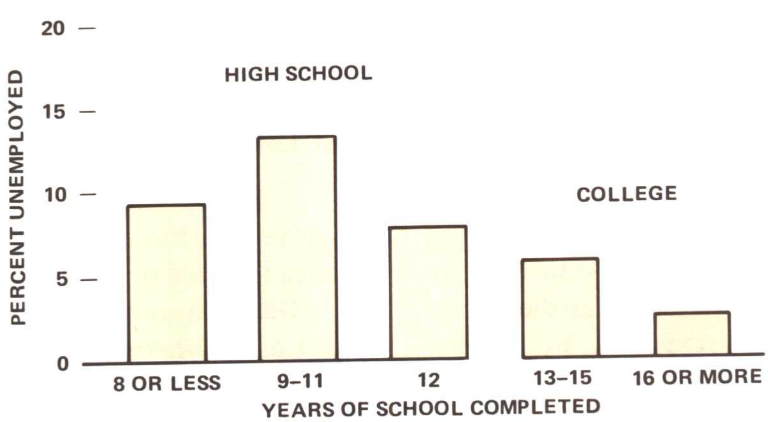


Fig. 2-6 The lowest unemployment rate is for persons with a college education. (*U.S. Government*)

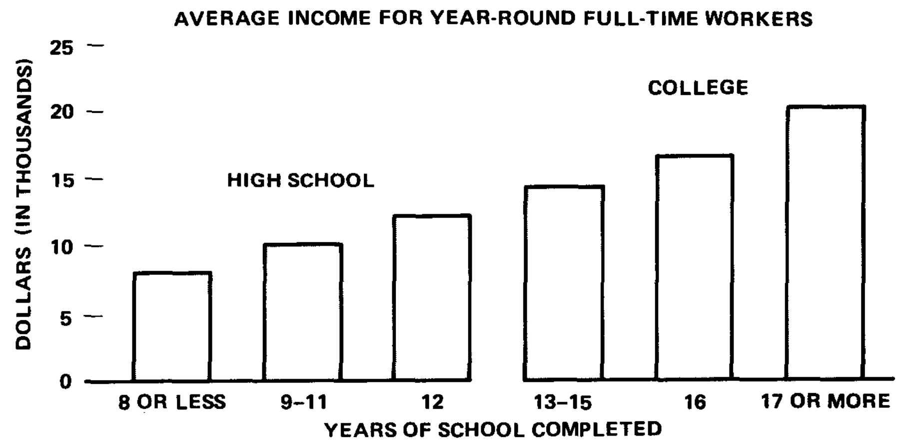


Fig. 2-7 Income increases as the number of years of schooling increases. (*U.S. Government*)

the necessity for training, skill, and hard work. Each higher job carries more responsibility than the one below it and each pays more. It is possible for good workers to climb such a ladder in most manufacturing industries.

MANUFACTURING CAREERS

Manufacturing industries employ almost 20 million people. Employment in manufacturing can be classified into industries that produce *durable goods* and those that produce *nondurable goods.*

Items that have a life of three years or more are called durable products. Manufacturers that produce steel, machinery, automobiles, and appliances are durable goods manufacturers. Sixty percent of all manufacturing employees work in durable goods manufacturing.

Items with a life of less than three years are referred to as nondurable products. Companies that produce products such as food, clothing, chemicals, paper, rubber, and leather are nondurable goods manufacturers. They account for forty percent of the manufacturing employees.

JOB CLASSIFICATIONS

There are thousands of different jobs in manufacturing. Every piece of equipment and each different process in manufacturing offer career opportunities for men and women. Jobs can be classified into six categories: (1) unskilled,

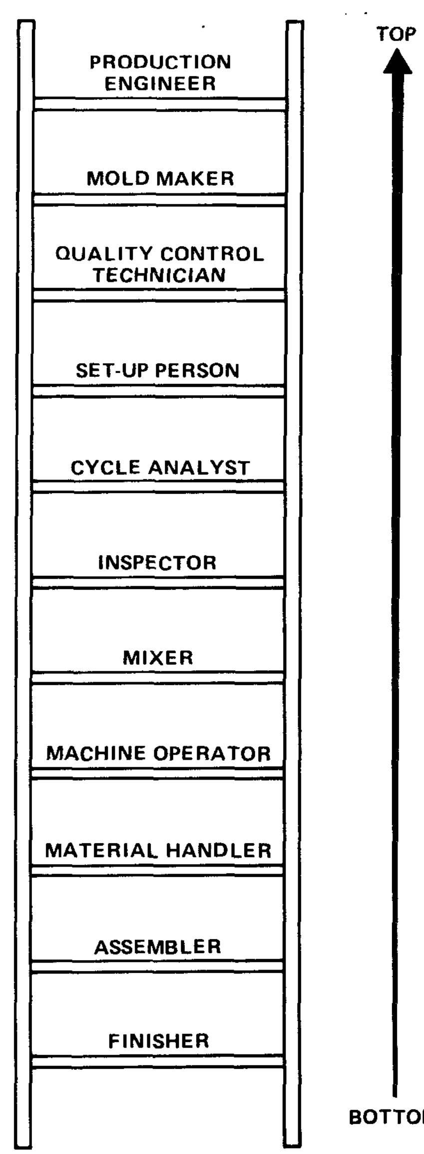


Fig. 2-8 A career ladder for jobs in the plastics industry