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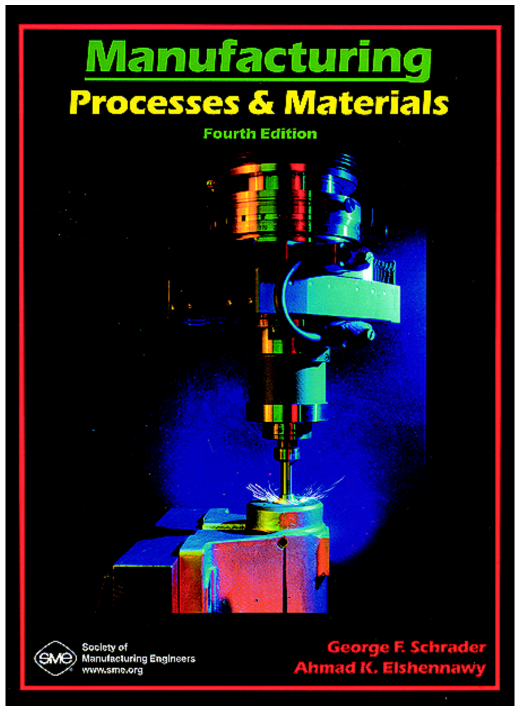

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Society of
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Manufacturing Foundations

1

A tool is but the extension of a man's hand and a machine is but a complex tool.— Henry Ward Beecher

1.1 MANUFACTURING

Manufacture means to make goods and wares by industrial processes. The derivation of the word *manufacture* reflects its original meaning: to make by hand. Today, however, manufacturing is done largely by machinery and, as the technology of manufacturing advances, less and less manual labor is involved in the making of a product. In fact, most manufacturing firms in the U. S. strive to minimize the labor cost component of their products to remain competitive. Thus, machinery, vis-a-vis technology, has and will probably continue to replace the human labor element in manufacturing much the same as it has done in the U. S. agricultural industry. In a contemporary sense then, manufacturing involves the assembling of a system of people, money, materials, and machinery for the purpose of building a product.

1.2 HAND TOOLS TO MACHINE TOOLS

1.2.1 Early Hand Tools

Tools of one kind or another have enabled mankind to survive and contribute to societal development for over a million years. If the original meaning of manufacture, "to make by hand" is applicable, then manufacturing in some form has existed over that time. Early prehistoric mankind learned to retain certain skeletal remains of animals, such as horns, tusks and jaw bones, and fashion them into hand tools for use in hunting and preparation of food. Later on, as the evolution of "tool making" progressed, an even greater variety of tools were made from stone and wood. During this period, flint stone was recognized as a very hard material and became a common substance for use in fashioning spears, axes, arrowheads, and even crude saws and drills. The *Bronze Age*, beginning about 6,500 years ago, ushered in the use of metal as a primary element in the construction of hand tools. For the most part, these tools were still relatively primitive, with the bronze metal being used primarily to replace the stone axe heads, spear heads, and hammer heads that were popular during the Stone Age. However, the Bronze Age did see some very slight transformations of hand tools to what might be called semimachine status. For example, the bow drill, which used a bow string to rotate a bronze drill, provided some mechanical advantage to the rotational process.

1.2.2 The Iron Age

The *Iron Age*, beginning about 3,400 years ago, gave birth to a broad spectrum of new hand tools for many different trades and a refinement of the tools from previous periods. Early in this period, hand tools were hammered out of meteoritic iron removed from meteorites that were embedded in the earth. However, the use of large quantities of iron and steel for tools and other implements did not take place until after the invention of the blast furnace in Europe at around 1340 A.D.

The installation of an operating blast furnace in the U. S. in 1621 facilitated increased production of a large variety of hand tools, semimachines, horse-drawn vehicles, agricultural implements, and so on. The machines and vehicles during that period were powered or driven or propelled by water, animal, or human energy. A variety of devices were employed, such as water wheels, treadmills, windlasses, horse-drawn whims, and the like. In addition, many creative devices were used to obtain a significant amount of mechanical advantage. For example, the development of a fitted horse collar to replace the traditionally used yoke made it possible for draught animals to increase their pulling power nearly fourfold. Many machines were operated by foot treadles, and in the early 1700s, a simple windlass was used to pull a rifling broach through the barrel of a rifle. Finally, in 1775, John Wilkinson developed a water wheel-powered horizontal boring mill in Bersham, England that permitted James Watt and Matthew Boulton to bore a true hole in the cylinder of their steam engine. Thus, the age of the engine-powered industrial revolution was born.

1.2.3 Industrial Revolution

With power available to drive them, hand tools were rapidly converted into machine tools, and thus the *industrial revolution* began in Europe and the United States. The boring machine developed by John Wilkinson in 1775 led to the development of the first engine lathe in 1794 by Henry Maudsley. A few years later, he added a lead screw and change gears to that lathe, thus giving birth to the screw cutting lathe. The need for further versatility in machine tools then inspired the invention of the planer in 1817 by Richard Roberts of Manchester, England and the horizontal milling machine in 1818 by Eli Whitney of New Haven, Connecticut. Those three machines, the lathe, planer, and mill, not only provided a basis for producing a large variety of products, but also enabled the entrepreneurs of that era to build additional similar machines that could be used to produce other products. During the late 1700s and early 1800s, most manufacturing was performed in family workshops and small factories. The availability of power to drive machine tools was, to a great extent, a controlling factor in the movement and expansion of the industrial revolution. As is evident from the timetable in Table 1-1, the steam engine was the most significant source of power for the machines of production for more than 50 years. In the early periods, a centralized engine was used to drive line-shafts which, in turn, provided power to many individual machines. Later on, as steam engines became more compact and efficient, smaller engines were placed in strategic positions around a factory to drive machine groups.

Probably one of the most significant developments occurring during the early stages of the industrial revolution was the introduction of the concept of *interchangeable manufacture*. (Interchangeable manufacture means that the parts for one particular product will fit any other product of that same model.) This idea apparently manifested itself almost simultaneously in Europe and the United States in the late 1700s via the use of templates or patterns, often referred to as filing jigs. Eli Whitney was one of the early pioneers to take advantage of this concept in the building of musket parts for the U. S. military in about 1798. Although the concept of interchangeable manufacture is usually credited to Eli Whitney, it should be pointed out that the accomplishment of this process through the use of filing jigs was mostly a manual operation, not a machine process. The credit for machine-produced interchangeable manufacture should probably go to Elisha Root, who was the chief engineer for the Colt Armory in Hartford, Connecticut. In about 1835, Root and Samuel Colt engineered the machine production of over 300,000 units of different models of the Colt revolver to a significant degree of precision. This accomplishment is often heralded as a milestone in the development of the concept of interchangeable manufacture and *mass production* in the U. S.

Table 1-1. Manufacturing process and machine tool design timetable

2000
- Coated cutting tools (1974)
- Numerically controlled jig boring machine (1974)
- Wire electric discharge machining (1969)
- Flexible manufacturing (1969)
- Silicon chip (1969)
- Programmable logic controller (1968)
- Industrial robots (1963)
- NC machining center (1958)
- Transistor (1957)
- Synthetic diamond (1955)
- Numerically controlled vertical milling machine (1953)
- Stored program digital computer (1951)

1950
- Electronic digital computer (1946)
- Electrical discharge machining (1943)
- Tungsten-carbide cutting tool (1926)
- Stainless steel (1913)

1900
- Generating-type gear shaper (1899)
- High-speed cutting tools (1898)
- Aluminum oxide (1893)
- Silicon carbide abrasive (1891)
- Gear hobbing machine (1887)
- Band saw blades (1885)
- Hydraulic forging press (1885)
- Electric motors (1885)
- Surface grinder (1880)
- Board drop hammer (1880)

1900 (cont.)
- Automatic turret lathe (1873)
- Four-stroke gas engine (1873)
- Universal grinding machine (1868)
- Dynamo electric generator (1867)
- Open-hearth steelmaking (1866)
- Tool steel cutting tools (1865)
- Water-cooled gas engine (1860)
- Turret lathe (1855)
- Milling-type gear cutter (1855)
- Two-stroke gas engine (1855)

1850
- Drill press (1840)
- Gravity drop hammer (1839)
- Mass production (1835)
- Gas engine (1833)
- Precision measuring screw (1830)
- Gage blocks (1830)
- Reproducing lathe (1820)
- Horizontal milling machine (1818)
- Planer (1817)
- Thread-cutting lathe (1800)
- Electroplating (1800)

1800
- Interchangeable manufacture (1798)
- Engine lathe (1794)
- Double-acting steam engine (1787)
- Steam-powered coining press (1786)
- Horizontal boring mill (1775)
- Atmospheric steam engine (1775)

Another significant milestone in the industrialization process was the development of precision measuring devices in about 1830 by Joseph Whitworth. As a protégé of Henry Maudsley, Whitworth pioneered early screw thread designs and then incorporated that work into the development of the micrometer screw. The ability to measure was, of course, a fundamental prerequisite to a successful interchangeable manufacturing process.

The spectrum of manufacturing capability was further enhanced in about 1840 by the development of a drill press with power feed by John Nasmyth, also a student of Henry Maudsley. About 15 years later, mass production capability in the U. S. was greatly improved by the introduction of the turret lathe by Elisha Root and Samuel Colt. Forty years or so later, the development of the surface grinding machine and the metal saw blade completed the stable of machine tools available to the early manufacturer. Thus, during the late 1800s and early 1900s, these basic machine tools: the boring mill, lathe and turret lathe, milling machine, broach, planer, shaper, surface grinder, and saw, served as the workhorses for the ever expanding industrial capacity in Europe and the United States.

1.2.4 Automation

As indicated in Table 1-1, a large proportion of the basic machine tools used in discrete parts manufacture were introduced prior to 1900. These machines and the engine power required to drive them were key elements in the industrial revolution. In the early days of that period, the machines were essentially manually operated with the quality and quantity of product output being almost totally dependent on the skill and ingenuity of the craftsmen who operated them. Recognizing the difficulties inherent in a skill-dependent production system, the machine tool builders gradually improved the operational features of their machines to lessen the level of skill required to operate them. In essence, they were gradually *automating* their operation, while at the same time improving precision, reliability, and speed.

Although not recognized as such, one of the pioneering efforts in the automation movement was made by an Englishman, Thomas Blanchard, who developed a reproducing lathe for wood turning in about 1820. Blanchard's lathe was used to turn and form the intricate shape of a wooden rifle butt. Replacing manual carving by woodworking craftsmen, Blanchard's early design of a reproducing lathe was able to produce two rifle butts in an hour. Later improvements enabled him to increase production to as many as a dozen an hour.

The conversion to automatic machine tool operation on metal products was spearheaded in 1873 by an American, Christopher Spencer, one of the founders of the Hartford Machine Screw Company. Spencer's so-called "automat" was essentially a turret lathe equipped with a camshaft and a set cams that moved levers which, in turn, changed the turret position and fed the tools forward. As the forerunner of the automatic screw machine, Spencer's machine was extremely well received by industry and used extensively for producing screws, nuts, and other small parts in large quantities. In a sense, Spencer's automat was reprogrammable by simply changing to a different set of cams.

The evolution of machine tool automation continued during the early 1900s largely through technical improvements to the concepts introduced by Spencer's automat. Electrical, pneumatic, and hydraulic servomotors were added to effect tool and workpiece position changes but, for the most part, these were still automated by various types of cams to carry out a specified program of cutting operations. The introduction of high-speed steel cutting tool materials in 1898 by two Americans, Frederick W. Taylor and Mansel White, permitted the use of higher cutting speeds on these automatic machines, thus increasing production rates. Since higher cutting speeds increased the rate of metal removal, increased horsepower for spindle motors was required. In addition, higher cutting forces required machines of greater strength and rigidity. Similarly, modifications to machine tool design were required by the introduction of tungsten carbide and other hard metal-cutting tool materials (Chapter 17) in about 1926.

Although technical improvements on the automatic and semi-automatic machines of production during the early 1900s were significant, they were, to some extent, lacking in the high degree of flexibility and precision required in the highly competitive and ever-changing world marketplace that evolved after World War ll. This weakness was mitigated to a great extent by the introduction of numerical control (NC) technology (Chapter 31) in 1952 by the Massachusetts Institute of Technology and its adaptation for mass-produced milling machines by Giddings & Lewis in 1955. Numerical control technology was followed by the development of the programmable logic controller (PLC) in 1968. With the development of microcomputer technology in the late 1970s and early 1980s, most NC controllers have been built around that technology. Thus, modern machine tools are referred to as computer numerically controlled (CNC) machines. Computer numerical control of the machines of production provides the basis for accomplishing a multiplicity of operations and operational flexibility in manufacturing that was not possible with its predecessor machines.

Another element of the manufacturing automation scenario, the industrial robot (Chapter 29), was developed in the U. S. and first appeared in the marketplace in 1963. Generally, a robot consisted of an extended arm with a gripping mechanism, a power unit, and a control unit. In theory, the robot was designed to emulate the action of the human arm and hand in reaching for, grasping, and transferring a part from one location to another. Thus, the early robots, with limited degrees of freedom, were designated as "pick and place" devices to be used to load and/or unload parts into or from machines. Now, programmable robots with many degrees of freedom and precise movements are used in a variety of manufacturing situations to complement the automation process.

The ultimate concept and scenario in manufacturing for many manufacturing engineers and executives is to achieve a completely automated manufacturing system (automated materials handling, machining, and assembly) to permit the operation of a "hands off/lights out" factory. Although feasible for some types of manufacturing situations, this concept has yet to be demonstrated on a large scale. Needless to say, progress in automated manufacturing has been spectacular since Spencer's "automat" in 1873, and it can be predicted that further progress will be made in the next century.

1.3 TYPES OF PRODUCTS

For statistical purposes, the U. S. Department of Commerce groups manufacturing establishments into 20 commodity categories according to the two-digit standard industrial classification (SIC) code shown in Table 1-2. These 20 major groups include establishments that are primarily engaged in the mechanical or chemical transformation of materials or substances into new products. These establishments are usually referred to as plants, factories, mills, or shops and they characteristically use power-driven machines and material handling equipment applicable to the type of manufacturing involved.

The 20 major groups of manufacturing establishments given in Table 1-2 are further subclassified into 139 three-digit industry groups, and then into 459 four-digit industries. The four-digit industries are then further subclassified into five-digit product classes and a seven-digit product line classification scheme. For example, the hierarchy of "Miscellaneous Fabricated Metal Products" (SIC 349) stemming from the major classification number 34, "Fabricated Metal Products," is given in Table 1-3.

Every 5 years for years ending in 2 or 7, the U. S. Bureau of Census conducts a census of manufacturing establishments to obtain information on that industry sector. This information, which is available through the U. S. Government Printing Office, is very useful to the government in determining national economic conditions and to the individual manufacturing establishment for comparative purposes. In 1992, all manufacturing establishments employing one or more persons at any time during the census year were included in the census. During that year, the manufacturing universe included approximately 380,000 establishments, of which 237,000 were selected for inclusion in the census report. (The North American Industry Classification System [NAICS] is replacing the SIC system. The Census Bureau's reports will be converted to NAICS beginning with those published in 2000. An outgrowth of SIC, NAICS is intended to recognize new industries, provide better international comparability, and permit more consistency in grouping industries.)

To illustrate the economic contribution of just one industry class, the 1992 census lists employment in the industry class 3491 (industrial valves) as 51,400, which was up some 12% from 1987. The report also indicated that the total value of shipments from the 493 firms included in that class was \$6.8 billion and that the average hourly wage of production workers was \$12.51. These and other statistics in the 1992 report exemplify the tremendous contribution the manufacturing sector makes to the economic health and well-being of this country.

1.4 ORGANIZATION FOR MANUFACTURING

1.4.1 Types of Manufacturing Systems

In general, the design of a manufacturing organization is dependent to a great extent on the type of manufacturing system involved. As indicated in Table 1-2, manufacturing establishments are classified into 20 product categories. Some of these categories represent process-type manufacturing systems, while others represent discrete parts or fabricating systems. Process types of establishments generally manufacture

Table 1-2. Standard industrial classification (SIC) of manufacturing establishments

Primary SIC Code	Product Group	All Establishments		All Employees Number (1,000)	Production Workers Number (1,000)	Value Added by Manufacture (million $)	Value of Shipments (million $)
		Total Number	With 20 Employees or More				
	All industries	381,870	124,927	18,253.80	11,654.10	1,428,707.40	3,006,275.20
20	Food and kindred products	20,792	9,325	1,504.80	1,100.00	156,843.40	403,836.00
21	Tobacco products	114	79	38.40	27.10	27,167.10	35,136.70
22	Textile mill products	5,887	3,203	614.80	527.00	29,862.10	70,694.20
23	Apparel and other textile products	23,048	8,564	985.60	824.40	36,357.00	71,617.00
24	Lumber and wood products	35,834	6,909	658.20	541.70	33,352.40	81,797.60
25	Furniture and fixtures	11,630	3,758	473.20	373.60	22,820.80	43,688.40
26	Paper and allied products	6,435	4,253	626.20	478.50	59,922.70	132,954.40
27	Printing and publishing	65,466	12,760	1,505.50	790.20	113,244.30	167,284.10
28	Chemicals and allied products	12,042	5,059	850.30	479.10	165,134.80	305,761.00
29	Petroleum and coal products	2,125	686	114.40	73.60	23,797.20	149,960.80
30	Rubber and miscellaneous plastic products	15,823	7,967	906.90	696.50	58,477.00	113,543.90
31	Leather and leather products	2,035	756	100.80	82.60	4,516.70	9,676.50
32	Stone, clay, and glass products	16,285	4,850	469.90	357.00	34,557.80	62,479.10
33	Primary metal industries	6,568	3,568	663.00	508.10	51,816.40	138,333.20
34	Fabricated metal products	36,357	13,522	1,369.80	999.30	83,870.80	167,015.00
35	Industrial machinery and equipment	34,973	14,103	1,742.10	1,087.70	132,143.60	258,273.10
36	Electronic and other electric equipment	16,952	7,677	1,444.30	913.50	121,949.60	217,905.70
37	Transportation equipment	11,259	4,289	1,646.40	1,079.00	161,058.40	401,213.90
38	Instruments and related products	11,346	4,282	910.10	460.90	89,805.80	135,479.20
39	Miscellaneous manufacturing industries	17,056	3,475	365.30	254.40	22,009.70	39,625.60

(Census of Manufactures 1992)

Table 1-3. Hierarchy of SIC 34

Primary Code 34	Fabricated metal products
Industry Group 349	Miscellaneous fabricated metal products
Industry Class 3491	Industrial valves
Product Class 34911	Gates, globes, angles, straightway (Y-type), checks, through stop and check, cross, 3- and 4-way, etc.
Product Line 34911-11	Iron body, including ductile or modular, all pressure (excluding Iron Body Bronze-mounted (IBBM), American Waterworks Association (AWWA), and Underwriters' Laboratories [UL] standards)

a product by means of a continuous series of operations, usually involving the conversion of a raw material. Food, chemical, and petroleum products are often produced by processes that are generally particular to each of the raw materials being converted. Thus, they are usually referred to as process industries even though discrete products, such as bottles of milk, bags of fertilizer, or containers of motor oil are the end products.

This text is primarily concerned with the discrete parts or fabricating types of manufacturing systems that make discrete items of product, such as nails, screws, wheels, tires, and paper clips, or assembled products, such as autos, televisions, and computers. A variety of manufacturing systems are employed to manufacture such products, including job shops, flow shops, project shops, continuous processes, linked-cells, and computer-integrated systems, all of which are described in Chapter 29.

1.4.2 Small Organizations

The four major ingredients of a manufacturing organization, *people, money, materials* and *machines,* must be brought together in an organized fashion to maximize their combined effectiveness and productivity. It is particularly important in a manufacturing environment that the structure and operating characteristics of the organization support, rather than impede, the process of building a quality product for a reasonable price. This is essential in a highly competitive marketplace.

The structure of a manufacturing organization depends on a number of factors, including the size of the establishment, the type of manufacturing system, and the complexity of operations involved. A simple *line organization,* as depicted in Figure 1-1, is often used when a company starts up with a small number of employees. A line organization, as the name implies, consists of a vertical line of organizational components, all representing personnel who are directly involved in producing a product or supervising those who are producing a product. This form of organization is often used in small family-owned and -operated firms in which a family member serves as president and general manager of a small number of employees. In this case, the general manager/owner handles all or most of the functions incident to the operation of the business, personnel matters, finance and bookkeeping, sales and marketing, as well as

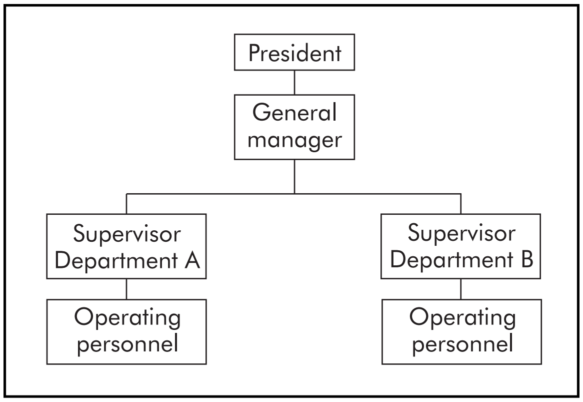

Figure 1-1. A simple line organization.

managing the production function. Quite often the line supervisors will assist the general manager in taking care of many of the technical details, such as production planning, tool design, and inspection. In many cases, certain business functions, such as payroll, accounting, and tax preparation, may be contracted out to service organizations who specialize in that kind of support service to small business establishments. In addition, many small shops may even subcontract a number of technical activities, such as product design, tool and die design, and fabrication.

According to Table 1-2, only about one-third of the manufacturing establishments counted in the 1992 census had 20 or more employees. Thus, some 256,943 establishments, representing two-thirds of the total number of manufacturing plants in the U. S., have less than 20 employees. Most of these could very well be operated via a simple line organization.

As an organization grows and the owner/manager and line supervisors find that they do not have the time or skills to handle many of the business and technical details of a manufacturing organization, specialists may be employed to take care of those activities. As this occurs, the line organization evolves into a *line and staff* type of structure. As shown in Figure 1-2, three staff specialists, a bookkeeper, chief engineer, and sales manager, have been added to the organization chart of Figure 1-1. These staff specialists provide support to the line personnel, but, in most cases, they do not have direct authority over the line operations. They report to the president and any line-related recommendations that they generate are transmitted from the president to the general manager, and on down the line. This conforms to the "one boss" principle of management that is necessary to prevent conflicting demands on operating personnel.

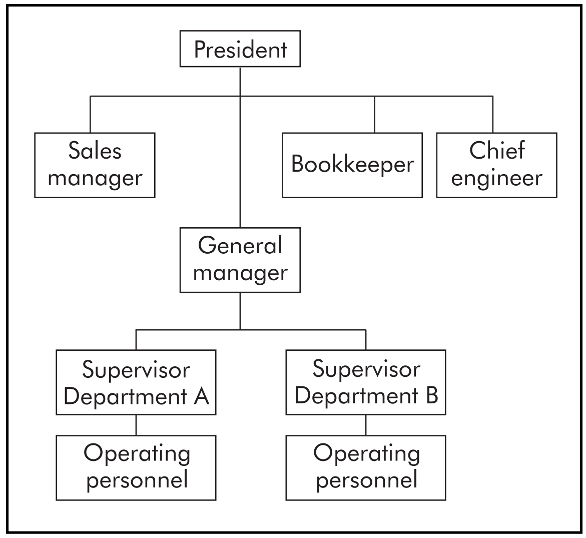

Figure 1-2. Small line and staff organization.

1.4.3 Large Organizations

The structure of a manufacturing organization generally continues to expand as the size of the organization increases. In other words, if the number of line employees is increased, then it can be expected that some increase in the number and size of the staff groups will be required. The increase in staff should not be in constant proportion to the size of the line as some economies of scale should be expected. For example, as a manufacturing firm expands its line of products or product models, it is likely that the sales or marketing staff will be increased. In time, that entity will become large enough to be a department, as will other staff groups in the organization.

The grouping of staff functions or departments and their designations varies with different organizations. Attempts have been made to classify activities as either service, advisory, coordinative, or control. However, some staff departments function within more than one and sometimes all of these categories.

The organization chart of Figure 1-3 illustrates an expanded line and staff hierarchy with seven staff groups and a superintendent of plant operations all reporting to a general manager. Some of the staff groups provide direct support to the line operations, while others have a less direct relationship. In most cases, however, the staff functions do not have direct authority over the line operations, and any recommendations that these groups make must, in theory, go through and be approved by the general manager. In practice, though, some staff groups routinely transmit information, schedules, design changes, unit costs, guidelines, etc., to different line elements for response.

Although all of the staff groups shown in Figure 1-3 interact to some degree with line operations, the three staff groups, Product Design and Test, Manufacturing Engineering, and Quality Assurance usually have a closer association. As implied by the title, the Product Design and Test group is responsible for the engineering design of new products or new models of existing products, design changes, maintaining design standards for products and components thereof, and developing and conducting feasibility and functionality tests on prototypes for these products. In modern manufacturing organizations, this group is often referred to as the Research and Development (R & D) group and it is responsible for long-range planning and research for new product development. In addition, the R & D group often conducts research on new materials for use in existing product lines and on new applications for products. The R & D group usually works closely with the Sales and Marketing staff to identify new products and to determine if product modifications may be necessary to maintain and possibly expand the firm's customer base.

The purpose of the Quality Assurance group is to provide the necessary surveillance and control of the manufacturing system to assure that product quality is consistent with customer requirements. The organization and functions of that group are described in Chapter 15.

1.4.4 Manufacturing Engineering

The planning, tooling, coordination, and control of manufacturing processes are critical to the operation of an effective and efficient

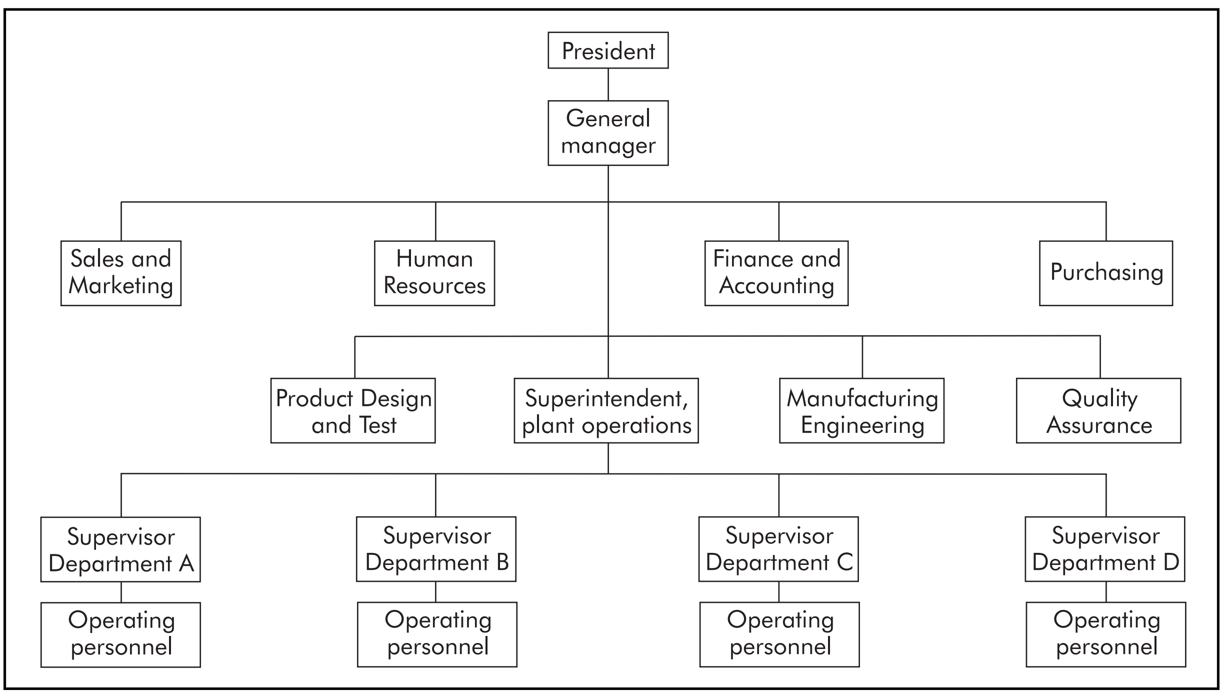

Figure 1-3. Line and staff organization for a medium-size manufacturing establishment.

manufacturing system. In fact, some manufacturing executives contend that a large proportion of the problems encountered are systems problems and are not necessarily the result of faulty machines or processes. In many large manufacturing organizations, the task of providing systems support and service to the manufacturing group is centralized in one comprehensive staff group referred to as either Manufacturing Engineering, Production Engineering, or Industrial Engineering. In other firms, many of the activities or elements of manufacturing engineering are decentralized and assigned to other staff groups or set up as stand-alone entities.

Regardless of how it is organized, the Manufacturing Engineering group or department is a staff service organization whose main role is to provide support to the manufacturing operations on production plans, processes and tools to be used, information and instructions on methods and procedures, labor standards, and assistance in solving problems. In addition, Manufacturing Engineering must work closely with Product Design and Quality Assurance to facilitate the infusion of new products and new quality standards into the manufacturing operation's product mix. It is particularly important that the manufacturing engineering group be involved in nearly every step of the product design process to assure the *manufacturability* of new products. "Manufacturability" infers that a product be designed in such a way that it can be produced in a cost-effective manner.

Depending on the extent of support activities required, the manufacturing engineering function is usually divided into several specialty areas, a number of which are shown in Figure 1-4. The Fabrication Processes group is responsible for developing production plans for the various processes involved in the manufacture of a product and its component parts. Thus, if one of those parts has to be cast, machined, and then cleaned and painted, the Fabrication Processes group will work up a set of plans encompassing the five subspecialties under that heading. Similarly, the Assembly Processes group develops plans and procedures for the various activities involved in the assembly of products and their components.

The other specialty areas shown in Figure 1-4 have definite line operations support responsibilities. The Tool Control group is responsible for providing the tools, dies, jigs, fixtures and other pieces of equipment required for both the fabrication and assembly operations. The Facilities Maintenance group provides the various utilities required to operate the manufacturing equipment, maintains the equipment, and also maintains the plant environment.

The Industrial Engineering group plays a major coordinative role in the manufacturing process through its activities in establishing work standards, setting up and balancing production schedules, and providing timely and accurate information on the status of many elements of the manufacturing system. The function of this group, often called the Manufacturing Systems group, is to assure that the manufacturing system works; that it functions smoothly and builds products on-time, on-cost, and on-quality. The coordinative role played by this group becomes increasingly important as a manufacturing organization moves from the more traditional mass-production type of operation to a more agile and flexible mass-customization type of manufacturing system. In the mass-customization environment, it is particularly important that a centralized and constantly updated computerized manufacturing information system be available to serve as the eyes and ears of the manufacturing operations.

1.5 QUESTIONS

1. Define the term "manufacturing."
2. What type of metal was used to replace stone for making hand tools during the seventh century?
3. Who is credited for developing the first machine tool and when did this occur?
4. How was the first machine tool powered?

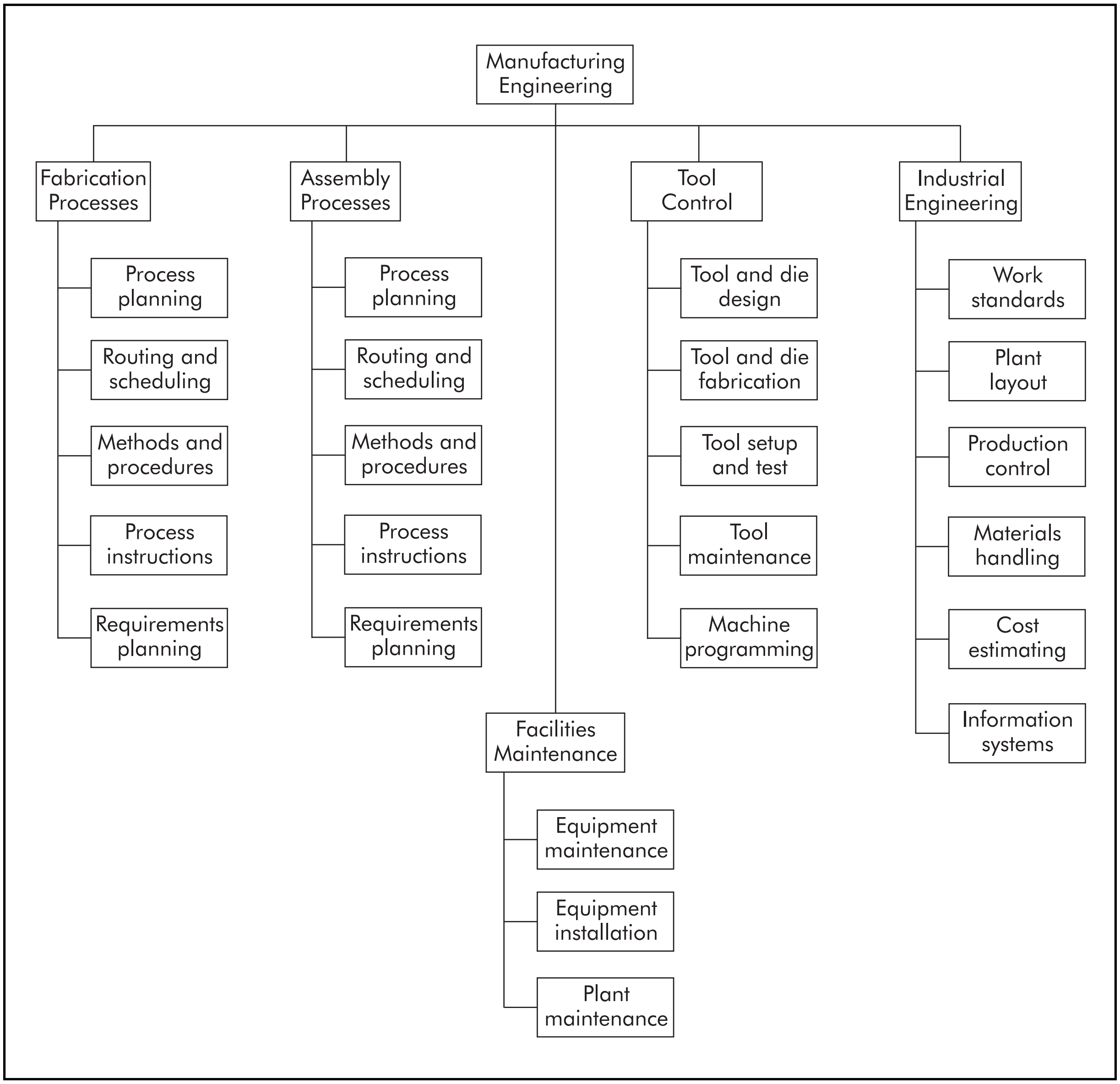

Figure 1-4. Typical areas of specialization for the Manufacturing Engineering group.

5. About when did the industrial revolution begin?
6. Define the term "interchangeable manufacture."
7. Who is credited with the early pioneering work on precision measuring devices and when was it done?
8. What are some of the advantages of automating the operation of machine tools?
9. When was high-speed steel introduced as a cutting tool material and who was responsible for its development?
10. What is the difference between numerical control (NC) and computer numerical control (CNC)?

11. Explain the hierarchy of the SIC classification for fabricated metal products.
12. Of the 20 major product groups listed in Table 1-2, which one had the largest number of establishments in 1992, which one had the greatest number of employees, and which one added the most value by manufacture?
13. What is the difference between a process-type manufacturing system and a discrete parts system?
14. Explain the difference between a line organization and a line and staff organization.
15. How are the line functions and the staff functions in a line and staff type of organization differentiated?
16. Define the term "manufacturability."

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