# INTRODUCTION TO ENGINEERING TECHNOLOGY

Eighth Edition

Robert J. Pond
Jeffrey L. Rankinen

## Engineering Prefixes

| *Number* | *Power of Ten* | *Prefix* | *Symbol* |
|---|---|---|---|
| 1 000 000 000 | $10^9$ | giga- | G |
| 1 000 000 | $10^6$ | mega- | M |
| 1 000 | $10^3$ | kilo- | k |
| 1 | $10^0$ | unity | none |
| 0.001 | $10^{-3}$ | milli- | m |
| 0.000 001 | $10^{-6}$ | micro- | μ |
| 0.000 000 001 | $10^{-9}$ | nano- | n |
| 0.000 000 000 001 | $10^{-12}$ | pico- | p |

## Table of Equivalents

These equivalents are useful in establishing “unit ratios.” All underlined figures are exact.

| | | |
|---|---|---|
| *Units of Length* | 1 inch = 2.54 centimeters = 25.4 mm<br>1 mile = 1.609 kilometers<br>1 microinch (μin.) = $10^{-6}$ in. | 1 foot = 0.3048 meter<br>1 statute mile = 5280 ft<br>1 μm = $10^{-6}$ m = $10^{-4}$ cm |
| *Units of Area* | 1 square inch = 6.45 $cm^2$<br>1 square mile = 2.59 $km^2$ | 1 square foot = 929 $cm^2$<br>1 acre = 43 560 $ft^2$ |
| *Units of Volume* | 1 gallon (U.S.) = 231 $in.^3$<br>1 gallon = 3.79 liters<br>1 gallon water = 8.34 lb @ 60°<br>1 $in.^3$ = $2.54^3$ $cm^3$ = 16.4 $cm^3$ | 1 gallon = 4 quarts = 8 pints<br>1 liter = 1000 milliliter<br>1 L = 1000 $cm^3$ (cc) |
| *Force and Mass* | 1 newton = 0.102 kg force (wt) = 0.225 lb<br>$10^{-5}$ Newton = 1 dyne<br>1000 kg = 1 metric ton = 1.103 English tons | 1 oz = 28.3 g<br>1 pound = 16 oz<br>1 ton = 2000 lb<br>1 slug force (wt) = 32.2 lb |
| *Speed* | 60 mi/hr = 88 ft/s | 1 mi/hr = 1.609 km/hr |
| *Angle* | 1 revolution = 360° = 2π rad | 1 radian (rad) = 57.3° |
| *Temperature* | °Fahrenheit = 1.8°C + 32<br>°Rankine = °F + 460 | °Celsius = (°F − 32)/1.8<br>Kelvin = °C + 273 |
| *Pressure* | 1 newton/$m^2$ = 1 pascal (Pa)<br>1 atmosphere = 76 cm Hg = 29.95 in. Hg = 14.7 lb/$in.^2$<br>This conversion can be used to form unit ratios, i.e.,<br>$\frac{76\text{ cm Hg}}{29.95\text{ in. Hg}} = 1$ | 6890 pascal = 1 lb/$in.^2$ |
| *Computer Conversions* | 8192 bits = 1K (kilobyte) RAM of memory<br>$\frac{1\text{ page}}{\text{minute}} = \frac{25\text{ characters}}{\text{second}}$ (printer speed based on 60 characters/line and 25 lines/page) | 1 screen pixel = at least 1 bit |

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EIGHTH EDITION

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**Text Printer/Binder and Cover Printer:** Courier
**Text Font:** Minion 10/12

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**Library of Congress Cataloging-in-Publication Data**
Pond, Robert J.
Introduction to engineering technology / Robert J. Pond, Jeffrey L. Rankinen.—Eighth edition.
pages cm
Includes index.
ISBN-13: 978-0-13-284011-8 (alkaline paper)
ISBN-10: 0-13-284011-1 (alkaline paper)
1. Engineering—Vocational guidance. I. Rankinen, Jeffrey L. II. Title.
TA157.P66 2014
620.0023—dc23

2013028783

10 9 8 7 6 5 4 3 2 1

PEARSON

ISBN 10: 0-13-284011-1
ISBN 13: 978-0-13-284011-8

# PREFACE

Students graduating from our nation's technical programs will play a vital role when they join the workforce: These students will implement today's technical concepts and transform them into tomorrow's reality. They will work on the cutting edge of technology and will need to combine a practical understanding of materials, machinery, and processes with the theories of today's practicing engineer. These students will be challenged by their careers and rewarded by their successes. This book is for them.

## NEW TO THIS EDITION

1. Updated salary and job outlook for engineering technology careers.
2. Updated information concerning renewable energy.
3. New Excel spreadsheet examples.
4. New trigonometric examples.
5. Discussion about Android and Windows 8 operating systems.
6. Statistical Process Control (SPC) case study.

## OUR MESSAGE TO STUDENTS, THE FUTURE OF ENGINEERING TECHNOLOGY

### Critical Information

For any nation to remain competitive in tomorrow's world, it will need enough technicians and technologists to supervise skilled workers and support research efforts and to produce, install, and maintain cutting-edge technology. This book's holistic approach will help you fill this vital role. It presents you with an overall picture of the engineering world, explains your role, and provides you with the critical science and mathematics background you will need on the job.

### Practical Skills: In School and in Your Career

For you to remain competitive in school and in your career, you will need practical skills to help you succeed. In this book you will learn about using the technical library and maintaining good grades and study habits. You will also learn about resumé writing, interview techniques, and professional societies that are most responsive to technicians.

# OUR MESSAGE TO INSTRUCTORS: A BOOK FOR EVERY LEVEL

## Two-Year and Four-Year College Classrooms

This textbook has been a success in both **two-year and four-year college classrooms.** Students with a strong math and science background will find it challenging. Students seeking to improve that knowledge can learn from the book. Appendices B and C review the mathematical principles necessary to understand the text.

*Introduction to Engineering Technology* may be used as the primary text for Orientation to Engineering Technology courses or as a supplement for courses requiring the use of applied mathematics, computers, or scientific calculators. This edition includes a new section on the use of spreadsheet software for solving problems.

## Secondary-School Tech Prep Programs

This text may be used in secondary-school **tech prep** programs. Dale Parnell's popular book *The Neglected Majority* discusses the need for more **structured mathematics and science education** for the "middle fifty percent of any high school's student body." This text provides a vital practical base to support such a structured approach:

- This book contains numerous practical applications to enhance understanding of the concepts discussed.
- Students learn to work with current applications (e.g., graphing calculators in Chapter 4 and ladder diagrams in Chapter 9) as well as learn the basics.

It is recommended that you discuss the applications in class as well as to discuss your own problem-solving experiences.

# COVERING KEY INFORMATION

## Background

The book begins with a brief history of engineering and career information for technicians and technologists. Career information includes topics such as the following:

- The role of the technologist
- The need for good communication skills and teamwork
- Potential salary information

Major technologies discussed are chemical, civil, architectural, electrical/electronic, computer, industrial, and mechanical.

## Excelling at School and Beyond

The book covers **college survival skills**—using the technical library, maintaining good grades, scheduling adequate study time, and applying basic problem-solving skills. It also teaches fundamental skills for **career advancement:** Resumé writing, interviewing techniques, and looking ahead to graduation prepare students for their ultimate goal—gaining desirable employment. Membership in a professional society is recommended. Appendix A provides a list of the professional societies that are most responsive to technicians.

## Vital Math Skills

This book covers the following vital math skills:

- Use of the calculator and spreadsheet software
- Use of algebraic logic systems and the mathematics of signed numbers
- Rules for adding, subtracting, multiplying, and dividing signed numbers
- Use of dimensions and units
- A simple four-step approach to unit conversion
- Examples that feature step-by-step solutions to help students with the geometry needed to understand the technologies

## Communication Skills

This book covers the following communication skills:

- Proper experimental methods
- Graphing, oral reporting, and report writing

## Computer Skills

This book covers the following computer skills:

- The necessities of microcomputers and personal computers
- The language of computer technology
- Networking, the Internet, and industrial automation
- Computer-integrated manufacturing (CIM), including controllers and control loops; numerical control (NC); flexible manufacturing systems (FMS); and distributed control systems (DCS)
- Future technological challenges, including robotics, expert systems, optical systems, new composite materials, nanotechnology, and protection of the environment
- Abbreviations and acronyms used in technology

*Introduction to Engineering Technology*, eighth edition, presents the same fundamentals found in the previous edition while updating key information and images. This edition supports instructors with an Instructor's Manual, which contains worked-out solutions to all problems, and PowerPoint presentations.

## Download Instructor Resources from the Instructor Resource Center

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com/irc to register for an instructor access code. Within 48 hours of registering, you will receive a confirming e-mail including an instructor access code. Once you have received your code, locate your text in the online catalog and click on the Instructor Resources button on the left side of the catalog product page. Select a supplement, and a login page will appear. Once you have logged in, you can access instructor material for all Pearson textbooks. If you have any difficulties accessing the site or downloading a supplement, please contact Customer Service at http://247pearsoned.custhelp.com/.

# ACKNOWLEDGMENTS

We thank the following reviewers of this edition for their helpful comments: Larry W. Brillhart, Lone Star Community College; Barbara Christe, IUPUI; Otha C. Hawkins, Alamance Community College; Dr. Brian Matthews, NC State University, Raleigh, NC; and Paige Wyatt, Columbia Basin College.

The staff of Pearson Education provided us with the professional support needed to make this text a quality product. Thanks to all of them.

Robert J. Pond: I could not have written this text without the support of my wife, Constance. To have an honest and sensitive critic who is always there is paramount to any writer's success.

Jeffrey L. Rankinen: I am forever indebted to my wife, Amy, for her persistent encouragement in the revision of this eighth edition. It has been a pleasure coauthoring this text with Robert Pond, from whom I've learned a great deal. He has given me the opportunity to contribute to the field of engineering through this text and support materials.

We welcome your feedback and suggestions. You can contact the authors at rbtpond@gmail.com and jrankin@pct.edu.

# CONTENTS

CHAPTER ONE

# ENGINEERING TECHNOLOGY AS A CAREER

All of us wish to understand the world we live in and to know our place in it. As children we depended on our parents to protect and feed us and establish an atmosphere we could depend on. In those early years, stability was necessary for normal development. But change was inevitable as we encountered a wider world by beginning school and interacting with other children and adults. That unpredictable world was frightening and intimidating at first, but we learned to adapt. Most of us even learned to look forward to and expect change.

Change creates opportunities for those who prepare themselves with the skills, knowledge, and attitudes to solve problems. This book is about technology, and about the skills, knowledge, and attitudes possessed by the technologists who live and work in a world where "the only constant is change."

You may become a part of the exciting world of technology. To do so you will need to acquire a practical knowledge of mathematics and science. You must also learn how to communicate well with others. But, above all, you must be prepared to constantly adapt to the ever-changing world of technology.

Technologists are responsible for providing the material things necessary for human subsistence and comfort. Automobiles, transportation systems, buildings we work in, efficiently automated industrial and business processes, improved power systems, new materials, more powerful computers, and highly integrated communication systems are but a few of the commodities we expect from technologists (Figure 1.1).

Technology has improved our lives. At the turn of the century, half of the population of the United States lived on farms, working from sunup to sundown merely to feed everyone. Now, with advanced farming techniques made possible by our modern technology, only 3 percent of the population feeds the entire United States plus a significant proportion of the rest of the world. And, while today's farmer may still work from sunrise to sunset, the work is much less labor intensive.

People live much better than they did just 40 years ago. Consider the automobile and the home: The automobile has improved significantly. Fuel efficiency has almost doubled, and the *hybrid car* promises another doubling. Newly developed safety accessories like air bags and antilock brakes have been added. The advent of front-wheel drive has minimized vehicle size and weight while improving traction. As for the home, the average area of new ones has grown by more than 600 square feet. An increasing number of homes have central air conditioning and labor-saving devices like dishwashers, washing machines, and dryers. High-definition and 3D televisions are available for less than the cost of a television set from 40 years ago.

**FIGURE 1.1** Technologists provide for society's needs. (Reprint courtesy of International Business Machines Corporation, copyright © International Business Machines Corporation.)

Much of today's explosive growth of technology began in the 1950s. In 1951 direct long-distance telephone dialing was made possible by electronic switching, which eliminated the need for the *operator*. Also, the first commercial computer, the UNIVAC, was developed. But, most importantly, the integrated circuit (IC)—the *chip*—became reality in 1958, guaranteeing the explosive development of the personal computer in the 1970s and 1980s.

New computer-related products are continually emerging. The VCR was popular in the 1990s and now this type-based machine has been replaced by the digital DVD player and the digital video recorder (DVR). The cell phone, smart phone, and new tablet computer deliver both voice and data wirelessly and have made a sea change in our personal and working lives.

Internet connections are also becoming part of every household. Today broad-band as opposed to narrow-band connections offer data transfer rates that allow for sharing pictures and much more data downloading and uploading than in the past. Business growth has accelerated and will continue to be dependent on *information technology* (IT), and the IT field is one of the fastest growing for the aspiring technician.

Technology offers the world unparalleled opportunities. It accounts for over half of U.S. economic growth over the past 40 years. We must sustain the initiative of the past by preparing more of our population for interesting and profitable careers in all engineering fields. This textbook is designed to help you better understand the world of technology and to visualize how you may fit into it.

## 1.1 HISTORY OF ENGINEERING AND TECHNOLOGY

### Ancestral Engineering—Humankind's Search for Identity

To fully appreciate the world of technology, we begin with some early history. The technologists and craftspeople of early civilizations built huge objects. The Great Wall of China was built by people who learned through trial and error. But its construction also required precise surveying and an amazing talent to use the lever and the inclined plane. Algebra and trigonometry were well understood and applied during those early years. Construction of the

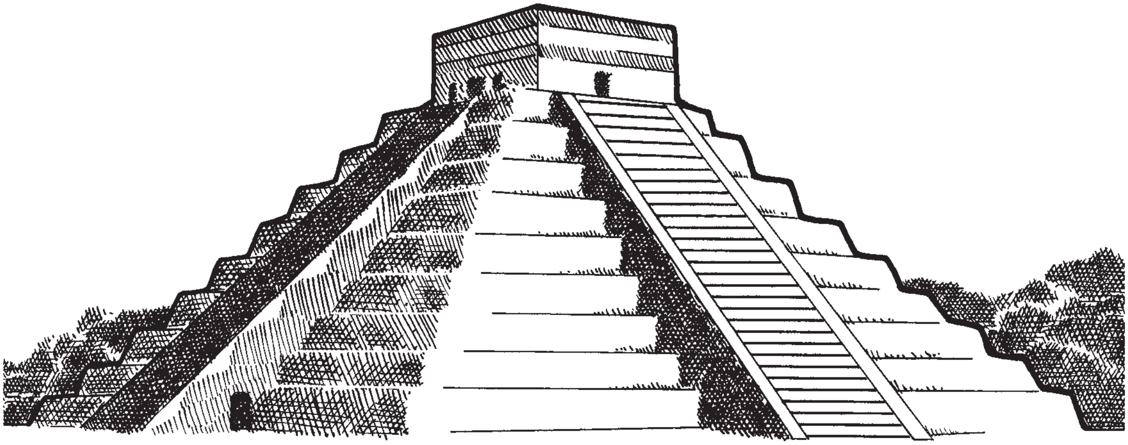


**FIGURE 1.2** This Mayan pyramid (Yucatan Peninsula, Mexico) was precisely oriented to form the shadow of the seven triangles of the serpent's back only on the vernal and autumnal equinoxes, which occur in spring and fall, respectively.

pyramids of Egypt and of Central and South America required experience (trial and error) and the labor of many people. In addition, however, many of the pyramids are oriented with great accuracy to the movement of the sun (Figure 1.2) or to the cardinal points of the compass. Such accurate positioning required the use of a well-developed system of mathematics and science. Sophisticated long-range planning was necessary in all of the great, early projects.

These huge constructions, so precisely located, helped humankind establish identity and satisfied the basic need to build and create. Engineering and technology activities satisfy this same basic need. The early builders were the forerunners of today's civil, mechanical, and mining engineers.

## The Five Main Branches of Engineering (1700–Present)

Modern engineering and technology began in the 1700s and developed into five main branches: civil, mechanical, mining and metallurgical, chemical, and electrical.

**Civil Engineering** The civil engineer, the earliest defined engineer, is the builder of our infrastructure—our foundation. You cannot have civilization without civil engineers, says the American Society of Civil Engineers. Some essential elements are public utility systems, buildings, roads, railways, airports, bridges, and waterways. Civil engineers must understand soil consistencies so they can design and build sound foundations. They must be familiar with the many types of construction materials and be able to determine the capabilities and limitations of each. Because they make structures that humans depend on, they must accept a high level of responsibility for their actions.

Future challenges for technologists in the field of civil engineering include modernizing our present infrastructure, building new systems to clean and maintain our environment, and developing more efficient power-delivery systems.

**Mechanical Engineering** Steam power in the early 1800s brought the need for a new engineer, the mechanical engineer. Mechanical engineers and technologists made possible the development of machine tooling and manufacturing. Today's modern, automated industries are largely the result of the early efforts of the mechanical engineer.

Today's technologists in the mechanical area must understand energy-transfer and energy-conversion devices. Lasers (the acronym laser stands for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation), gasoline engines, motors and generators, and fluid-power systems are but a few examples of such systems. Mechanical technology workers design, build, and test all types of machinery and work in most industries.

The aerospace industry is one of the challenges for mechanical engineering personnel. Improved materials must be used to build faster, more efficient, and safer aircraft. Space stations and space transportation vehicles are urgently needed for society to explore our solar system and to enjoy the rich resources of other worlds. In addition, some manufacturing processes can be greatly improved in a gravity-free environment.

**Mining and Metallurgical Engineering** The 1800s also saw the evolution of mining engineering. The need for coal to heat homes and fuel factories came first. Later, petroleum exploration and refining became necessary.

A mining engineer is concerned first with how to extract minerals safely and efficiently. Mining engineers and technologists must be familiar with civil engineering in order to construct safe, well-ventilated mine shafts. They must be aware also of soil conditions and related problems, such as drainage, making geology an important part of their preparation.

A metallurgical engineer is also concerned with extracting metal-yielding minerals from the ground. More often, however, this technical area is concerned with how to mold, cast, and shape metals and how to improve such metallic properties as strength, hardness, and stiffness.

Mining engineers and metallurgists face many challenges. Oil and mineral deposits below the surface of the ocean have scarcely been touched. Space vehicles require new materials to reduce weight, improve strength, and increase heat-dissipation properties. New ways must be found to protect the environment during and after mining.

Materials technology, closely related to the discipline of metallurgy, will bring important new materials to our homes, businesses, and industries (Figure 1.3). New uses for ceramics and polymers will improve our living standards.

**Chemical Engineering** Chemical engineering evolved later in the 1800s, with society's increasing need for mass-produced chemicals. Like a metallurgist and materials technologist, a chemical engineer controls the chemical processes that convert raw materials into useful commodities.

Chemical engineers and technologists are specifically involved with the manufacture of chemicals. They are responsible for such varied chemically related industries as food processing, drug manufacturing, environmental control, and nuclear energy.

Future challenges in chemical technology will be in the continued search for more efficient production of pharmaceuticals, while maintaining the high quality already present in such processes, and improved testing of food products. Chemical engineering's greatest contribution, however, will be in the development of new energy systems. Fusion energy systems and improved solar energy systems will bring clean, safe, and cheap energy to homes and industries. Development of less expensive and nonpolluting energy systems is probably one of our society's highest priorities.

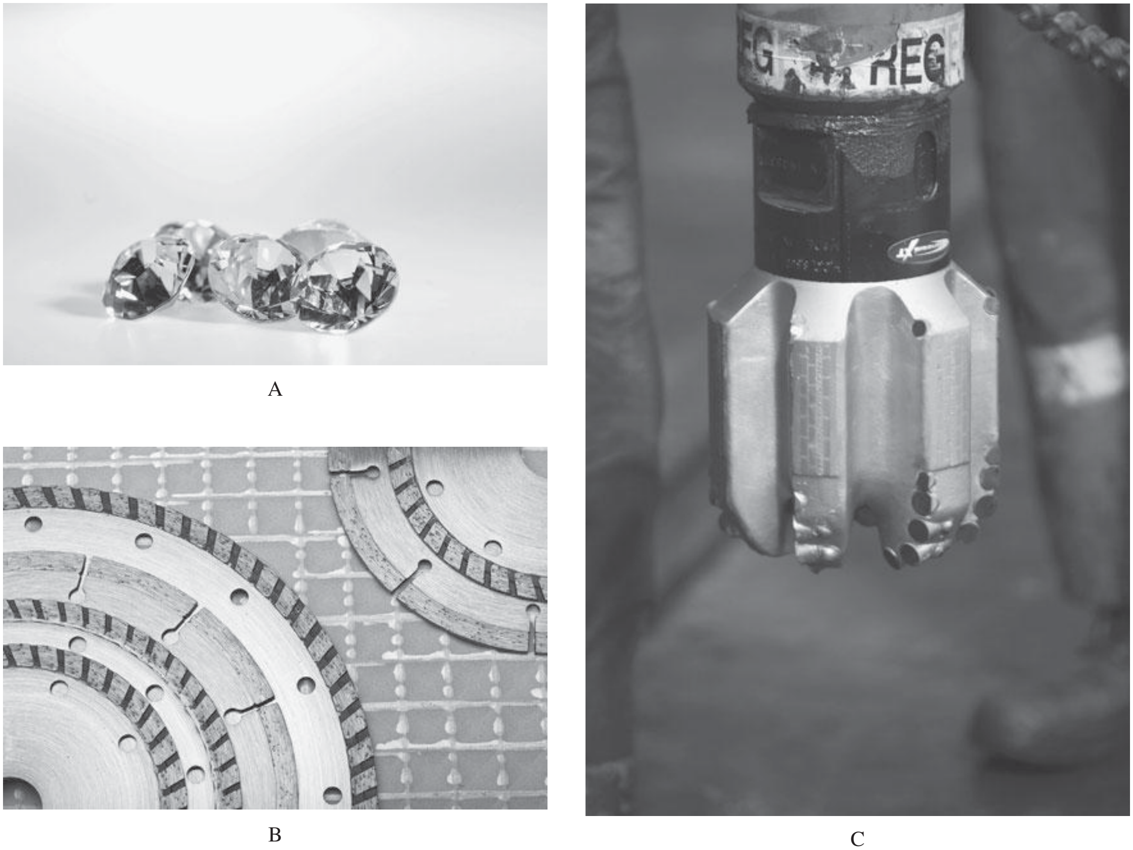



**FIGURE 1.3** Materials technology led to synthetic diamonds (A) used for diamond-tipped saw blades (B) and powerful drill bits (C). (A. Courtesy imagebroker/Alamy; B. Courtesy Konstantin Kulikov/Alamy; and C. Courtesy Paul Bock/Alamy.)

**Electrical Engineering** Electrical engineering was not a distinct field until the 1900s. Young as it is, it is now the largest branch of engineering. Early in the century, electrical engineers were concerned primarily with the production and distribution of electrical energy—power plants and power lines.

Early electrical engineers worked in the mechanical world as much as the electrical. They were the first electromechanical engineering technologists. Charles Kettering, working with a group of highly creative technicians, invented the automobile self-starter in the early part of the century (see Chapter 3). Kettering and the “barn gang” are outstanding examples of the flexible, cross-disciplinary character of early electrical technologists. These versatile builders of yesterday contrast greatly with the specialized electronics engineers of today.

Electronics technology arrived with the development in 1904 of the vacuum tube, leading to the first amplifier in 1907. From the 1920s to the 1950s the vacuum tube led to the inventions of television and computers. In the 1950s the transistor and other solid-state devices, including ICs, replaced the energy-hungry vacuum tube.

The electronics industry is one of the largest employers of engineers today. Electronics engineers are found in most other industries as well. Challenges in the field of electronics will exist primarily in the areas of computers, machine control, and improved communication systems.

### Today's Engineering Fields

Today, demand has created more than 30 different engineering fields from the original five main branches. Emphasis on energy conservation and managing environmental impact has given rise to new fields including renewable energy and sustainable manufacturing. New degree areas include

| | | |
|---|---|---|
| Aerospace | Engineering science | Petroleum |
| Agricultural | Environmental | Renewable energy |
| Architectural | Industrial | Sustainable manufacturing |
| Biomedical | Marine | Systems |
| Computer | Materials | Welding |
| Electromechanical | Nuclear | |

**The Emerging Need for Technicians and Technologists** With the launching of *Sputnik* by the former Soviets on October 4, 1957, the need for more specialized and more scientific engineers became apparent. By this time technology had become quite complicated, and new space systems offered almost overwhelming challenges. Four-year engineering schools were funded to upgrade curriculums and to produce engineering graduates with greater scientific skills.

Graduates of the engineering programs of the 1960s had more theoretical knowledge but less practical knowledge and manufacturing experience. These new "engineering-scientists" achieved beyond expectations and allowed the United States to enter and win the space race of the 1960s and 1970s. New space systems planned for the 21st century promise to make space and other planets as much a home for humankind as earth is now. However, the practical engineer who could build and maintain traditional industrial systems became a rare commodity. Technical education was developed to bridge the gap. Technicians and technologists, graduates of technical programs, took responsibility for the more practical and less specialized scientific work.

## 1.2 THE INDUSTRIAL TEAM

Today's industries are divided into two fundamentally different types: *manufacturing* (goods-producing) and *service* (service-providing) industries. Manufacturing industries make products. The need for technicians was first recognized in manufacturing, but greater growth now exists in the service industries. A 10.1 percent growth in employment is projected between 2008 and 2018 for the service industry as comparative a 0.02 percent growth for the manufacturing industry.

Should you consider a career in manufacturing with only 10 percent of the workforce employed in these jobs? The answer is a resounding *yes*! Graduates of technology programs—both two-year and four-year programs—will find at least average employment opportunities and better-than-average opportunities in computer-related positions in manufacturing. Manufacturing provides better fringe benefits and often increased job security. Also keep in mind that the U.S. manufacturing sector produces more than the entire economies of most countries in the world, accounting for almost one-fourth of the world's total manufacturing output.

In both manufacturing and service sectors, teamwork will be required if companies wish to survive. Teamwork in manufacturing means that the scientist, engineer, accountant, technician, technologist, and skilled worker all cooperate in bringing improvements to manufacturing processes that produce goods. Teamwork in service means that the owner or manager of the organization trains and supports technologists to achieve customer satisfaction. The computer-service technologist sent to a customer's computer facility to solve a problem that has resulted in downtime will be under extreme pressure to fix the problem in a very short time. With the proper resources available from his or her company, the knowledgeable and well-trained technologist will not only satisfy but delight the customer. The result will be increased business for the service company.

## The Role of the Technician and Technologist

The technician and technologist work in strategic positions on the business or industrial team. The main difference between technicians and technologists is the years of higher education required and the technical sophistication of their occupational experience. Most technicians possess a two-year education beyond high school, while technologists take an additional three to five years of coursework.

Regardless of their titles, both technicians and technologists act as

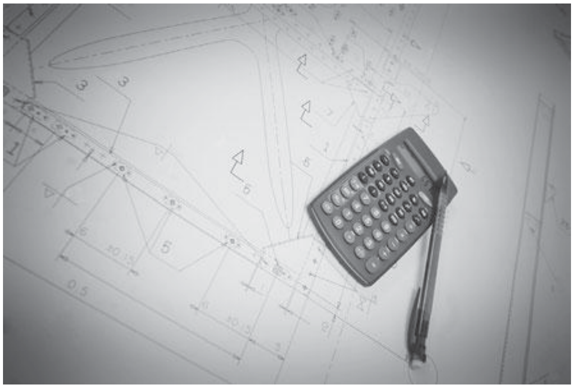
1. communicators between management or engineering and the skilled employee,
2. implementers who interpret the ideas of management and implement them, and
3. calibrators and testers who perform tests and measurements to make sure equipment is operating correctly and according to specification.

All employees in a business or an industry are expected to communicate with others. Technicians and technologists must be *communicators* who can explain complex technical ideas to both management and skilled workers. This task is often accomplished through the preparation of engineering drawings or charts and graphs for presentations and through direct informal communication with others. Responsible for planning and supervising, the tech requires interpersonal communication skills, including *listening* as well as speaking and writing skills.

For example, a civil engineering *technician* takes the plans of a civil engineer and prepares detailed drawings of a certain part of the project. A *technologist* then takes the drawings to the bridge or highway being constructed and directly supervises the construction personnel in the field.

Technicians and technologists must be able to speak clearly and accurately to enjoy credibility with coworkers and managers. They must not use confusing language when discussing detailed factual material.

Technicians and technologists take on active roles in *implementation*. This frees engineers to continue the flow of creative design ideas (Figure 1.4A) and to deal with broad



A

B

**FIGURE 1.4** The design equations of the engineer and scientist (A) become reality with the work of the technician and technologist (B). (A. Courtesy gmg9130/Fotolia; B. Courtesy anyaivanova/Fotolia.)

concerns such as the personnel, managerial, and economic consequences of a project. Technicians implement an engineer's ideas, making the ideas reality (Figure 1.4B). They measure the quality of production, install new equipment, interpret the chart recordings and gauges monitoring a manufacturing process, or supervise the construction of the superstructure (steel skeleton) of a large office building.

In research and development (R&D), technicians work with engineers to introduce new materials and processes and to test new materials for such qualities as strength and durability.

*Calibration of test equipment* is vital in today's industry. Heat sensors, flow meters, fluid-pressure sensors, and electrical measuring equipment such as oscilloscopes and voltmeters are a few of the many types of instruments used to measure industrial processes. A technician trained to read schematic drawings of industrial measuring instruments and possessing the knowledge of how the instruments operate must often repair, maintain, and calibrate them. The technician in Figure 1.5 repairs and calibrates communication equipment, ensuring reliable, accurate operation.

The preceding discussion illustrates the three essential roles expected of technicians and technologists: communicator, implementor, and calibrator and tester. The role of the manufacturing engineer is often filled by the engineering technologist, described in the following section. By studying to become a technician in two years and perhaps continuing for a four-year bachelor of science in engineering technology (B.S.E.T.) degree, you will be well prepared to find a position in industry that will be both challenging and rewarding for years to come.

## Teamwork in Manufacturing

Manufacturing industries require the teamwork of the scientist, engineer, technician and technologist, and skilled worker (Figure 1.6). The *scientist* is engaged principally in research and the development of new materials—in advancing the state of the art. The *engineer* provides system design and technical management. Many engineers are professional engineers (PEs) licensed by state boards to practice. The *technician* and *technologist*

**FIGURE 1.5** Technicians and technologists repair, maintain, and calibrate sensitive measurement equipment. (Courtesy anyaivanova/Thinkstock.)

provide the practical, hands-on manufacturing expertise. The *skilled worker* operates and repairs specialized machinery. Table 1.1 depicts the amount of theory and applied knowledge needed for these five industrial classifications.

The skilled worker performs tasks that require some mathematics and other theoretical knowledge but relies mostly on hands-on experience. Examples of skilled workers are

**FIGURE 1.6** Teamwork in the laboratory. (Courtesy Alexander Raths/Fotolia.)

**TABLE 1.1** The Industrial Team—Duties and Education

| Duties | % Theory | % Applied | Education Required/Degree |
|---|---|---|---|
| Scientist—hypothesizes and verifies laws of nature | 90 | 10 | Five to seven years of college/ M.S. or Ph.D. |
| Engineer—designs and creates hardware and software from scientific ideas and laws of nature | 70 | 30 | Four or five years of college/ B.S. or M.S. |
| Technologist—makes design prototype, suggests redesign or modification, acts as manufacturing engineer | 60 | 40 | Four years of college/B.S.E.T. |
| Technician—makes model of prototype, tests and trouble-shoots prototypes and hardware/software in actual production use, acts as manufacturing supervisor | 50 | 50 | Two years of college/A.S.E.T. |
| Skilled worker (craftsperson)—produces parts (e.g., holding fixtures) from completed designs, installs and runs hardware | 20 | 80 | Four years of on-the-job training (OJT) and/or vocational high school<br>High school diploma and training/experience |

M.S. = master of science, Ph.D. = doctor of philosophy, B.S.E.T. = bachelor of science in engineering technology, A.S.E.T. = associate of science in engineering technology.

machinists and electronic assembly workers. Indispensable to production and used often in maintenance, the skilled workers are a vital element of the industrial team.

In both service and manufacturing, the roles of the technician and technologist may be clarified by comparing and contrasting their occupational tasks. Technologists are often responsible for *design* and *development* in R&D laboratories. They may perform such tasks as *designing the interface* for a computer circuit board, *developing new packaging systems* for a product, *collecting and organizing statistics* for a service provider to aid in decision making, or *troubleshooting* a pilot production line.

The typical four-year engineering technology curriculum provides a background equivalent to that of the baccalaureate engineer's curriculum of the 1950s. The result of the additional two years of education is the manufacturing engineering technologist. A manufacturing engineering technologist is often more willing and better suited to be involved with the day-to-day problems of manufacturing than is today's more scientifically educated engineer.

For example, a fiberglass insulation line slows because of the material sticking to the rollers. The supervisor of manufacturing engineering assigns the problem to a technologist. The technologist first analyzes the problem in light of the physical characteristics of the material, a task involving an applied knowledge of chemistry and physics. The technologist, while troubleshooting, measures the temperature and humidity and determines that humidity is higher than normal. Skilled workers are then assigned to inspect the duct system and find that a large ventilating fan is inoperative. The technologist then reports the problem and recommends that the fan be replaced.

Occupational tasks of an electronic engineering technician are similar to those of a technologist in some areas but may differ markedly in others. A technician may supervise

**FIGURE 1.7** Technical students couple hands-on experience with theory in the process control laboratory. (Courtesy of Stephen Coburn/Shutterstock.)

the assembly of specific equipment, breadboard and test circuits designed by an engineer or a technologist, perform drop tests to measure the protection offered by a packaging system, or inspect specific products or processes.

Technicians are also expected to learn their jobs faster than those with four- or five-year degrees. Because technicians are prepared in college for hands-on (practical) applications, employers expect them to perform new laboratory tests in a short time (Figure 1.7). Employers have admitted that they expect a technician to be fully productive within 30 to 60 days after beginning employment.

How may the technician and skilled worker cooperate with one another? Consider, for example, a hydraulic pump that continues to overheat because of inadequate system design or defective parts (Figure 1.8). An engineering technician, prepared to deal with the real-world problems of industry, is called in. An electromechanical, mechanical, or fluid-power technician is trained to test pumps and know what conditions must be present for pumps to operate effectively. The technician quickly isolates the problem by determining that (1) a specific type of relief valve incorporated into the inadequate system will solve the problem, (2) the oil reservoir is too small, or (3) the pump is defective.

If new parts are required (e.g., oil reservoir, pump) the technician will order the substitutes by establishing the correct replacement specifications, researching suppliers' catalogs, and making telephone calls to determine availability. The skilled worker will complete the necessary maintenance by installing the new parts. Alternatively, repair of a part may be necessary. If the pump is determined to be defective, for instance, the skilled mechanic would be better qualified to tear down and rebuild the hydraulic pump than would the technician who has been trained only to test pumps, not to deal with the placement of seals and other internal components.

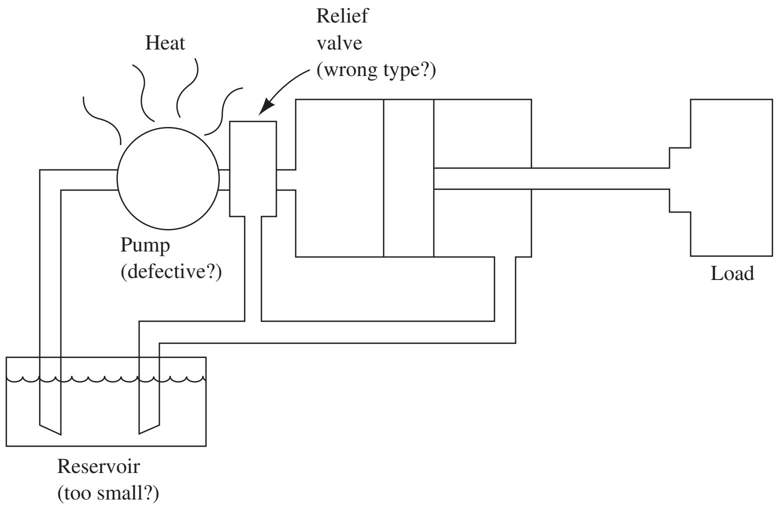



**FIGURE 1.8** Training prepares a technician to troubleshoot a faulty hydraulic system.

### Example 1.1

If the faulty hydraulic circuit in Figure 1.8 is diagnosed to require a different type of relief valve—one that ports hydraulic fluid to the reservoir if system pressure becomes too great—who would specify the new relief valve? Who would determine the problem if complex piping or hose runs are at fault?

#### Solution

If the relief valve is at fault, the technician is quite capable of determining the specifications of the new valve and will specify a suitable replacement. If, on the other hand, the piping or hose (conductor) runs are long and complex, then the technologist or engineer is often needed to redesign the system and solve complicated fluid-mechanics problems. These problems may require sophisticated mathematics skills that the technician does not possess.

## Communication and the Industrial Team

One of the critical roles technicians or technologists play is that of communicator. They "glue the industrial team together" and make it function as a whole (Figure 1.9). Technicians and technologists are best prepared to communicate with the skilled worker because of a technical education that includes a great deal of laboratory experience, including work with the actual tools and machinery used in industry.

During college, technicians and technologists are exposed to the language of the engineer, who uses information from mathematics, physics, chemistry, and other sciences to solve theoretical problems and to design new systems. The technician's college education requires a sound base of algebra and trigonometry (sometimes calculus) and at least two courses in physics or chemistry. The technologist's curriculum includes mathematics through calculus and advanced applied science courses.

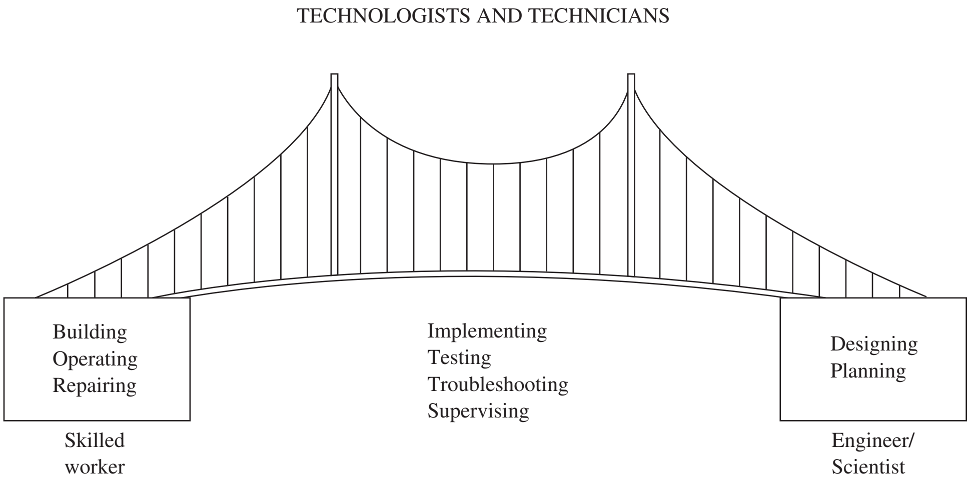



**FIGURE 1.9** The technician acts as the bridge for the industrial team.

Knowledge of the symbols and words used by both the skilled worker and the engineer enables the technician or technologist to become a critical link between them. Forging this link between the quite different worlds of the skilled worker and engineer is challenging. How do technologists build bridges (see Figure 1.8) and ensure that communication occurs between people who are expected to perform markedly different work? Technologists can accomplish these tasks only if they

1. have confidence in the real skills and knowledge they possess,
2. can logically and reasonably transmit their messages to others, and
3. know and can use the appropriate conventions of the language—for instance, good spelling, good grammar, and good sentence and paragraph structure.

Of course, *good human relations skills must be added to all of the above criteria.* One critical factor in human relations is listening to others. A technologist who can listen to the skilled worker will be much more effective and will learn a great deal more than one who can only direct others.

## Organizational Structures and the Industrial Team

A medium to large company must have an organizational plan for the industrial team to function correctly. The organizational plan fixes decision-making responsibilities, showing specifically how the members of the team interact and who makes decisions at a particular level. The plan may be shown as an *organizational diagram* or *organizational chart.*

Technicians and technologists should be aware of both formal and informal decision-making structures in their organization. Understanding the concepts of *line* and *staff functions* from an organizational chart is a good first step.

For instance, consider Figures 1.10A and 1.10B. In Figure 1.10A, the quality assurance manager is in a staff position, reporting to the plant manager and coordinating quality assurance activities between the group managers. The quality assurance manager acts

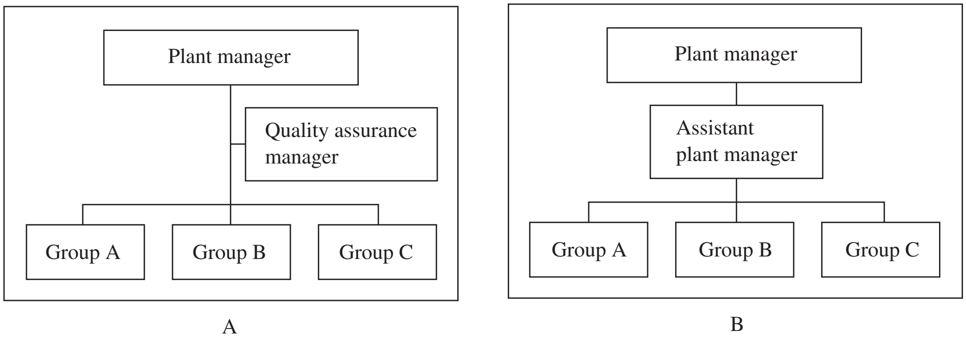



**FIGURE 1.10** Staff (A) vs. line (B) relationships in an organization.

only in the capacity of an advisor and does not enjoy line authority. In Figure 1.10B, the assistant plant manager is in a line position—no longer simply an advisor but in a position that may involve directing the group managers.

Confusing line and staff functions may result in serious misunderstandings in an organization. It pays for the organization to be clear about who manages whom and for each employee to be clear about whom to report to. Figure 1.11 is the organizational structure for a large manufacturing company. Can you identify the line and staff positions in the diagram?

If you are a member of a staff organization (many industrial engineering functions are staff organizations), you must be prepared to work differently with others in the organization. A staff department must work with, not direct, other managers. Top management should assist staff organizations to do their jobs by breaking down any barriers between departments.

## Competition vs. Teamwork

Competition in manufacturing or service industries should be directed toward competitors and not occur between members of the same organization. Top management has a central role in setting the climate for eliminating unhealthy internal competition. Companies where there is bickering and backbiting between employees and between departments will not survive in today's global economy. Such an environment is too inefficient.

Teamwork is the business strategy of the 21st century. Teamwork is enhanced by freeing teams to make more decisions on their own. Employees at all levels working in teams that consist of people from many disciplines make decisions on equipment needs, production levels, staff support, and financial support for a particular project. In this environment, engineers and technologists interested in simply being left alone to work with a certain piece of equipment cannot survive long. They must learn to work with others.

Your courses in psychology and sociology will be of great benefit to you in learning how to work with others. In your technical laboratory courses, you will be expected to work with at least one other person. Your technical instructors will assign real-world projects that involve several students. Strive to understand others, and your career will be greatly enhanced.

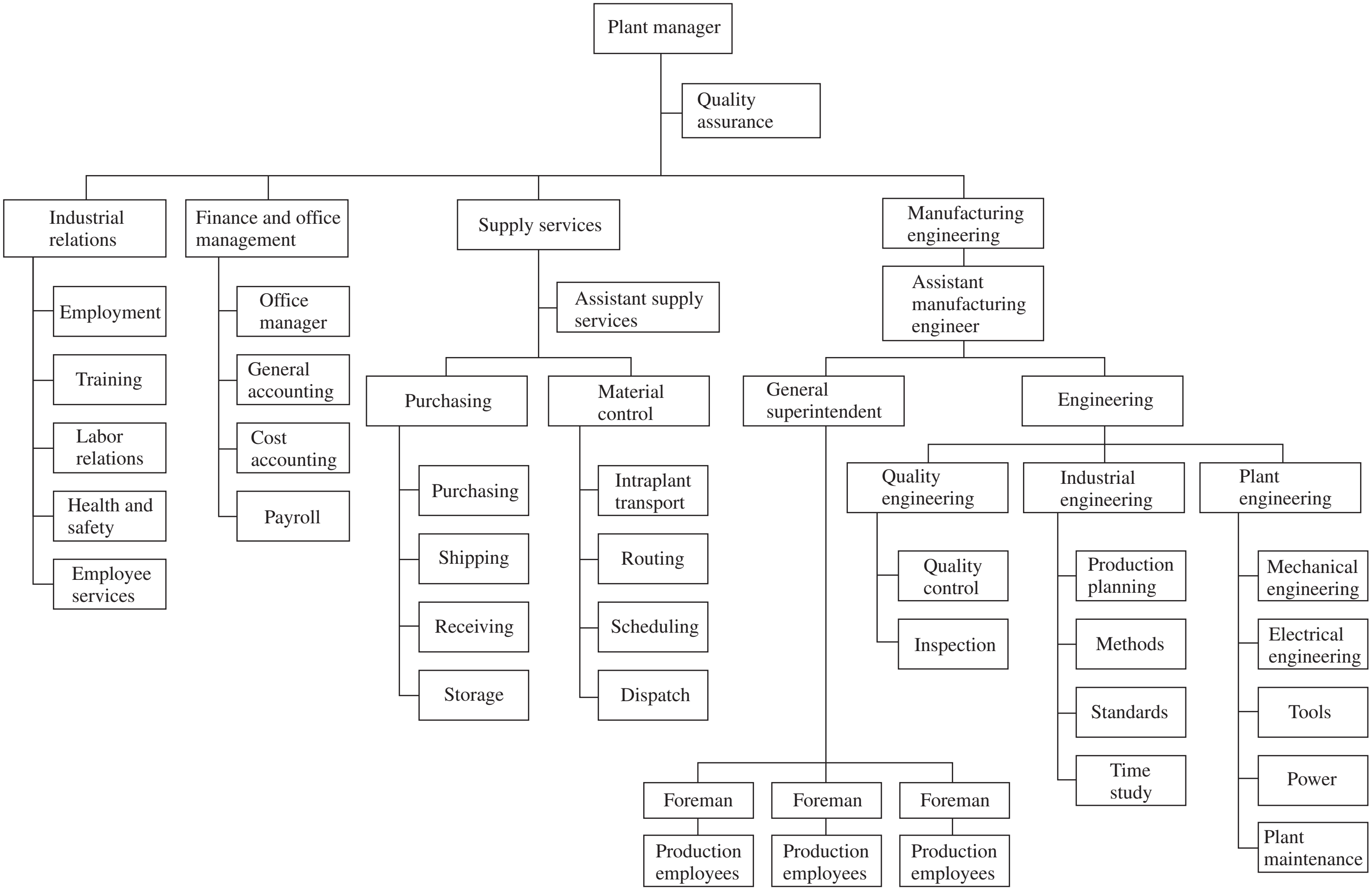



**FIGURE 1.11** A typical organizational chart for a large manufacturer.

Service industries especially are looking for technologists who are flexible in dealing with customers. This means an ability to work with any client. Nontechnical clients are often put off by service technicians who can only use technical abbreviations and acronyms to describe what they do. Technologists must learn to explain what they do in popular terminology.

The greater the teamwork and the more personable the employees, the better will be the product or service. Technologists who can show that they are willing to work with other people will be far more successful than others in obtaining jobs. Companies used to hire on the basis of good grades. Now interviews are used to select graduates who can work with a team, have good communication skills, and have experience working with others on projects.

## 1.3 THE CAREER DECISION

To achieve the challenging and rewarding position of technician or technologist, you must be properly motivated in order to complete the rigorous curriculum requirements.

What are the important elements in career exploration? There are at least three: (1) occupational satisfaction, (2) availability of employment, and (3) salary potential.

*Occupational satisfaction* involves answering the question, "Will my day-to-day occupational tasks be enjoyable?" An older student, already experienced in industry, can satisfactorily answer this question. Recent high school graduates and others lacking industrial experience must base their decisions on personal experiences relating to the tasks an engineering technician must perform. The role of the technician in industry has already been examined. With that information you can address the following questions:

1. Do I enjoy working with equipment and machinery?
2. Do I enjoy working with numbers (data)?
3. Do I enjoy math and the sciences, especially when I can see how they apply directly to the real world?
4. Do I enjoy solving puzzles?
5. Do I enjoy working with a group of people to achieve a common goal?
6. Do I enjoy communicating with others?

These important questions may be difficult to answer honestly at first. If more than one of the above questions receives a "no" answer, you should reconsider career goals.

One of the latest methods to determine your best career choices is to use a *career information delivery (CID)* system. A CID system is a computer-assisted career planning tool that enables the user to search through large amounts of occupational information with the click of a button. It works like a greatly expanded version of the questioning exercise above. Your school library likely has their own CID system and it would be worth your time to use the system to identify a career choice best suited for you.

It is easier to answer the second element in career exploration—*availability of employment.* Since the launching of *Sputnik* by the former Soviets in 1957 and the introduction of the computer, the need for technicians has exceeded the number of individuals capable of performing in this role. In short, there are employment opportunities available to engineering technicians and technologists.

The most recent *Occupational Outlook Handbook* may be found in your college library. The 2010–2011 *Handbook* reports that well-qualified engineering technicians should find good employment opportunities through the year 2018. This forecast is due to the increasing need for technical products and services. The *Handbook* also identifies related occupations and projected openings for those classifications. In addition, you may wish to consult the *Occupational Outlook Quarterly*. This periodical, issued every three months, can keep you even more up-to-date on expanding technologies and job prospects.

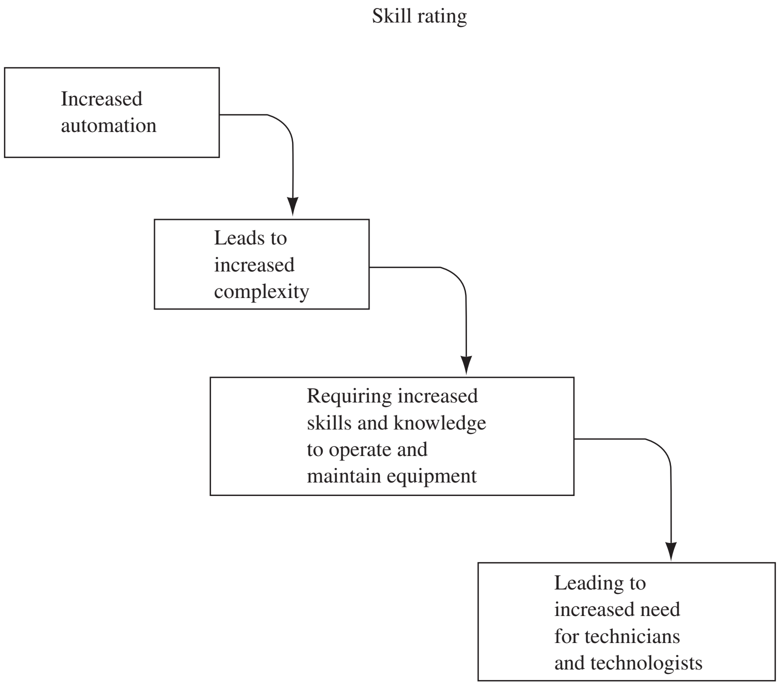
*Automation* is the key reason cited for optimistic employment projections in manufacturing industries. Each time the minimum wage set by Congress is increased, industry increases automation. Foreign competition has also increased the need for automation. Automation leads to better-quality products by decreasing the variability in the parts of that product. Increased automation also adds to each employee's productivity, thereby decreasing manufacturing costs. The result is fewer employment opportunities for the semiskilled worker but more employment opportunities for the technician and technologist (Figure 1.12A). The technologist is trained to design, develop, and manage the installation of automated systems, whereas the technician is trained to consistently and reliably install and maintain them (Figure 1.12B). Computer advances have enabled manufacturing industries to automate faster than before. This fact, coupled with more rapid machine processing and the use of improved materials in manufacturing has ensured the increased need for technicians for the foreseeable future.

The computer has also invaded the burgeoning service sector. As has already been shown, service industries will experience much greater growth than manufacturing industries, and salaries are comparable. A recent Labor Department study projects for the 2008–2018 decade that employment at computer support specialists is expected to increase by 14 percent. Representative technical occupations in the service sector include maintaining computer and computer-based machines such as ATMs, installing new software and networking office computers, and providing consulting services for the appropriate installation and use of new technical products.

National, state, and city governments hire *health and regulatory inspectors* to enforce a wide range of regulations that protect public health and safety. Employers prefer applicants with college training, but requirements include a combination of education, experience, and a passing grade on a written examination. Some examples of specific jobs include consumer safety inspectors, occupational safety and health inspectors, sanitarians, and pollution control engineers.

Your technical college will have information regarding local employment projections for the particular technologies offered on your campus. Responsible colleges offer only those technical programs that prepare graduates for positions needed now and in the future.

Generally, workers holding a higher degree will earn more than those with a lesser degree (Figure 1.13). Studies have shown, however, that a fair percentage (approximately 15 percent) of those without a bachelor's degree earned more than the median for workers with a bachelor's or higher degree. Many of these high-wage earners work in engineering technologies and hold a two-year associate degree. Technicians holding associate degrees are displacing those who have completed only high school and others who were high-level managers and professionals who—through downsizing—have lost their jobs because they did not keep up with the state of the art. There are many high-paying jobs that require the skills and knowledge gained in technical colleges, and the holders of these jobs will reap the




A

B

**FIGURE 1.12** (A) Phases in the increasing need for technicians and technologists in industry. (B) Technicians and technologists set up and maintain automated systems. (B. Courtesy michaeljung/Fotolia.)

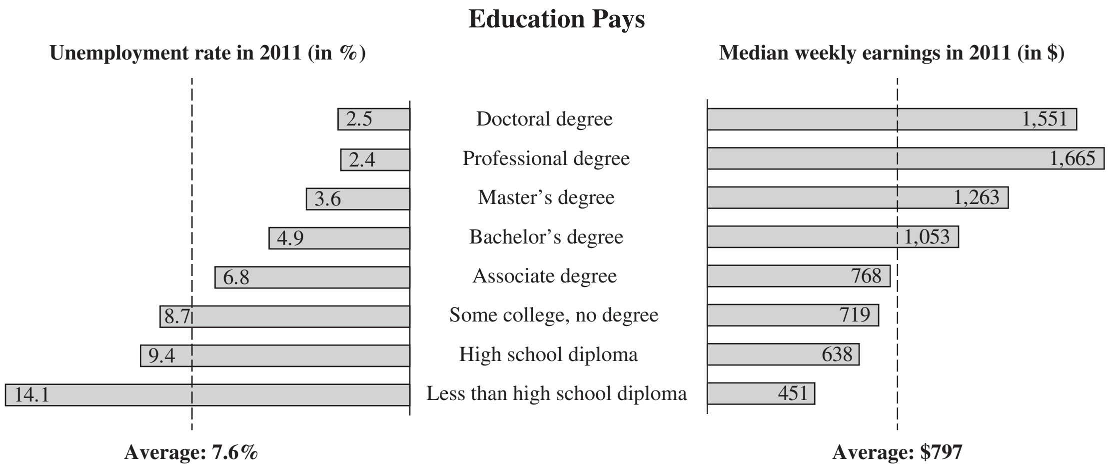



**FIGURE 1.13** Education pays in higher earnings and lower unemployment rate. *Source: Bureau of Labor Statistics, Current Population Survey. https://www.bls.gov/emp/ep-chart-001.htm*

reward of a high-technology society. The B.S.E.T. degree could be even more profitable to the degree holder, as the next example points out.

## Example 1.2

You have completed your associate degree and are planning to continue in college for two more years and graduate as an engineering technologist. Your instructor gives you a rule of thumb of 50 percent as the increase in starting salary over the technician starting salary of \$38,000. Calculate your anticipated annual starting salary as a technologist.

### Solution

The starting salary for a technician with less than one year experience is \$38,000 per year. The annual starting salary is multiplied by 1.50, automatically adding the 50 percent figure to the base salary:

$$\$38{,}000 \times 1.50 = \$57{,}000$$

The aspiring technologist can expect a starting salary of almost \$57,000 per year. Technologists require two additional years of formal education, consisting of more mathematics and science, greater depth in their chosen technology, and management training. They can usually expect a starting salary 50 percent more than that of the technician.

Check with your local college placement office concerning earnings of graduates. Local information is more useful than national averages. Also, be sure to keep in mind that salary is only one aspect of career exploration. Other important factors to consider include benefits, potential for advancement, and job security.

The U.S. government and industry realize that the only way to ensure an adequate number of technicians and technologists is to employ an increasing number of women, ethnic minorities, and persons with disabilities. These people now constitute two-thirds of the population, and, if the present workforce does not become more diverse, the country's growth in technology will slow and our economy will suffer. Women, for instance, make up about 35 percent of the overall workforce but compose only 15 percent of the engineering workforce. Female technicians earn more than other women in the workforce, so a woman considering a career in the engineering technologies is definitely on the right track.

## 1.4 A CAREER IN ENGINEERING TECHNOLOGY

This chapter has provided you with career information that will help you decide whether to pursue a technology degree. One thing is for sure: *Technicians and technologists are needed in our society*. New and cheaper technical products are proliferating, and the high-technology workers needed to recommend, install, and maintain these products are in short supply.

If you enjoy using mathematics and logic to solve problems with computers and computer-based technical products, or to build new buildings and maintain their sophisticated heating and cooling systems, or to help clients meet their computer needs, you will profit from a technical or technology education. You will also be challenged to learn the necessary mathematics and science that will aid you in understanding the concepts necessary.

Graduates with technical or technology degrees will find that their efforts in college will be rewarded for many years to come with increased job security and decent living wages. The most successful will continually seek to update their skills in order to keep up with tomorrow's new technology.

## PROBLEMS

### Section 1.1

**1.** Research and select one technological development that has occurred during your lifetime and list at least two ways it has improved your life. Also, list at least one potentially harmful impact it may have on your life and the lives of others.

**2.** Pick one of the original five main branches of engineering. Through personal research discover one early contributor to the selected branch and describe his or her contribution in two paragraphs or less.

**3.** List four technical devices or appliances, *in common use* today, that were unavailable in 1950.

**4.** Interview a person aged 60 or older. List what he or she feels has been the most significant technological developments in his or her lifetime.

### Section 1.2

**5.** In one paragraph, discuss whether you would like to be employed in a service-providing industry or a goods-producing industry. Support your answer in a second paragraph.

**6.** In four or five sentences, describe personal qualities you possess that would lend themselves to effective teamwork on a job.

**7.** List three services the technician or technologist is expected to perform in industry. See the beginning of Section 1.2.

**8.** Describe in three sentences or more how the role of the technician compares with the role of the technologist or engineer in manufacturing.

**9.** Through personal research with friends, neighbors, and other acquaintances, surmise and diagram the organizational chart for a large company that exists in your area or a local company selected by your instructor. Compare your hypothetical organizational chart with other students' charts. Use software such as Excel or Visio to create diagram.

**10.** For the following listed job functions, classify each as most appropriate for the technologist (1), technician (2), or skilled worker (3). See Example 1.1 and the first job function here, which shows the correct response.

| Job Function | Classification (1, 2, or 3) |
|---|---|
| a. repairs a hydraulic control value | 3 |
| b. designs a computer network | ______ |
| c. supervises an assembly operation | ______ |
| d. troubleshoots a faulty hydraulic circuit | ______ |
| e. performs as a manufacturing engineer | ______ |
| f. repairs a T.V. set | ______ |
| g. breadboards a newly designed circuit | ______ |
| h. designs a data collection system for a warehouse | ______ |
| i. consults on materials for a new product | ______ |
| j. designs a new production line | ______ |
| k. supervises the installation of an elevator | ______ |

## Section 1.3

**11.** List three crucial elements you should consider when deciding on a career.

**12.** Use the career information delivery (CID) system in your library or career services center. Submit your findings as to whether you feel a career in engineering technology is appropriate for you.

**13.** What does an increase in automation (e.g., robotics and computer-aided manufacturing) have to do with the need for technicians in industry?

**14.** Locate the *Occupational Outlook Handbook* in the college library's reference section (or access the website *www.bls.gov/oco*). Find the occupation *engineering technicians* and write a one-page summary of your findings. Include a definition for the job outlook "as fast as the average."

**15.** Go to your college library and locate an issue of the *Occupational Outlook Quarterly* that contains information on openings for technicians. Research the projected number of job openings in a job classification of interest to you. Organize and submit your findings to the instructor.

**16.** You have just graduated from a two-year program and are considering a four-year degree program in the engineering technologies. Assume a 60 percent increase in starting salary as a technologist over that of a technician. Calculate your estimated starting salary with the four-year degree, using the method shown in Example 1.2.

**17.** Prepare a two to three-paragraph report on the content of Figure 1.13. In the report, include information about your local job opportunities and salaries.

## Section 1.4

**18.** Design a job questionnaire. It should include such questions as What do you enjoy most about your work? What do you enjoy least about your work? How do you interact with engineers and skilled workers on the job? What technical skills and knowledge (e.g., math skills, drafting skills) are vital to your job? Which technical skills and knowledge are seldom used, if at all?

What promotions have you already received and when? Add at least three other questions. Then interview a working engineering technician/technologist (preferably a degree holder). As an option, create the survey using the survey Monkey website, *http://www.surveymonkey.com*. Submit the completed questionnaire to your instructor.

**19.** Using search engine, enter local job listings to find *local career information*. Download a webpage with technical job information for your local area and attach a one-page report on your findings. A popular job site is *http://www.monster.com*.

**20.** With a team of students organized from your class, find a new technology used in your community. Prepare a five-minute oral report for the class.

## SELECTED READINGS

*Occupational Outlook Handbook,* 2010–2011 ed., or latest. Washington, DC: U.S. Department of Labor and Bureau of Labor Statistics.

*Occupational Outlook Quarterly*. Washington, DC: U.S. Department of Labor and Bureau of Labor Statistics.

CHAPTER TWO

# CAREER CHOICES IN THE ENGINEERING TECHNOLOGIES

This chapter includes the major technical areas used to classify technicians and the responsibilities of those positions. Encompassing all of the technologies is the awareness of earth's limited resources and the importance of limiting the environmental impact of our society. If you do not find your chosen technology listed, it is probably included as a part of one of the following six general areas. Your instructor may modify this list according to the particular classifications used in your college's service area. The major areas are

1. chemical engineering technician (ChET),
2. civil and architectural engineering technician (CET),
3. electrical/electronic engineering technician (EET),
4. computer engineering technician (CpET),
5. industrial engineering technician (IET), and
6. mechanical engineering technician (MET).

## 2.1 CHEMICAL ENGINEERING TECHNICIAN

*Chemical engineering technicians (ChETs)* generally work in three major areas of industry: (1) research and development (R&D), (2) production, and (3) technical sales. Chemical engineering technicians and technologists work with little or no supervision in a team composed of chemists and chemical engineers.

In R&D, a ChET sets up and operates laboratory equipment to test products for such characteristics as clarity, content of specific chemicals in the material, temperature sensitivity, and strength. A ChET uses complex instrumentation to measure the effects of temperature change on materials and to collect strength and hardness data. Often, he or she uses a computer to analyze the data. The R&D area also includes small production lines (pilot lines) that allow technicians to prove the feasibility of a manufacturing plan or process.

The *production technician*, or *process engineering technician*, supervises or operates the manufacturing process in a plant and inspects the quality of a product or the amount of product produced per day. Often, a chemical engineering technologist directs equipment operators to adjust valves that regulate equipment, start pumps or compressors, or shut down a system if safety is questionable. (The 1979 incident at the Three Mile Island nuclear energy plant would not have occurred if operating personnel had been properly trained. At Chernobyl in the former Soviet Union, operators were instructed to *disobey* standard operating procedures.) To verify process conditions, a technologist bases most decisions on observing meters, gauges, or recorders.

*Technical sales and development (TS&D) technicians* are concerned with identifying and meeting the needs of customers. They test and determine characteristics of a product (e.g., color, taste, durability) that will have an effect on sales and then sell the product to distributors and train them on the benefits and limitations of the product.

Technicians enjoy their own separate division within the *American Chemical Society* (ACS, see Appendix A). This separate division demonstrates the society's commitment to meeting the needs of the technician. It also means that technicians are needed in the broad field of chemical engineering.

ChETs are found in the *Occupational Outlook Handbook (OOH)* under "Science Technicians" (see Example 2.1). Technicians in other specialty areas that may be considered as ChETs are shown in the following list. Any of these technologies may be offered as specific two-year or four-year programs at your college:

- Biological engineering technology
- Nuclear engineering technology
- Materials engineering technology
- Environmental engineering technology
- Petroleum engineering technology
- Forensic science technology

Materials science is a complex field that acts across many engineering disciplines, such as mining and metallurgy, chemical, and mechanical engineering. A materials scientist determines the properties of matter in order to develop the lightest and most durable materials for the manufacture of commodities. Materials technologists assure that the materials can be used in manufacturing environments. They are often involved in the manufacture and use of *composite materials* (Figure 2.1). Formed of a combination of glass and plastics, composite materials are lightweight, corrosion free, resistant to breakage, and easily repaired. Desirable properties of composites that can be controlled are electrical conductivity, vibration damping, spring rate, and tribology (a quality characteristic used in bearings, gears, and disk drives). Petroleum engineering technology occupations include operations technicians that will be responsible for the production and processing of natural gas once wells have been completed. In the northeast United States as well as in other parts of the world, technology has been developed to retrieve natural gas from deposits over a mile underground. These technicians will monitor corrosion as well as operate electronic instrumentation for gas measurement and control.

### Example 2.1

Research a specific technology within the broader occupational area of ChET that is expected to expand within the next decade.

#### Solution

According to the *Occupational Outlook Handbook* (find "Science Technicians" in the *OOH* in your college library or at *www.bls.gov/oco.htm*),

> Science technicians held about 270 900 jobs in 2009. As indicated by the following tabulation, chemical and biological technicians accounted for 54 percent of all jobs:

| | |
|---|---|
| Biological technicians | 79 500 |
| Chemical technicians | 64 100 |
| Forest and conservation technicians | 35 000 |
| Environmental science and protection technicians, including health | 34 000 |
| Agricultural and food science technicians | 21 900 |
| Geological and petroleum technicians | 15 200 |
| Forensic science technicians | 12 900 |
| Nuclear technicians | 6400 |

Environmental concerns about manufacturing have increased. An *environmental engineering technician* helps ensure that our air and water are protected. The Environmental Protection Agency (EPA) and other legislative bodies have recently enacted laws in defined areas such as air

**FIGURE 2.1** A technical associate in chemistry holds a photo produced by a computerized color imaging technique he invented. The result displays the elements of a composite sample. (Courtesy Lawrence Livermore National Laboratory.)

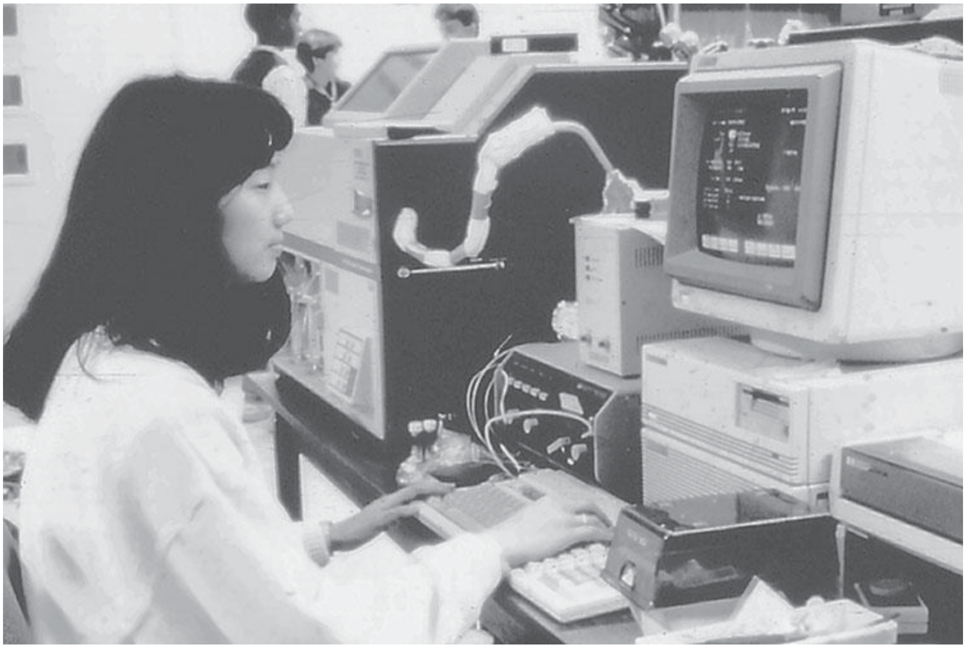


**FIGURE 2.2** An environmental technologist measures pollutants from soil and water.

and water pollution, soil and groundwater pollution, toxic materials used in products (e.g., asbestos), and the use of pesticides. An environmental engineering technician's work is performed outside, collecting samples, and in the laboratory, analyzing the samples (Figure 2.2).

As evidence of the demand for environmental technicians, an environmental science professor at the Pennsylvania College of Technology reports that jobs of recent graduates include wastewater technician, chemical technician, wetlands specialist, groundwater specialist, hydrologic technician, regulatory compliance manager, analytical laboratory manager, safety and environmental manager, brownfield specialist, hazardous waste manager, project manager for superfund sites environmental permit writer, jobs in DEP and EPA, soil conservation specialist, wildlife officer for DCNR, environmental specialist for PA Fish and Boat Commission, and quality control specialist in chemical manufacturing. Additionally, with Pennsylvania's Marcellus Shale natural gas drilling activity, the professor receives regular calls from companies with environmental technician job opportunities.

According to the *Occupational Outlook Handbook,* the overall employment of science technicians is expected to increase as fast as the average through 2018. Environmental technicians are projected to grow faster than average because of the increased need to help regulate waste products and to help clean up contaminated sites.

Personal qualities needed to achieve success as a ChET include

- an ability to work well with others as part of a team,
- an aptitude for and enjoyment of detail work,
- accuracy and patience when conducting laboratory tests, and
- an ability to exercise care when working with toxic chemicals or disease-causing organisms.

## 2.2 CIVIL AND ARCHITECTURAL ENGINEERING TECHNICIAN

*Civil engineering technicians and technologists (CETs)* are perhaps the most versatile of all technical workers. They are responsible for such varied occupations as surveying roads (Figure 2.3A and B), implementing the plans for large structures, supervising the building of highways, constructing bridges, and inspecting all parts of the infrastructure. *Property surveying* is often offered as a separate technical degree program. Property surveying technologists trace deeds, find and use old survey markers, and utilize special computational processes. Global information systems/global positioning systems (GIS/GPS), involve the latest technology in mapping the surface of the earth. GIS/GPS technologists are needed for environmental monitoring, natural resource management, emergency planning, and transportation system design.

A B

**FIGURE 2.3** (A) Civil engineering technician surveys a new highway. (B) A technical student trains with the latest surveying equipment known as the Total Station. (A. Courtesy Auremar/Shutterstock; B. Courtesy Florence-Darlington Technical College.)

*Architectural design technicians* select appropriate building materials and build structures that are safe, attractive, and efficient. They consult on repairs, prepare final drawings for private dwellings, and confirm compliance with building codes. They are often design originators as well as acting always as the design producers; private dwellings may be designed by those who are not registered architects (RAs). Architectural design technicians are also energy technicians. They are responsible for specifying heating and cooling systems that conserve rather than waste energy.

Green-collar jobs (see "Environmental Technician," Section 2.1) are increasing dramatically, and the building industry is a prime target for reduction of $CO_2$ emissions. In 2004 $CO_2$ emissions from buildings in the United States made up 39 percent of total greenhouse gas emissions. Architectural design technicians, construction managers, and contractors will be required to be certified by the U.S. Green Building Council (USGBC) to build green-certified buildings or LEED (Leadership in Environmental Design)–certified buildings. It is predicted that within the next decade, all new buildings will be LEED certified.

Many civil and architectural design projects involve the safety of large groups of people (Figure 2.4). Bridges and large buildings must be designed by a registered professional engineer (PE) or by an RA. Both civil and architectural technologists are the design implementors. They carry out the extensively researched and considered design of the professionally registered engineers. Concern for public safety and the need for improvements in construction quality will require *construction and building inspectors.* Job prospects will be best for graduates of technical colleges with extensive experience in the construction industry. Certification (see Section 3.4) is often necessary.

One recent example of the need for upgrading and improving U.S. infrastructure was the I-35 bridge collapse in the Twin Cities on August 1, 2007. The bridge, which fell into the Mississippi River, had a 20-year history of problematic inspection reports. In 1990 the bridge was declared "structurally deficient." This serious negative rating was overlooked because the United States has 77 000 bridges so designated. Infrastructure upgrades are necessary but often viewed as too expensive or inconvenient. Improved inspection practices and more well-trained inspectors are warranted to keep citizens safe from such tragedies.

CETs experience greater fluctuations in employment than other technologists. There is always a sizable backlog of public works projects. Highways and bridges, sanitary systems, mass transit systems, waterways, and buildings for business and industry need to be built or repaired. How much of this work is contracted, though, depends on the economy and, of course, seasonal weather conditions. Increased efficiencies due to the growth of computer-aided design and drafting (see "Drafting and Design Technician" in the following subsection) and automated manufacturing and fabrication mean that fewer employees will be needed overall.

The Bureau of Labor Statistics states that the median annual earnings for CETs were $46,290 in 2010. Although the earnings of *construction managers* is quite variable, the median annual salary for that group in the labor force was $83,860 in 2010.

Personal qualities needed in order to achieve success as a CET include

- a willingness to work with others as part of a team and to direct others,
- an aptitude for science and mathematics,
- a need to exercise creativity and an ability to make decisions,
- an ability to think and plan ahead, and
- a willingness to travel and work outdoors.

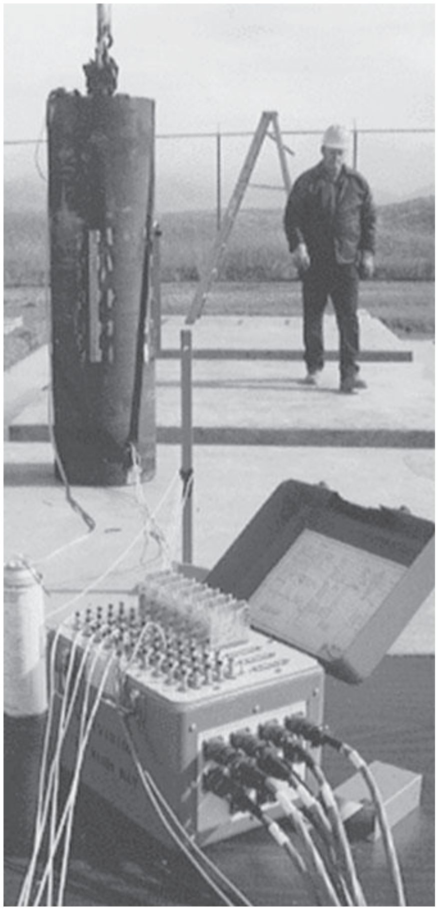


**FIGURE 2.4** Inspecting a building that houses nuclear power equipment. (Courtesy Lawrence Livermore National Laboratory.)

## Drafting and Design Technician

Drafting and design is central to many industries, as well as to civil and architectural engineering technologies. Drafters produce the design drawings used to guide others who build structures or equipment. It is important to realize that their work is not simply to draw up the plans but also to specify the right materials and establish suitable dimensions and tolerances. Drafters use handbooks, scientific calculators, and computers in their design work.

Manufacturing industries employ both electronic and mechanical drafting and design technicians. *Electronic drafters* must know the symbols and electrical concepts used to build suitable circuitry. Experienced electronic drafters are in demand and often command large salaries. Mechanical design technicians are discussed further in Section 2.6.

Drafting and design technicians using computer-aided design and drafting (CADD) systems are known as CADD technicians. A CADD system is a computer program that allows designs drawn to be stored and easily modified later (Figure 2.5). For example,

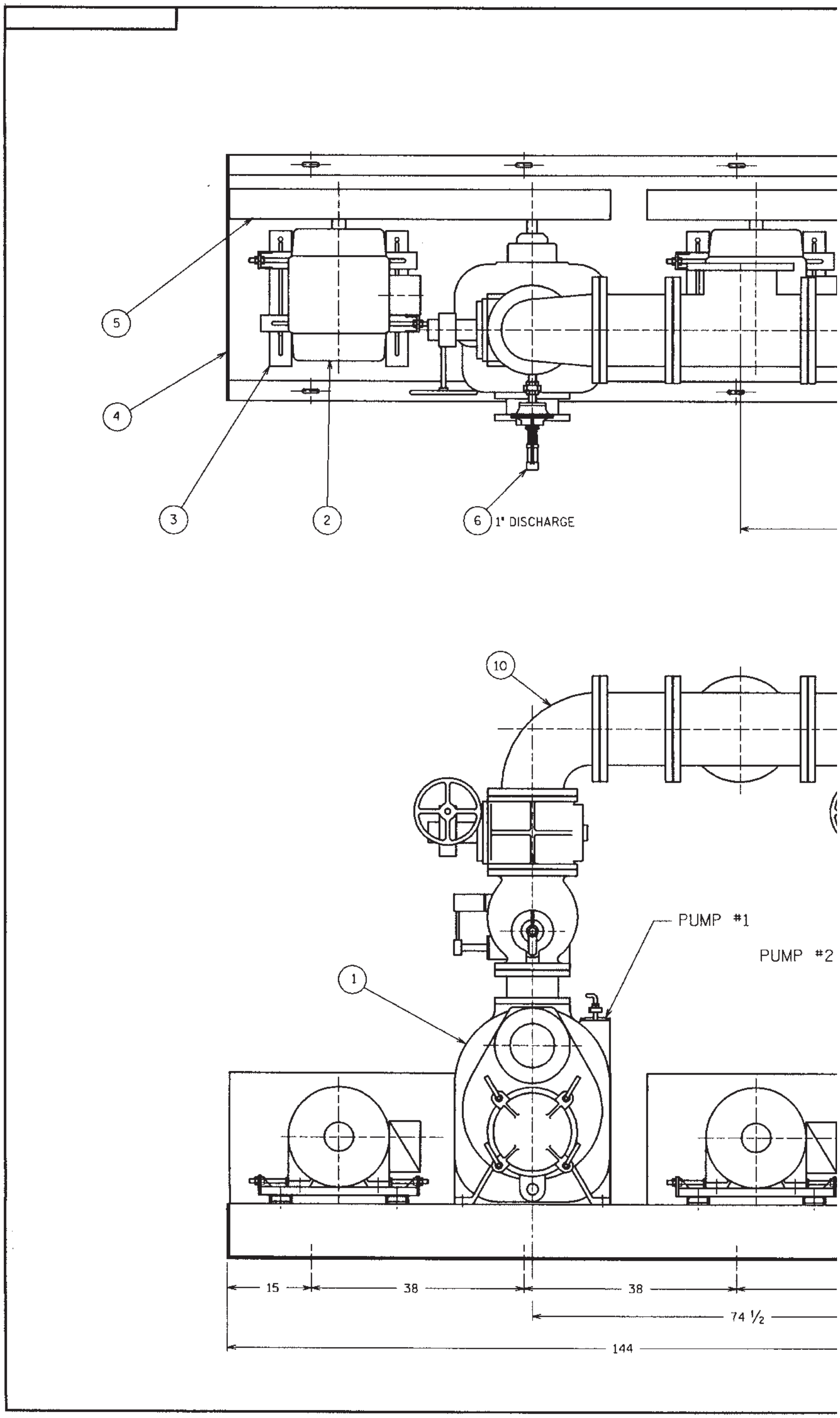
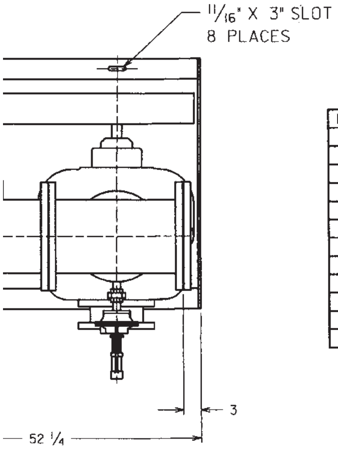
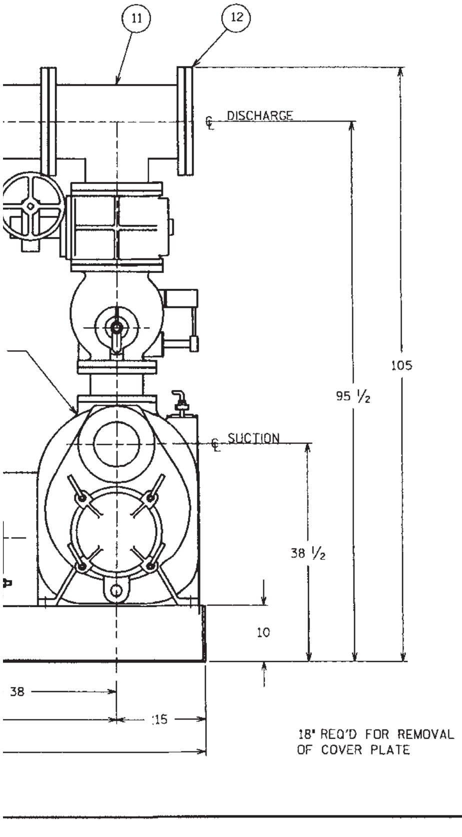
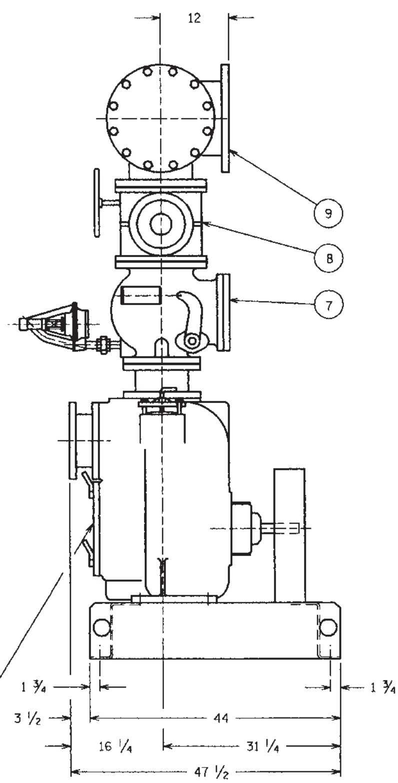



**FIGURE 2.5** CADD systems are vital in manufacturing. (Courtesy Gorman-Rupp Company.)




| ITEM | DESCRIPTION | MATERIAL & SIZE |
|---|---|---|
| 1 | PUMP | CAST IRON T8A-B |
| 2 | MOTOR | CAST IRON |
| 3 | MOTOR RAIL ASS'Y | GALV. STEEL |
| 4 | BASE ASS'Y | STEEL |
| 5 | BELT GUARD ASS'Y | STEEL |
| 6 | AIR RELEASE VALVE | CAST IRON 1" (SHIPPED LOOSE) |
| 7 | CHECK VALVE | CAST IRON 8" X 10" |
| 8 | PLUG VALVE | CAST IRON 10" 2-WAY H.W. |
| 9 | DISCHARGE TEE | CAST IRON 12" |
| 10 | DISCHARGE ELBOW | CAST IRON 12" X 10" |
| 11 | REDUCING TEE | CAST IRON 12" X 12" X 10" |
| 12 | BLIND FLANGE | CAST IRON 12" |



when designing a construction project, electrical and plumbing schematics may be layered on the system. Layering shows how the various elements will fit together and eliminates the necessity for many laborious drawings of the same building.

CADD will certainly become more prevalent, and those who know how to effectively use such systems will remain competitive in the industry. It is especially important for students who aspire to owning their own contracting business to learn and integrate CADD systems in their operations.

According to the *Occupational Outlook Handbook,* “the employment of drafters to grow by 6% between 2010 and 2020, which is slower than average for all occupations.” Median annual earnings for mechanical drafters were $48,810 in 2010. Electrical and electronics drafters earned a median wage of $46,430 in 2010.

Personal qualities needed in order to achieve success as a CADD technician include

- an ability to learn new software,
- creativity and artistic ability, and
- attention to detail.

CADD students have shown themselves to be among the most dedicated, spending many hours learning the latest CADD software.

## 2.3 ELECTRICAL/ELECTRONIC ENGINEERING TECHNICIAN

Technical students should understand the fundamental difference between electrical and electronic technologies. **Electrical** technology involves hard-wired systems and high-power systems, such as those used in large power systems that deliver heat, light, and motor power. **Electronic** technologists usually work with low-power devices considered smart or intelligence-bearing devices. Examples of smart devices are computers, telephone equipment (e.g., fax machines, modems), and robotic or other machine controllers.

Electrical engineering technicians install, control, and troubleshoot electric power distribution systems. They are almost always involved with high voltages and currents. This means that they must be able to interpret the National Electrical Code (NEC) and standard procedures established by the National Electrical Manufacturers Association (NEMA). Often, an electrical technologist will supervise skilled workers—electricians. Sound safety practices must be communicated clearly to all electrical workers, so they may protect themselves as well as others in contact with equipment they have installed. Even though electrical currents may be dangerous, the safety record for electrical workers is good.

*The abbreviation EET is most often used for electronic engineering technician.* EETs help develop, manufacture, and service equipment such as audio and video systems, radar and sonar systems, industrial instrumentation systems, automated systems, robotics, and medical equipment. An EET is usually involved with computers and may be appropriately known as a computer engineering technician (CpET). The rapidly changing computer area is covered in the next section.

Many EETs are employed as *field service representatives.* They represent their companies by traveling to customers’ sites to advise them on how to install, maintain, and use their companies’ electronic equipment. Used in offices, factories, hospitals, and government installations, the complex equipment field service representatives are responsible for must be set up in a timely manner and operate flawlessly. A field service representative must often travel, be able to work under stressful situations, solve problems quickly under pressure, and have good communication skills for reporting to managers. You will probably never be concerned about finding a job or obtaining a good salary position if you enjoy travel and this becomes your area of expertise.

Perhaps one of the most rewarding long-range technical careers is instrumentation, which involves the control of manufacturing processes (Figure 2.6). *Instrumentation technicians* must understand such devices as electromechanical transducers that measure process characteristics such as heat and pressure and the computer controller that keeps process characteristics under control. Instrumentation technicians work in sales, manufacturing, installation, and maintenance of all types of transducers and controllers.

An electronics engineering technician is also a natural fit for many of the new job opportunities in the emerging *nanotechnology* industry (refer to Section 10.4), Technical programs are being created in the field of nanotechnology in order to fill the need for more trained and educated technicians and technologists. For example, in Pennsylvania,

**FIGURE 2.6** Instrumentation technicians control industrial processes. (Reprint courtesy of International Business Machines Corporation, copyright © International Business Machines Corporation.)

a partnership between Penn State University and other colleges offers an associate degree program, and minors in nanofabrication manufacturing technology.

Field service representatives and instrumentation technologists also benefit from an electromechanical program. *Electromechanical engineering technologists* understand hydraulic, pneumatic, and mechanical transfer equipment as well as electronic circuitry. In short, they understand the "electronic brains and mechanical muscle" that is present in most automated equipment. For instance, a computer printer has both electrical and mechanical parts. A robotic system contains an electronic controller as well as hydraulic or pneumatic systems and the manipulator (Figure 2.6). The electromechanical technician understands both the electronic and mechanical fields and is the most versatile member of the service or industrial team.

### Example 2.2

List an occupation, other than those already listed, that may be considered an electromechanical occupation. Describe the type of equipment installed and maintained in this occupation.

#### Solution

One example of an occupation requiring electromechanical knowledge is *biomedical equipment technician.* According to Wikipedia, the online encyclopedia at *www.wikipedia.org*, this occupation is also listed as *medical equipment repairer* in the *Occupational Outlook Handbook*. Job security should be excellent due to the rapidly expanding health care industry and elderly population. Medical equipment repairers earn more than $42,300 annually, but those with a two-year technical degree can expect over $45,000. These technicians are generally on call, meaning they may be needed at odd hours during the day and night.

The wide range of equipment biomedical equipment technicians may be involved with includes ECG monitors, telemetry and other monitoring systems, infusion pumps, artificial kidney machines, and ventilators. Biomedical equipment technicians learn to safely connect equipment to people (see the Ralph Nader reference at *www.wikipedia.org*). To do this, they must be knowledgeable about human body functions. Imaging equipment requires knowledge of fiber optics. Life-support and intensive-care equipment requires safe grounding, radio frequency interference (RFI) shielding, and infection-control procedures. Technologists trained in this field could enjoy many rewarding opportunities in the future.

Other electronic engineering technicians work in one of two major areas: (1) communication electronics or (2) computer electronics. This section will consider the communication electronics technician; the next section will be devoted to the computer electronics technician.

Many *communication electronics technicians* are employed in cellular, radio, and television broadcasting industries. Recently, cable T.V. systems have enhanced employment opportunities in this area. In a small station, the technician is classified as a *chief technician*, is diversified, and performs tasks such as specifying (deciding what types of equipment to buy), connecting, and maintaining broadcasting or cable equipment. This equipment includes microphones, recording equipment, transmitters, receivers, sound and lighting control systems, television cameras, antenna towers, satellite receiving stations (dishes), and signal-processing equipment. In a large broadcasting station, the technician may be specialized and concentrate in one or a few of these areas. The chief technician ensures the system's compliance with all federal, state, and local safety regulations and usually is required to be certified by the Federal Communications Commission (FCC). Students interested in entering the broadcasting industry should check with their instructor to determine whether their college prepares them for FCC examinations.

The U.S. Bureau of Labor Statistics reports that employment of broadcast technicians is expected to grow about as fast as the average through 2020. Strong competition for jobs will continue in major metropolitan areas, and prospects for entry-level jobs will be best in small cities.

A few ambitious communications technicians become entrepreneurs, building their own stations and managing them. A technician choosing this path should take courses in small business administration.

Closely related to communications electronics are radar and microwave. Both areas involve sophisticated electronic circuitry, and the technician must service these systems on a regular basis (perform preventive maintenance).

The *Occupational Outlook Handbook* shows the overall employment of electrical and electronic technicians to increase slower than average for all other occupations through 2020. The median annual earnings were $49,170 in 2010.

Personal qualities needed in order to succeed as an EET include

- a willingness to work with others as part of a team and to direct others,
- above-average mathematical ability,
- analytical ability, and
- willingness to be on call and work overtime.

## 2.4 COMPUTER ENGINEERING TECHNICIAN

A *computer engineering technician (CpET)* services, connects, and programs personal computers or maintains the larger mainframe computer systems (Figure 2.7) used in both business and industry. In manufacturing, the microprocessor is the "brain" of the machine. In fact, the ability to automate in industry depends on a technician's ability to successfully interface (connect) the computer to a specific machine or process.

Everyone is familiar with the rapid growth of the personal computer industry. Personal computers are now used extensively in business, industry, and homes. Computers must be serviced periodically by computer support specialists (often called field engineers or customer service engineers). *Computer support specialists* are usually assigned to several customers. This means they are often on the road. Also, they need strong public relations skills to deal with sometimes irate business customers who depend on their computers and suddenly find that the computers no longer work.

In all areas of computer troubleshooting and repair, the technician must be able to isolate the particular circuit board or, less likely, the malfunctioning component. Many times the diagnostic work can be done by the computer, but the technician must be able to understand the various computer operating systems and to use system software. Electromechanical skills and knowledge are important to CpETs in industry. Without some understanding of industrial processes, largely mechanical, a technician cannot appropriately program a computer to maintain the correct sequencing of operations and avoid "crashing" the tool (Figure 2.8).

**FIGURE 2.7** A computer engineering technician adjusts the controls for an automated machine. (Courtesy Auremar/Shutterstock.)

The field of *information technology* (IT) was new in the 1970s but today encompasses many occupations with high job growth. The IT field is responsible for building and maintaining telecommunications equipment that safely and securely transfers the enormous loads of data that business and industry generate. For instance, when an ATM dispenses cash, the withdrawal information is transmitted to the customer's bank.

Within the IT field is the occupation of *network and computer systems administrator.* As more companies depend on computer systems that are interconnected, trained network technologists will be in great demand. It is one of the fastest-growing occupations in the United States, with a projected growth rate of over 18 percent in the 2010–2020 decade.

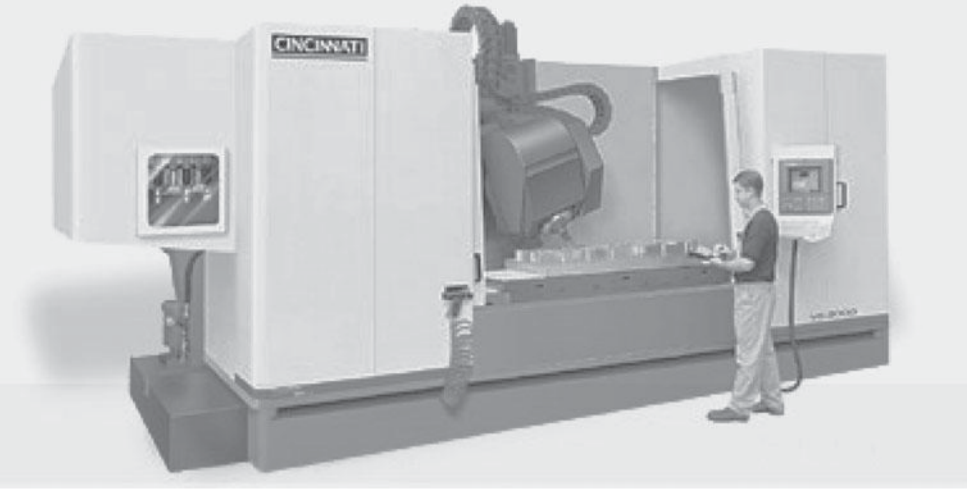



**FIGURE 2.8** A CpET programs a machine. (Courtesy Cincinnati Machine.)

### Example 2.3

Using a web browser, research the acronym STEM. What do the letters represent? Find an article or a report that ties together STEM jobs and computer technology.

**Solution**

The *Occupational Outlook Quarterly (OOQ)* for Spring 2007 explains STEM as an acronym for science, technology, engineering, and mathematics. It says that technicians usually work in computer-related occupations: "Workers in these occupations use logic, mathematics, and computer science to make computers function." Another quote from the article is "the number of associate degrees awarded in computer fields more than tripled in a decade." Could the increase in associate degrees reflect the growing and lucrative job opportunities available?

Computer security has become vital with the expansion of computer usage in businesses and homes. The umbrella term for the myriad of job titles is *cybersecurity*. An aspiring *cybersecurity technologist* must be prepared for a great deal of responsibility, such as the security of large databases of information, computer software, or networks; the cost of an insecure system is high.

IT workers are also needed by global companies in coordinating their offshore businesses. For instance, offshore manufacturing often requires designs for new product prototypes. These 3-D prototypes will then be digitally transferred to manufacturing technologists, who are able to lay out new assembly line configurations and plan for necessary personnel and machinery to produce the new products anywhere in the world.

There is a strong demand for computer support specialists of all types, and an associate or bachelor of engineering technology degree (Chapter 3) in computer-related fields is an increasingly attractive option for technical students. Employment for computer support specialists is forecast to increase 17 percent, or faster than the average, through 2018, with median annual earnings of $47,660 in 2011. Median annual earnings for network and system administrators were higher, at $70,970.

Personal qualities needed in order to succeed as a CpET include

- a willingness to work with others as part of a team,
- problem-solving ability,
- a willingness to work long hours to meet deadlines,
- a constant drive to be retrained on new hardware and software, and
- a willingness to travel.

## 2.5 INDUSTRIAL ENGINEERING TECHNICIAN

*Industrial engineering technicians (IETs)* are involved in methods and time study, production control, quality control, and industrial supervision. This means they are generalists, working across many technologies, and are responsible for the integration of personnel, materials, machinery, methods, and plant layout.

An IET performs *methods and time study,* ensuring the efficient use of personnel and machines in a manufacturing operation. The tasks involved are studying and recording the time to do a particular job (changes in management philosophy, e.g., just-in-time [JIT] manufacturing, have decreased the need for time study), preparing charts and graphs

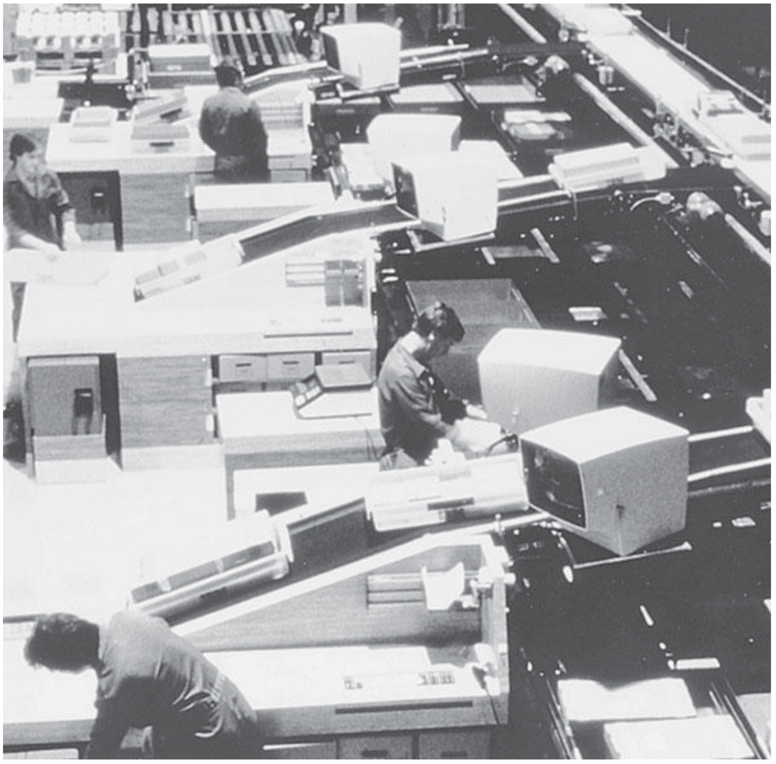


**FIGURE 2.9** Methods studies by industrial engineers and technicians result in a new automated materials distribution center for Scotland. (Reprint courtesy of International Business Machines Corporation, copyright © International Business Machines Corporation.)

illustrating work flow and efficiency, preparing layouts of machinery (Figure 2.9), specifying the number of machines necessary for an assembly line, and performing statistical analysis of work flow with computers.

It should be noted that methods studies are necessary in areas other than manufacturing. Service industries such as grocery stores, fast-food restaurants, and amusement parks employ industrial technicians to improve methods (Figure 2.10) to show people how to "work smarter, not harder."

*Production controllers* use data from customer receipts and post-production records to set the production schedule for a plant. They may also measure the production of a particular manufacturing process. An important contribution is coordinating production between sections or divisions. Controllers move a product between sections and aid in decisions concerning the return of improperly manufactured items to the section responsible. They also inform the sales staff of the inventories ready for shipment to customers.

One of the most important members of the manufacturing team is the *quality controller*. If the product of a plant is not a high-quality item, the plant cannot compete

**FIGURE 2.10** An industrial engineering technician can improve restaurant efficiency. (Reprint courtesy of International Business Machines Corporation, copyright © International Business Machines Corporation.)

with other manufacturers and will be shut down. Quality controllers are involved in checking such product quality characteristics as

- dining room tables for a beautiful finish,
- automobiles for number of defects on leaving the assembly line (e.g., squeaks, rattles, scratches, poor fits),
- gears for runout (a measure of out-of-roundness),
- paint for its viscosity (its ability to spread easily), and
- restaurants for average time of service.

Checking a product's quality characteristics is called *inspection*, although the majority of quality control technologists are responsible for statistically measuring quality and for implementing the overall quality system in a plant—not simply for performing inspection. These technologists usually carry the title *quality assurance (QA) specialists.*

In the 1980s an inspection technique called *statistical process control* (SPC) was introduced to many U.S. industries for the first time. SPC is a technology that moves an industry from an inspection-after-the-fact quality control process to incorporating quality decisions in all phases of the product life cycle. SPC prevents quality problems from occurring. SPC also involves all of the workforce. Employees are no longer told to "just run the machine and don't think about what you are doing." Instead, they are trained to statistically understand the natural variation in all processes, to monitor these natural variations, and to identify variations that are not natural (i.e., not due to their particular process).

Minimizing unnatural variations allows a process to be brought into "statistical control." It is then predictable and repeatable and is capable of turning out one conforming part after another. Output from a process "in control" requires less inspection. In addition, abnormal variation can be spotted and corrected before the process drifts too far from a target value.

Many companies, especially in the auto industry, mandate that their suppliers adopt SPC methods. The major automobile companies also use statistical methods to check incoming materials. These "incoming inspection or acceptance checks" identify supplier problems before they affect the manufacturer's product. See Section 3.3, "Problem Solving."

Business and office operations will also find that SPC can make them more competitive in today's world. Whatever the business or industry, to survive, it must evaluate and control product quality. Careers in quality control offer experiences in such diverse areas as developing quality control systems (planning), testing and inspecting products (implementation), encouraging and training others to improve and maintain quality (human resource development), and calculating and controlling costs (quality cost or savings studies).

Finally, an industrial engineering technician may be employed as an *industrial supervisor*. In manufacturing, supervisors must be able to understand the equipment and materials they are dealing with. In addition, they must communicate the ideas of management to the skilled or semiskilled worker. This makes labor-management relations an important course for the IET planning to enter supervision.

With experience, an industrial supervisor may qualify as an *industrial production manager*. This manager ensures that workers, equipment, and materials are used properly and efficiently to maximize productivity. Managers or supervisors must possess people skills and be caring and articulate. Employers are increasingly hiring degreed IETs who have the knowledge and training to enjoy promotions to management. Industrial production managers earned a median salary of $93,370 in 2011.

### Example 2.4

The service sector (nonmanufacturing) will grow over 20 percent by 2014. Explain how an IET can work in this burgeoning career area.

#### Solution

Industrial engineering technicians and technologists will be needed to work in occupations that distribute and keep track of the products delivered to consumers. They will be needed to maintain health care, education, and recreation facilities. IETs will also supervise service employees. Typical job classifications are *inspector, production controller,* and *warehouse manager.* Health and regulatory inspectors will be needed to enforce a wide range of regulations concerning service industries.

In whatever capacity they serve, IETs work mainly with people. To be successful they must enjoy dealing with others. They must also understand the overall organization and priorities within their business.

The *Occupational Outlook Handbook* for 2010–2011 reports that the median annual salary for IETs was $46,760 in 2009, while the average annual salary for IETs in the semiconductor and other electronic component manufacturing industry was $46,640. Employment will increase as fast as the average through 2010.

Personal qualities needed in order to achieve success as an IET include

- a willingness to work as part of a team,
- an aptitude for mathematics, including statistics,
- an ability to do detailed work with a high degree of accuracy, and
- an ability to manage effectively, with good verbal skills.

## 2.6 MECHANICAL ENGINEERING TECHNICIAN

A *mechanical engineering technician (MET)* works with the muscle of industry—power transmission equipment. Some examples of such equipment are lever systems and gear trains, hydraulic and pneumatic systems, pumps and compressors, lathes, and milling machines (Figure 2.11). An MET calculates forces such as stress or strain on machine components, sets tolerances on shafts and bearings, and measures vibration. Often, an MET must specify equipment by the type of tooling necessary for the job and by researching the cost of comparable models.

Six excellent career fields within mechanical engineering technology are heating, ventilating, and air conditioning (HVAC)*; mechanical design (tool design); numerical control (NC); technical sales; fluid power; and laser technology.

*Heating, ventilating, and air conditioning technicians* aid in designing, manufacturing, specifying, installing, and maintaining HVAC systems (Figure 2.12). HVAC technicians must work with a wide range of skilled workers and engineers. In the manufacturing area, HVAC technologists are involved with product development and testing. They also contribute to the production areas where the equipment is built. Many manufacturing processes in HVAC are becoming automated, and those interested in careers in this segment of industry will need to understand computer-assisted production.

In the contracting and service area, HVAC systems must be properly mounted on solid foundations, they must be properly wired and plumbed, and they must meet the needs

**FIGURE 2.11** A manufacturing engineering technologist operates a CNC lathe. (Courtesy Dmitry Kalinovsky/Shutterstock.)

*Sometimes written as HVACR or HVAC & R to include *refrigeration*.