GLOBAL EDITION

Introduction to Engineering Technology

EIGHTH EDITION

Robert J. Pond • Jeffrey L. Rankinen

ALWAYS LEARNING

PEARSON

Introduction to Engineering Technology

This page is intentionally left blank.

Introduction to Engineering Technology

EIGHTH EDITION

GLOBAL EDITION

Robert J. Pond
Central Ohio Technical College

Jeffrey L. Rankinen
Pennsylvania College of Technology

PEARSON

Boston Columbus Indianapolis New York San Francisco Upper Saddle River
Amsterdam Cape Town Dubai London Madrid Milan Munich Paris Montreal Toronto
Delhi Mexico City São Paulo Sydney Hong Kong Seoul Singapore Taipei Tokyo

Editorial Director: Vernon R. Anthony
Senior Acquisitions Editor: Lindsey Gill
Editorial Assistant: Nancy Kesterson
Director of Marketing: David Gesell
Senior Marketing Coordinator: Alicia Wozniak
Marketing Assistant: Les Roberts
Program Manager: Maren L. Beckman
Project Manager: Holly Shufeldt
Art Director: Jayne Conte
Cover Designer: Lumina Datamatics, Ltd.
Image Permission Coordinator: Mike Lackey
Cover Photo: totally out/Shutterstock
Lead Media Project Manager: April Cleland
Full-Service Project Management/Composition: Integra Software Services, Ltd.
Text Printer/Binder and Cover Printer: Ashford Colour Press
Text Font: Minion 10/12
Head of Learning Asset Acquisition, Global Edition: Laura Dent
Acquisitions Editor, Global Edition: Karthik Subramanian
Senior Manufacturing Controller, Global Edition: Trudy Kimber
Project Editor, Global Edition: Aaditya Bugga

Pearson Education Limited
Edinburgh Gate
Harlow
Essex CM20 2JE
England

and Associated Companies throughout the world

Visit us on the World Wide Web at:
www.pearsonglobaleditions.com

Authorized adaptation from the United States edition, entitled Introduction to Engineering Technology, 8th edition, ISBN 978-0-13-284011-8, by Robert J. Pond and Jeffrey L. Rankinen, published by Pearson Education © 2014.

ISBN 10: 1-292-07211-3
ISBN 13: 978-1-292-07211-1 (Print)
ISBN 13: 978-1-292-07213-5 (PDF)

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library.

ARP impression 98

Typeset in 10 MinionPro-Regular by Integra Publishing Services.

Printed by Ashford Colour Press Ltd, Gosport.

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.pearsonglobaleditions.com/Pond 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.

Pearson would like to thank and acknowledge the following people for their work on the Global Edition:

Contributor:

Sandeep Bhat, M. S. Ramaiah Institute of Technology, Bangalore

Reviewers:

Sanjay H. S., M. S. Ramaiah Institute of Technology, Bangalore
Anand M. J., P. E. S. College of Engineering, Mandya

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

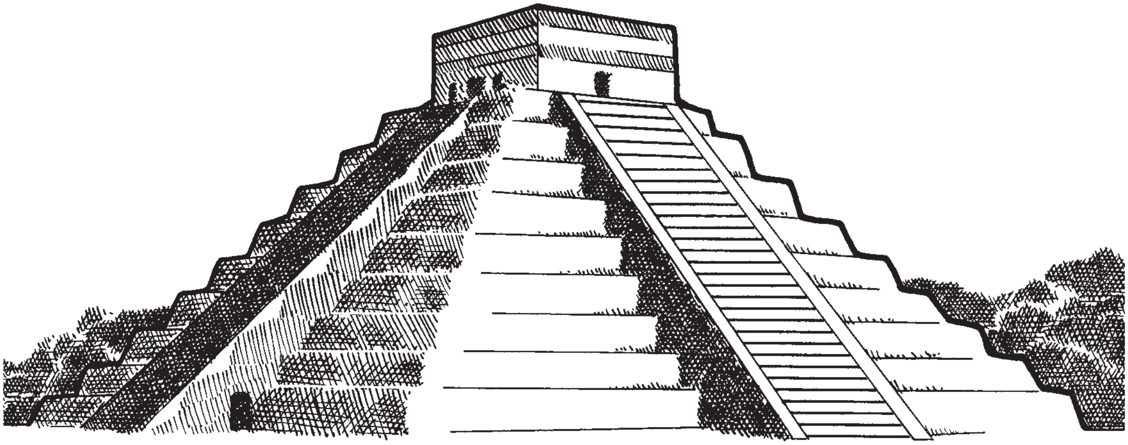


FIGURE 1.2 This Mayan pyramid (Yucatan Peninsula, Mexico) was precisely oriented to form the shadow of the seven triangles of the serpent's back only on the vernal and autumnal equinoxes, which occur in spring and fall, respectively.

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.

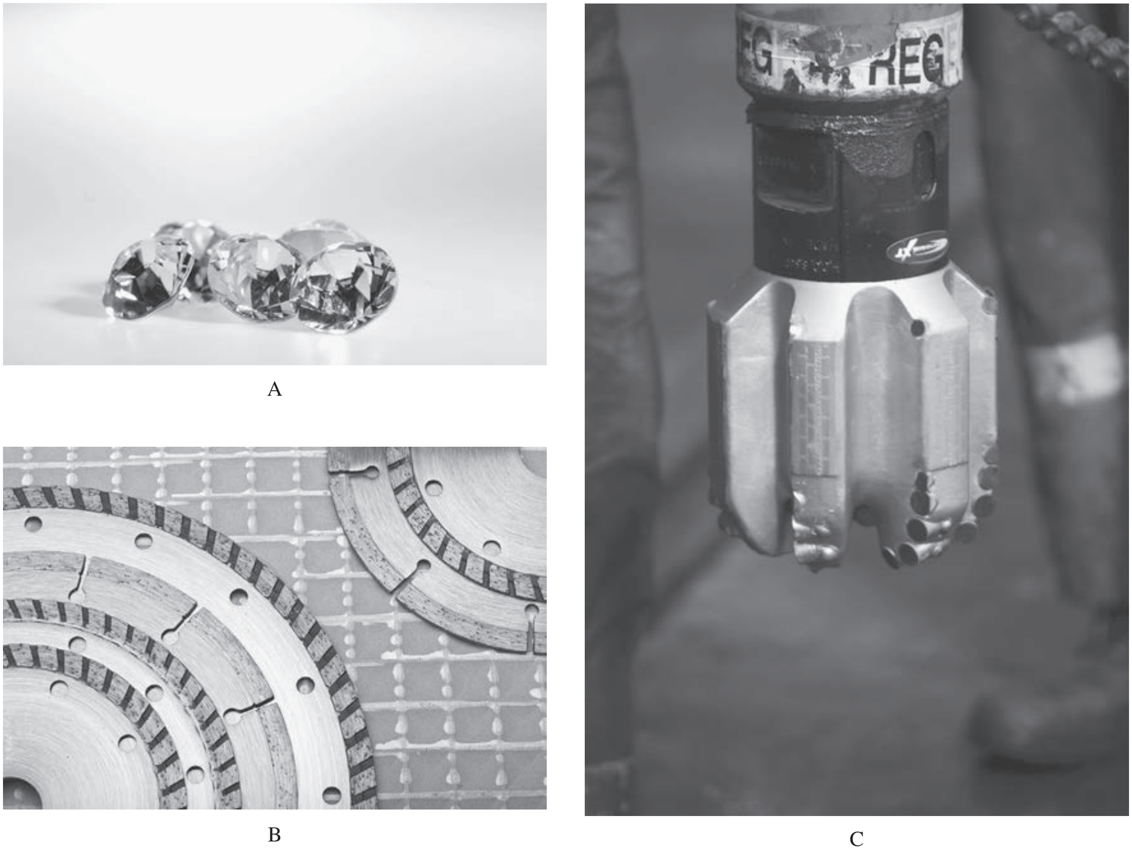


FIGURE 1.3 Materials technology led to synthetic diamonds (A) used for diamond-tipped saw blades (B) and powerful drill bits (C). (A. Courtesy imagebroker/Alamy; B. Courtesy Konstantin Kulikov/Alamy; and C. Courtesy Paul Bock/Alamy.)

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

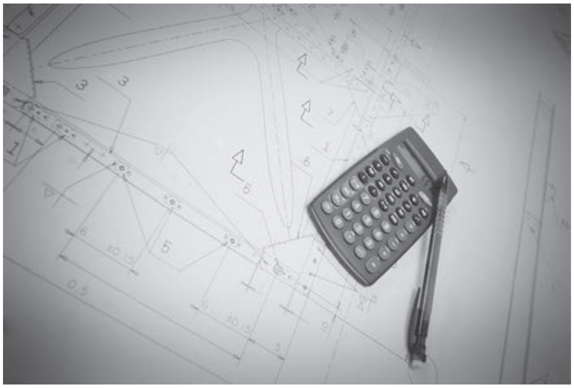
1. communicators between management or engineering and the skilled employee,
2. implementers who interpret the ideas of management and implement them, and
3. calibrators and testers who perform tests and measurements to make sure equipment is operating correctly and according to specification.

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 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.

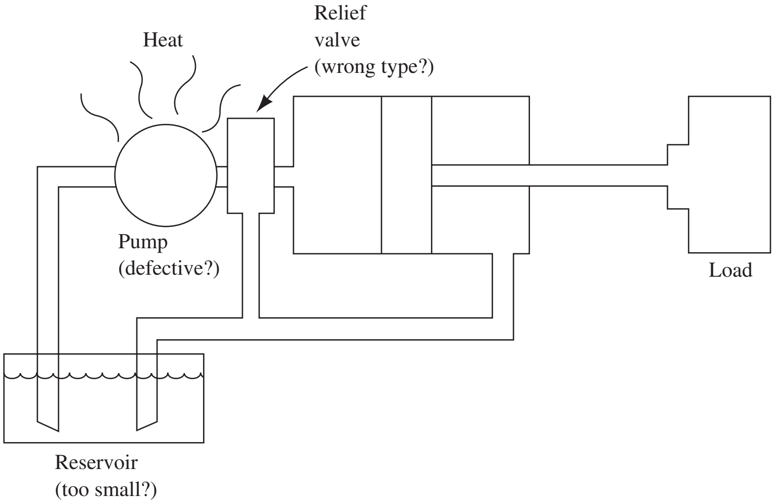


FIGURE 1.8 Training prepares a technician to troubleshoot a faulty hydraulic system.

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.

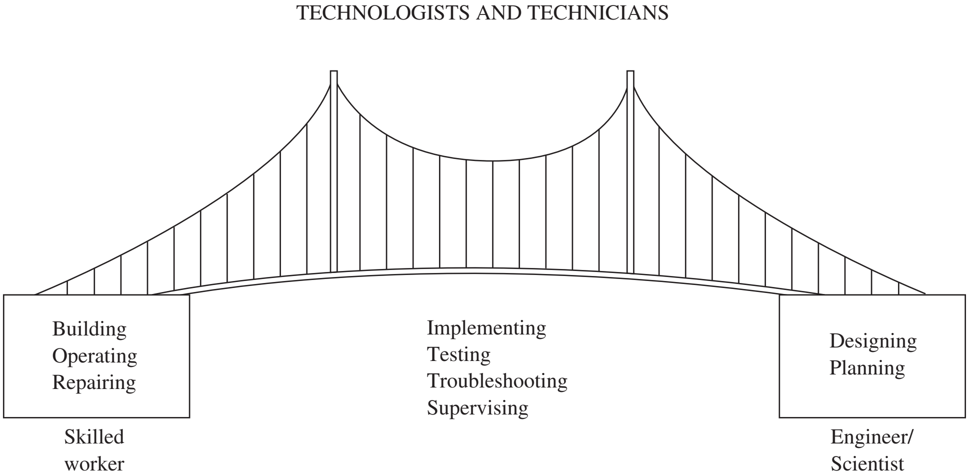


FIGURE 1.9 The technician acts as the bridge for the industrial team.

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

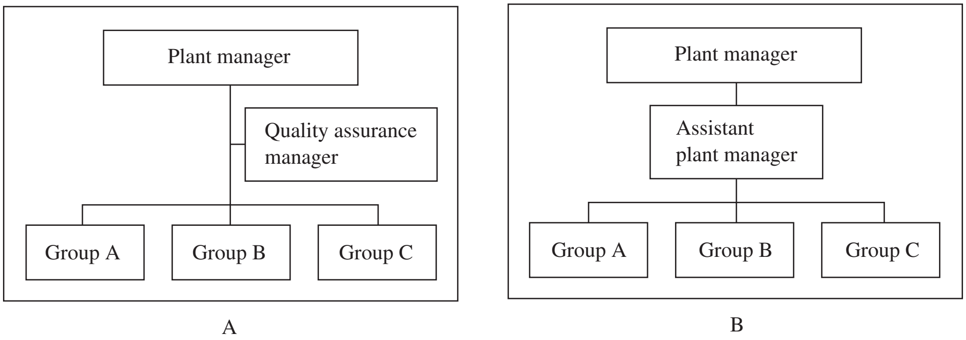


FIGURE 1.10 Staff (A) vs. line (B) relationships in an organization.

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.

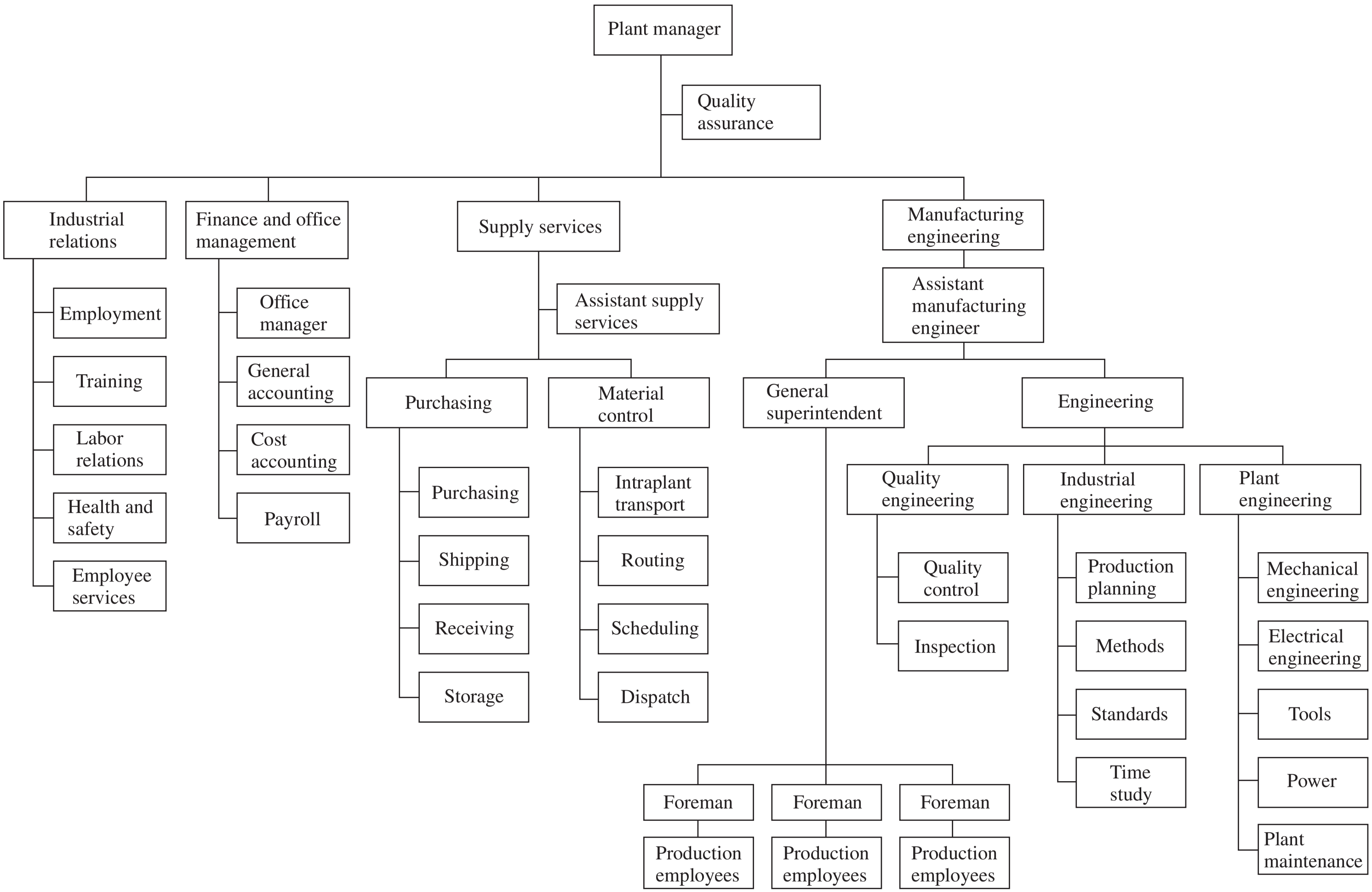


FIGURE 1.11 A typical organizational chart for a large manufacturer.

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.

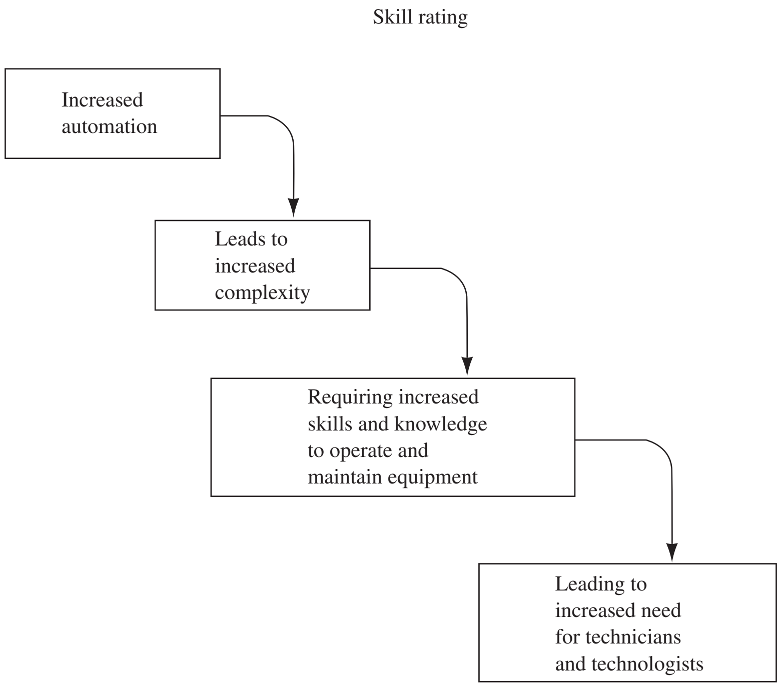
Automation is the key reason cited for optimistic employment projections in manufacturing industries. Each time the minimum wage set by Congress is increased, industry increases automation. Foreign competition has also increased the need for automation. Automation leads to better-quality products by 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 semi-skilled 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.)