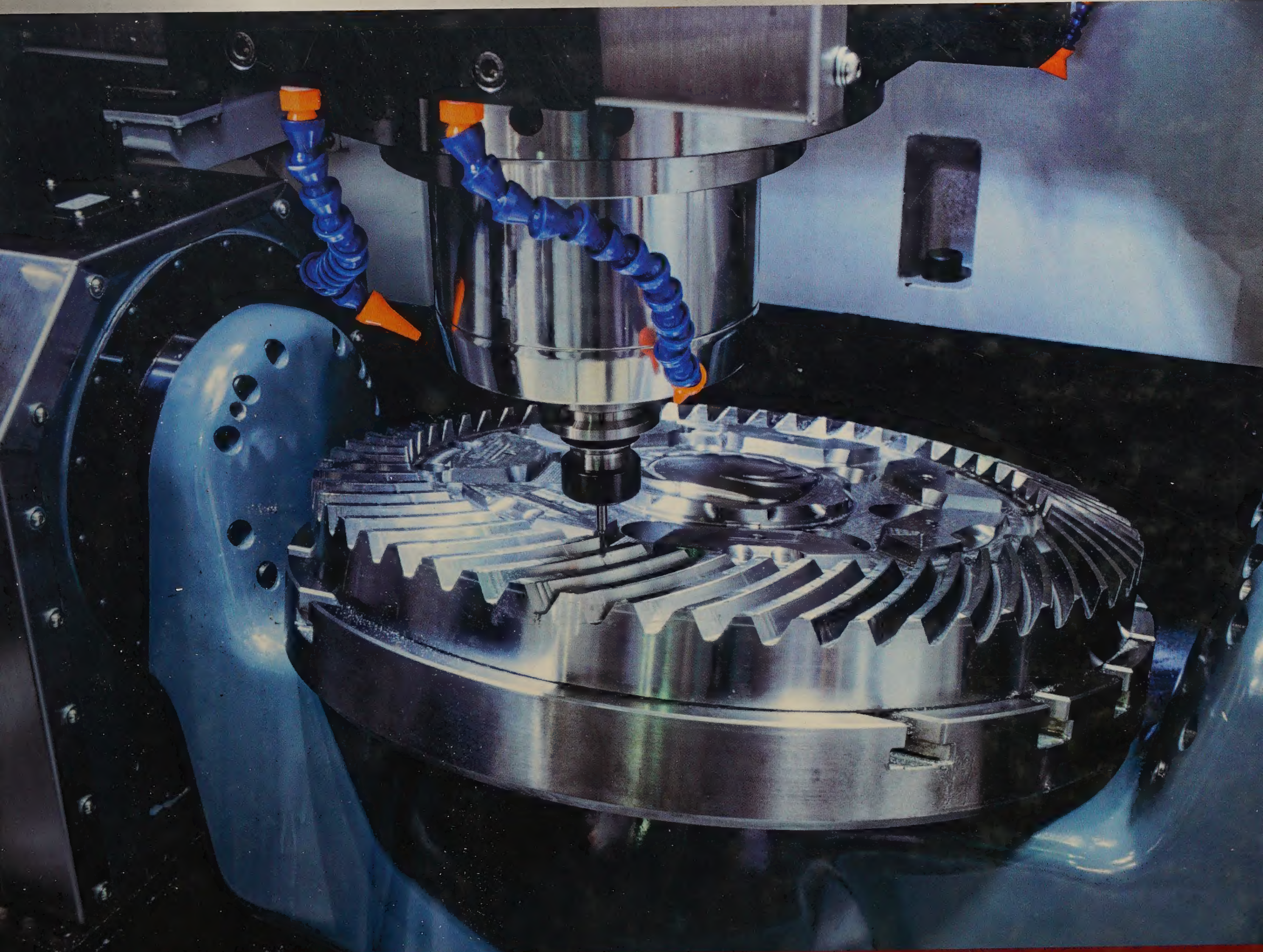
# MACHINE TOOL PRACTICES

Richard Kibbe | Roland Meyer | Jon Stenerson | Kelly Curran



ELEVENTH EDITION

## Typical drawing abbreviations

| | |
|---|---|
| Adjust | ADJ |
| American Wire Gage | AWG |
| Auxiliary | AUX |
| Bill of materials | BM or BOM |
| Center line | CL |
| Chamfer | CHAM |
| Counterbore | C'BORE |
| Countersink | CSK |
| Diameter | DIA |
| Dimensions | DIM |
| Drawing | DWG |
| Finish all over | FAO |
| Finish mark | $\overset{32}{\sqrt{\quad}}$ |
| Flat head | FH |
| Harden | HDN |
| High speed steel | HSS |
| Inside diameter | ID |
| Left hand | LH |
| Material | MATL |
| Maximum | MAX |
| Minimum | MIN |
| National coarse | NC or UNC |
| National extra fine | NF or UNF |
| Outside diameter | OD |
| Pitch diameter | PD |
| Required | REQD |
| Right hand | RH |
| Spotface | SF |
| Thread per inch | TPI |
| Tolerance | TOL |

## RPM and mill feed-rate formulas

### RPM

$$RPM = \frac{4CS}{D}$$

where CS is recommended cutting speed for material in surface feet per minute (SFPM), and
D is the diameter of workpiece or cutting tool

### Milling Feed-rate, in Inches per Minute (IPM)

IPM = RPM × recommended chip load per tooth × number of teeth on cutter

## Symbols and drawing formats for geometric dimensions and tolerances

### Geometric Symbols of Position and Location

| | |
|---|---|
| True position | ⌖ |
| Concentricity | ◎ |
| Symmetry | ⌯ |

### Geometric Symbols of Form

| | |
|---|---|
| Perpendicularity (squareness) | ⊥ |
| Straightness | — |
| Flatness | ⏥ |
| Angularity | ∠ |
| Parallelism | ∥ |
| Roundness | ○ |
| Cylindricity | ⌭ |
| Profile of any line | ⌒ |
| Profile of any surface | ⌓ |
| Runout (circular or total) | ↗ |

### Datum and Basic Dimensions

$\boxed{A}$ $\boxed{B}$

$\boxed{1.375}$

### Maximum Materials Condition (MMC) and Least Material Condition (LMC)

Ⓜ

Ⓛ

### Drawing Format for Geometric Dimensions and Tolerances

| 11 | A | .002 |
|---|---|---|

Form or location symbol
Datum (point, line place, surface, etc.)
Tolerance zone for specified dimension

## Metric Equivalents

### Linear Units

25.4 millimeters (mm) = 1 inch
1 millimeter = .03937 inches
1 meter = 3.281 feet
1 meter = 1.094 yards
1 centimeter (cm) = .03281 feet
1 cm = .3937 inches
1 cm = .01 meter (m)
1 cm = 10 millimeters
1 kilometer (km) = 3281 feet
1 km = .6214 miles
1 km = 1094 yards

### Area

1 square centimeter ($cm^2$) = .001076 square ft ($ft.^2$)
1 square centimeter ($cm^2$) = .1550 square inches ($in.^2$)
1 square meter ($m^2$) = 10.76 $ft.^2$
1 square meter = 1.196 square yards ($yd.^2$)

### Angular

1 radian = 57.30 degrees
1 radian = 3438 minutes
1 degree (angular) = .01745 radians

### Weight

1 pound (lb) = 453.59237 grams (g)
1 kilogram (kg) = 2.205 pounds
1 kilogram = .001102 tons

### Volume

1 liter (l) = 1000 cubic centimeters ($cm^3$)
= .03531 cubic feet ($ft.^3$)
= 61.02 cubic inches ($in.^3$)
= .001 cubic meters ($m^3$)
= .2642 gallons
= 1.057 quarts
1 cubic centimeter ($cm^3$) = .001 liter (milliliter or ml)
1 cubic foot ($ft.^3$) = 28.32 liters
1 $cm^3$ = .06102 $in.^3$
1 cubic inch ($in.^3$) = .01639 liters
1 gallon = 3785 $cm^3$
1 gallon = 3.785 liters

## Metric Prefixes and Equivalents

### Metric System Prefixes

| | |
|---|---|
| Tera (T) | 1,000,000,000,000 (trillion) |
| Giga (G) | 1,000,000,000 (billion) |
| Mega (M) | 1,000,000 (million) |
| Kilo (K) | 1,000 (thousand) |
| Hecto (H) | 100 (hundred) |
| Deka (DA) | 10 (ten) |
| Unit | 1 |
| Deci (d) | .1 (tenth) |
| Centi (c) | .01 (hundredth) |
| Milli (m) | .001 (thousandth) |
| Micro (mu) | .000001 (millionth) |
| Nano (n) | .000000001 (billionth) |
| Pico (p) | .000000000001 (trillionth) |

# Machine Tool Practices

ELEVENTH EDITION

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Pearson

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# Preface

As a definitive text in the field for more than 30 years, *Machine Tool Practices*, 11th edition, is geared toward successfully training machinists and tool & die makers about quality, blueprint reading, traditional machining processes, and CNC operation and programming. It is ideal for those enrolled in apprenticeship training, technical college programs, community college programs, and university courses. Presented in a student-friendly manner, the book lends itself well to classes that take a combined lecture/laboratory approach, as well as to a self-paced instructional environment.

## STRENGTHS AND UNIQUE SELLING POINTS

With hundreds of color illustrations and well over a thousand color pictures, *Machine Tool Practices* is the best-illustrated book in this field. The text emphasizes practical shop knowledge and machine tool technology throughout and superbly illustrates the tools, equipment, and techniques that students will encounter in an industrial machine shop.

## CLASSICAL PRACTICE/CURRENT TRENDS

Machine tools and machining practices have changed dramatically. This text has been aligned with standards that were developed by the National Institute of Metalworking Skills (NIMS). The National Institute for Metalworking Skills (NIMS) was formed in 1995 to develop and maintain a globally competitive American workforce. NIMS developed skills standards for industry, NIMS certifies individual skills against the standards and also accredits training programs that meet NIMS requirements. This text was developed for students studying machining who need to acquire the knowledge and skills required by industry and to obtain NIMS certifications, if they so desire.

*Machine Tool Practices* has the information that is essential for the reader to be effective in all areas of machining. With the solid background this text provides, readers will confidently understand and operate manual and CNC machines as well as other manufacturing processes.

## ORGANIZATION OF THE BOOK: TOTAL FLEXIBILITY TO SUIT YOUR TEACHING STYLE

The book is divided into 13 major sections and provides total flexibility to suit your teaching style. Appendix 1 contains Answers to Self-Tests, Appendix 2 offers practical General Tables, and Appendix 3 showcases Precision Vise Project Drawings. For the student, this project embodies many setups and techniques used in general precision machine shop work. The text also contains a Glossary and an Index. Many units are designed around specific projects that provide performance experience for students. The book structure makes it easy for instructors to include additional projects that are applicable to their specific needs.

## NEW TO THIS EDITION

This edition has been dramatically updated and improved to reflect changes in the machining field. The eleventh edition includes the following improvements:

- Vast improvements in the readability of the text to make it easier to read and understand.
- We have added coverage of several topics that graduates are sure to encounter in the workplace. Coverage of process plans and job packets (routings) has been added to help the student understand what they will encounter in the workplace. Practical coverage of ISO systems, calibration and the machinist's role in them has also been added.
- Blueprint reading coverage has been completely rewritten and expanded with additional coverage and extensive student questions and exercises. Geometric Dimensioning and Tolerancing (GD&T) has been added along with extensive questions and student exercises. We believe that there is enough coverage of

blueprint reading/GD&T that it could be the basis of a course if the instructor augments the material with additional worksheets, blueprints, and lecture to meet their individual needs. The supplements for this text, including the PowerPoints and the test bank, are additional materials that can be used for a BPR/GD&T class.

- CNC coverage has been completely rewritten and expanded. Coverage begins with the basics of CNC, then machining center programming followed by turning center programming. Coverage of canned cycles has been added for machining centers and turning centers. We believe that there is enough coverage in the CNC section that it could be the basis of a CNC course if the instructor augments the material with additional worksheets, blueprints, and lecture to meet their specific needs. The supplements for this text, including the PowerPoints and the test bank, provide additional materials that can be used for a CNC class.
- Speeds and feeds, carbide tooling, inserts and tool holders as well as their specification and selection have been dramatically expanded and improved.
- Extensive improvements in color photos and figures.
- Hundreds of color illustrations that ease comprehension and visually reinforce learning.
- Expanded self-test questions and exercises in each unit.
- A list of useful websites at the end of appropriate units that refer the reader to state-of-the-art information on cutting tools and machine shop equipment.

# Guided Tour

*Machine Tool Practices* is divided into sections comprised of several units. We invite you to take the Guided Tour.

## HALLMARK FEATURES

### Introductory Overview

Introductions summarize and provide an overview of the main themes in each major section and help reinforce topics.

### Objectives

Clearly stated objectives enable you to focus on what you should achieve by the end of each unit.

**OBJECTIVES**

After completing this unit, you should be able to:

- Install and remove a bronze bushing using an arbor press.
- Press on and remove a ball bearing from a shaft on an arbor press using the correct tools.
- Press on and remove a ball bearing from a housing using an arbor press and correct tooling.
- Install and remove a mandrel using an arbor press.
- Install and remove a shaft with key in a hub using the arbor press.

### Photographs

Extensive use of color photographs provides you with views of actual machining operations.

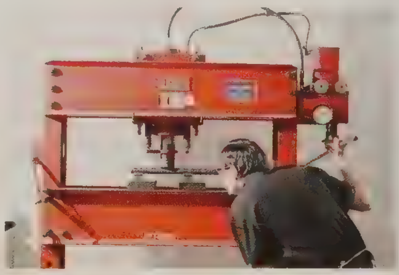

Figure B-19 Pressure being applied to straighten shaft.

### Graphic Explanations

These detailed explanations highlight important concepts, common errors, and difficulties that machinists encounter.

## Shop Tip

**Shop Tip** and **Shop Tip–Craftsmanship** boxes offer helpful tips and techniques to make the student a better and more intuitive machinist.

**SHOP TIP**

When reading any drawings in the machine shop, be sure to

1. Read any and all notes on the drawing.
2. Be sure that you are using the latest revision of a drawing. Errors can occur by machining parts to older drawing revisions. If you are unsure about the revision, check with your supervisor or instructor.

## New Technology

Directs students to the latest technology in the field.

**NEW TECHNOLOGY**

Twist drills ordinarily do not produce a smooth hole. Often, reamers are used to produce a more dimensionally accurate hole with a smoother bore. However, this process will not produce a finish smooth enough for all purposes. Burnishing drills are available, designed not only to drill the hole, but also to finish it to size and increase the hole quality. They can be used for production drilling of cast iron, die-cast aluminum, and other nonferrous materials. Burnishing drills are presently used in the automotive, aerospace, compressor, and computer parts industries.

## Professional Practice

**Professional Practice** provides tips from professional work environments.

**PROFESSIONAL PRACTICE**

The way a worker maintains his or her hand tools reveals the kind of machinist he or she is. Dirty, greasy, or misused tools carelessly thrown into a drawer are difficult to find or use the next time around. After a hand tool is used, it should be wiped clean with a shop towel and stored neatly in the proper place. If the tool was drawn from a tool room, the attendant may not accept a dirty tool.

## Safety First

**Safety First** boxes provide safety warnings related to handling and working with various pieces of equipment.

**SAFETY FIRST**

The primary danger in operating the vertical band machine is accidental contact with the cutting blade. Workpieces are often hand guided. One advantage in sawing machines is that the pressure of the cut tends to hold the workpiece against the saw table. However, hands are often in close proximity to the blade. If you should contact the blade accidentally, an injury is almost sure to occur. You will not have time even to think about withdrawing your fingers before they are cut. Keep this in mind at all times when operating a band saw.

Always use a pusher against the workpiece whenever possible. This will keep your fingers away from the blade. Be careful when you are about to complete the cut: As the blade clears through the work, the pressure that you are applying is suddenly released, and your hand or finger can be carried into the blade. As you approach the end of the cut, reduce the feeding pressure as the blade cuts through.

## Operating Tip

Advice on how to operate machinery students may come across in their studies or careers.

## Self-Test

End-of-unit self-tests gauge how well you mastered the material.

**SELF-TEST**

1. What is the kerf?
2. What is the set on a saw blade?
3. What is the pitch of the hacksaw blade?
4. What determines the selection of a saw blade for a job?
5. Hand hacksaw blades fall into two basic categories. What are they?
6. What speed should be used in hand hacksawing?
7. Give four causes that make saw blades dull
8. Give two reasons why hacksaw blades break.
9. A new hacksaw blade should not be used in a cut started with a blade that has been used. Why?
10. What dangers exist when a hacksaw blade breaks while it is being used?

## Internet References

The end of each unit lists pertinent Internet sites.

**INTERNET REFERENCES**

http://en.wikipedia.org/wki/Engineering_drawing
http://design-technology.info

# COMPREHENSIVE TEACHING AND LEARNING PACKAGE

## For the Instructor

### Instructor's Guide with Lesson Plans

This handy manual contains suggestions on how to use the text for both conventional and competency-based education. The manual has additional student exercises for the instructor to utilize as class assignments. It also includes unit post-tests and answer keys (ISBN–10: 0-13-498588-5).

### Blueprint and GD&T Exercises

Worksheets and exercises are provided that can be used by an instructor to supplement a blueprint/GD&T course. Worksheets and exercises are provided that cover sketching views, sketching parts from views, identification of views, and blueprint reading and GD&T reading prints.

### CNC

Worksheets, exercises and CNC projects are provided for machining centers and turning centers that can be used by an instructor to supplement a CNC course.

### PowerPoint Presentations

PowerPoint presentations are designed to aide the instructor's lecture on topics covered in the book (ISBN–10: 0-13-498580-X).

### TestGen (Computerized Test Bank)

TestGen contains text-based questions in a format that enables instructors to select questions and create their own quizzes and tests (ISBN–10: 0-13-498587-7).

To access supplementary materials online, instructors need to request an instructor access code. Go to www.pearsonhighered.com/irc, where you can 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, log on to the site for full instructions on downloading the materials you wish to use.

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Maximum Advantage–Carolinas
Mazak Corp.
Metal Web News
Micro-Mark
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Monarch Machine Tool Company
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Okamoto Corporation
Okuma America Corporation
Olson Saw Company
Pacific Machinery & Tool Steel Co.
Peerless Chain Company
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Regal Cutting Tools
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Vannattabros.com
Vermont Gage
Walker Magnetics
Weldon Tool–A Dauphin Precision Tool Brand
Wilson® Instruments
Wilton Corporation

# About the Authors

**Richard Kibbe (Late)** served his apprenticeship in the shipbuilding industry and graduated as a journeyman marine machinist. He holds an associate in arts degree in applied arts from Yuba Community College with an emphasis in machine tool technology. He also holds bachelor's and master's degrees from the California State University with an emphasis in machine tool manufacturing technology.

Mr. Kibbe has considerable machine shop experience as well as community college and industrial teaching experience and is the author and co-author of several publications in the machine tool manufacturing field.

**Roland Meyer** spent the first 20 years of his career in the metal-working industry as a tool and die maker and machinist in machine design and manufacturing. He completed his apprenticeship as a tool and die maker at Siemens in Germany and then worked in die shops in Toronto and Windsor, Canada, before moving to Chicago, where he worked as a gage maker at Ford Motor Company. He was in charge of the U.S. Army machine shops in Korea and Italy for five years. When he returned to the United States, he worked in a manufacturing company designing and building experimental machines used in the timber and plywood industry.

He next entered academia and became the lead instructor at Lane Community College's manufacturing technology program in Eugene, Oregon, where he taught for 25 years. As CNC became the new method in machining, he developed a CNC curriculum and program. When CAM became available, he also developed a state-of-the-art CAM program with the assistance of a local software company.

**Jon Stenerson** served an apprenticeship in Tool Making with Mercury Marine. He has a BBA from the University of Wisconsin-Oshkosh and a Masters Degree from the University of Wisconsin-Stout. He held certifications for Certified Quality Engineer, Certified Quality Auditor, and Certified Lead Auditor.

Jon is the author and co-author of several books in the machining and automation field. Jon spent many years teaching and developing self-paced machine tool and automation curriculum for Fox Valley Technical College.

**Kelly Curran** grew up in Michigan's Upper Peninsula where he started working in machine shops at a very young age. He holds an Associate of Applied Science degree from Ferris State College with an emphasis in machine tool technology. He also holds an Associates of Applied Science degree from the Northern Michigan University with an emphasis in Business and a Bachelor of Science Degree in Career, Technical Education from University of Wisconsin Stout.

Mr. Curran has considerable machine shop experience as well as industrial teaching experience and is the author and co-author of several publications in the machine tool manufacturing field. Mr. Curran has spent many years developing self-paced machine tool curriculum for the State of Wisconsin and Fox Valley Technical College.

SECTION A

# Introduction

| | |
|---|---|
| UNIT ONE | Careers and the Machinist's Role in Process Plans |
| UNIT TWO | Manufacturing Competitiveness and Improvement |
| UNIT THREE | Shop Safety |
| UNIT FOUR | Threads and Fasteners |
| UNIT FIVE | Blueprint Reading Fundamentals |
| UNIT SIX | Views and Line Types |
| UNIT SEVEN | Dimensions, Tolerances, and Fits |
| UNIT EIGHT | Fundamentals of GD&T |
| UNIT NINE | Geometric Tolerancing |

# INTRODUCTION

Machining processes are among the most important of the manufacturing processes. The fundamental cutting processes in machining such as milling and turning are still the most prominent. What has changed is the way in which these processes are applied. Changes include the cutting tool materials, the materials the parts are made from, and the methods of material removal. These new methods include the use of lasers, electrical energy, electrochemical processes, and high-pressure water jets.

Computer numerically controlled (CNC) machines have provided an exceptional degree of accuracy, reliability, and repeatability. This application of computer-driven automated equipment is creating many employment opportunities for skilled machinists and machine operators.

The computer has found its way into almost every other phase of manufacturing as well. One important area is computer-aided design (CAD). Product design is done on computers and CNC programs are generated directly from those designs.

In order to be competitive, industry will continue to automate. There will be increased use of manufacturing cells of machines, and increased use of robotics for loading and unloading parts to/from CNC machines. The automation will continue to improve the working conditions in manufacturing, reduce the manual labor required, and increase the need for skilled and knowledgeable workers.

## Units in This Section

The units in this section deal with careers, competitive manufacturing, safety, threads and fasteners, blueprint reading and GD&T.

# Careers and the Machinist's Role in Process Plans

**OBJECTIVES**

After completing this unit, you should be able to:

- Discuss various types of jobs that are available.
- List some characteristics that employers look for in potential employees.
- Explain what a job packet is used for and what it typically includes.
- Explain what process planning is.

The increased use of computer technology and processes in industry has had a significant effect on the types and numbers of jobs available in manufacturing. Many exciting career opportunities are available in manufacturing and in machining in particular.

Manufacturing creates wealth. Manufacturing is crucial to economic success. There is a large demand for skilled manufacturing people. Wages and benefits for skilled manufacturing people are excellent. Wages and benefits for manufacturing are usually higher than other types of jobs. Working conditions have also dramatically changed. Most modern manufacturing facilities are clean, bright, and well organized. Modern computer-controlled equipment has dramatically changed the role of the machinist from manual dexterity and manual skills to more knowledge-based skills.

## Helpers and Limited Machinists

A person's first job in manufacturing might be as a helper or limited machinist. They learn the trade from the floor up. They might be sweeping the floor or cutting stock to rough lengths for further machining. They are given additional responsibilities as they prove themselves in work. Remember that the supervisor is watching. The supervisor is looking to see if the new employee has work ethic and a good attitude. This determines whether they keep the job and how quickly they advance to becoming machinists.

## Machine Operator/Production Machinist

A machine operator's responsibilities are to operate computer-driven (CNC) machine tools such as turning or machining centers. The operator observes machine functions and tool performance, inspects parts, and has limited duties in setting up and making minor changes to programs. Figure A-1 shows a machinist programming a part on a CNC turning center.

Machine operators should be familiar with basic machining processes, tooling selection and application, speeds and feeds, basic blueprint reading, basic math calculations, basic machine setup, and basic use of measurement tools. Machine operators are generally taught to use one or more CNC machine controls. Machine operators may receive training from a technical college, industrial training programs, or they may learn on the job.

Figure A-1 Machinist programming a part on a CNC turning center (*Courtesy of Fox Valley Technical College*).

## Apprentice Machinist

The apprentice machinist learns the trade by entering a formal training program sponsored by a private company, a trade union, or a government entity. The period of training is typically four years and is a combination of on-the-job experiences and formal classroom education. Serving an apprenticeship represents one of the best methods of learning a skilled trade.

## Journeyman Machinist

The journeyman machinist will have the capability to set up and operate most CNC equipment. A person becomes a journeyman by serving an apprenticeship. A machinist apprenticeship is generally four years long. States have apprenticeship divisions that facilitate apprenticeships. An apprenticeship is a contract between the apprentice, the company, and the state. The contract is called an indenture. The role of the state apprenticeship division is to make sure that the apprentice learns a broad range of knowledge and skills during the apprenticeship. The apprenticeship agreement will specify the number of hours to complete the apprenticeship. A four-year apprenticeship would be approximately 8,320 hours. The pay for the apprentice generally increases every six months until the apprentice finishes and gets full pay. The agreement also specifies the hours of required education. The apprentice must attend the required classes during the apprenticeship. Classes are generally one day a week during the normal school year. Classes are generally offered at a technical or community college. Employers might give a beginning apprentice credit for prior experience or classes already taken. This boosts their pay and shortens the length of time required to complete the apprenticeship. When an apprentice finishes, he/she is awarded a journeyman's card by the state. The card is proof that he or she has completed an apprenticeship. A journeyman's card is held in high regard by potential employers if the machinist wants to change employers.

## Tool and Die Maker

A tool and die maker is usually an experienced machinist who served a tool and die apprenticeship. The tool and die apprenticeship is usually five years and requires more classes than a machinist apprenticeship. Tool and die makers may receive training through industrial apprenticeships and/or college and trade school programs. Although tool and die makers are often chosen only after several years of on-the-job experience, it is possible to start out in tool and die work through an apprenticeship program. Tool and die makers often receive premium pay for their work and are involved with many high-precision machining applications, tool design, material selection, metallurgy, and general manufacturing processes. Tool and die makers may be involved with making tooling and fixtures for automated processes and production.

## Quality Control Technician

Quality control technicians are involved with quality control and inspection. They utilize common measurement equipment as well as computerized measurement machines to inspect parts to make sure they meet the specifications (see Figure A-2).

Figure A-2 Quality control technician using a CMM to inspect a part (*Courtesy of Fox Valley Technical College*).

When parts are complex and or costly, the quality control technician often checks the first part coming out of a machine to be sure they meet requirements before more parts are run. Quality control technicians often have the responsibility for measurement tool calibration systems as well. They make sure that measurement equipment is accurate throughout the plant. Many quality control technicians began as machinists and moved into a quality control position. The quality control technician may receive training through college and trade school programs or on the job.

## Supervisor

Many shop supervisors begin their careers as machinists. A machinist who proves his or her ability might be chosen to be a supervisor. A supervisor is responsible for a group of people and a part of the production process. They may further their education by taking supervisory management classes at a local technical college, community college, or university.

## CNC Programmer

Some shops centralize the programming of CNC machines. Instead of having machinists write their own programs, they have specialized people doing the CNC programming with specialized software (Figure A-3). A machinist is very well prepared to be a CNC programmer. A machinist has knowledge of

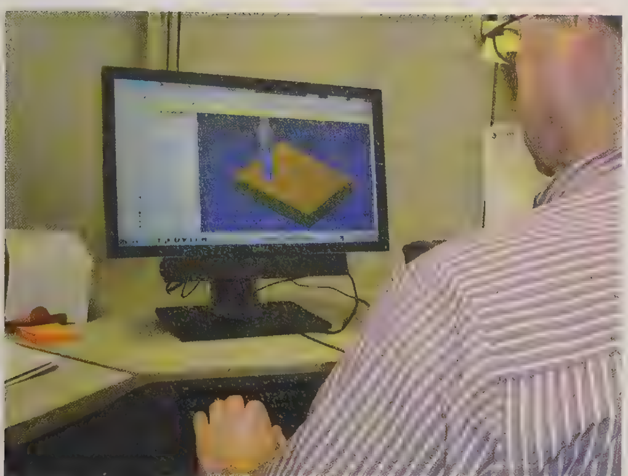


Figure A-3 A CNC programmer utilizing a CAD/CAM system to program a CNC machine (*Courtesy of Fox Valley Technical College*).

tooling, machining operations, feeds and speeds, and materials. To become a CNC programmer, a machinist would take a class on the software or be trained by another employee on the software that the company uses for programming.

### Manufacturing Engineer

The manufacturing engineer and/or industrial engineer is involved with the application of manufacturing technology. These individuals may be involved with the design of manufacturing tooling, setting up manufacturing systems, applying computers to manufacturing requirements, new product development, and improving efficiency.

### Estimator/Bidder

Most machine shops do not make complete products. They produce parts for larger companies that do produce products. Shops that produce parts for other companies are called job shops. Job shops must bid on work. An estimator/bidder looks at potential parts that need to be made and develops an estimate of how much it will cost to make. They consider costs such as material, tooling, machine, special processes, labor, shipping, and so on. They then develop a quote that is sent to the company that is requesting quotes on the parts. If the quote is accepted, the shop will get an order for the parts. The estimator/bidder must be skilled at developing the quotes. The quote price must be high enough to make a profit, but low enough to beat bids from other shops.

### Shop Owner

Most machine shops were started by machinists. Many shop owners were machinists who learned the trade, gained experience, and then bought one or more CNC machines and started their own company. Many manufacturing companies started this way and grew very rapidly to become large, successful businesses.

## SPECIAL OCCUPATIONS

### Automotive Machinist

The automotive machinist will work in an engine rebuilding shop where engines are overhauled. This person's responsibilities will be somewhat like those of the general machinist, with specialization in engine work, including boring, milling, and some types of grinding applications. Training for this job may be obtained on the job or through college or trade school programs.

### Maintenance Machinist

The maintenance machinist has broad responsibilities. The person may be involved in plant equipment maintenance, machine tool rebuilding, or general mechanical repairs, including welding and electrical repairs. The maintenance machinist is often involved with general machining as well as with general industrial mechanical work. The maintenance machinist normally just uses simple manual machines to make or repair parts for machines.

## MACHINING AND YOU

There are many exciting occupations available in manufacturing. These occupations provide a good working environment with wonderful wages and benefits as well as opportunities for advancement. Industry really needs people with good attitude and work ethic. There is a real demand for, and shortage of, individuals with good attitude and good work ethic. Industry is more than willing to invest in training and advancement for those individuals. Professional behavior will also serve you well. Appropriate clothing and language help promote a professional personal image. Dealing well with people is also an important attribute. A working knowledge of the machining processes and the related subjects described in this book will provide an excellent basis on which to build a successful career in manufacturing.

#### FURTHER INFORMATION ABOUT OCCUPATIONS IN MANUFACTURING

If you have further interest in machine shop career opportunities, discuss opportunities with an employment counselor at your school or a program instructor. Study the job advertisements in local newspapers to see what types of jobs are available. Talk to an employment agency about jobs that are in demand and the skills required to get them. Contact local manufacturing companies that employ machinists. Ask them for an opportunity to talk about employment opportunities and a tour of their facility. You may well find an employer who is willing to hire you as an intern while you go to school.

## Job Packets and Process Planning

Most manufacturing companies produce parts for other companies. They must bid on jobs to get work for their shop. A larger manufacturer typically solicits bids on work they need done. For example, assume a manufacturer (ACME Manufacturing) that makes and sells snow blowers. They do much of the work themselves, especially the assembly of the parts into the completed machine. But they have other companies produce many of the component parts that go into their final machine. These smaller machine shops are typically called job shops. Job shops do not have their own products. They make parts for other companies. Imagine ACME needs small axle-shafts made for their snow blowers. ACME puts out bid requests to their list of suppliers. The bid request would normally be transmitted electronically to all suppliers. The bid request would include a blueprint, material specifications, number of parts needed, due dates, any special requirements for packing shipping, etc. Each job shop can then evaluate the bid request to determine whether or not to bid on the work.

Imagine how one job shop (XYZ Machining) might evaluate the bid. XYZ receives the bid request in an email. XYZ has a customer service representative (CSR) who works with customers. The CSR looks at the bid request to see how many parts and what type of machining is required to quickly decide if XYZ has the machining capability to make the parts. The CSR must also determine if XYZ can produce the parts by the due date while considering all of the other work XYZ already has to do. Assuming XYZ has the machining capability and the time to make the parts, a price would need to be calculated. The CSR might confer with their CNC turning center supervisor to determine feasibility and cost per part. XYZ would also need to get a price on the steel that is required and make sure it will be available in the needed timeframe. Tooling costs, machine times, packaging, and shipping would all need to be considered. XYZ would also evaluate whether or not this is a customer they want to work for. XYZ would evaluate based on past history, if they have worked for them before. Did they pay their bills on time? Were they difficult to work with, and so on? If everything looks good at this point, the CSR would put together a bid price for the parts. Note that the price would need to be low enough to get the job, but high enough to make a profit. When there is a lot of work, companies tend to bid higher. When work is scarce bids get very competitive. In fact, in slow times a company might take work they normally would not take, just to keep their workers working. Note that ACME might accept bids from more than one company for parts. Their real need might be 10,000 shafts and they might split it between two job shops to reduce ACME's risk.

Assume that ACME Manufacturing accepts the bid from XYZ Machining. The order calls for 1,000 parts a month from January through May. The CSR orders steel once the bid is awarded by ACME. The CSR begins to prepare a job packet and schedules the job. Assume the parts must be shipped three days before the month end and it will take 38 hours of setup and machine time to make them. The CSR must evaluate the shop schedule and determine when the parts should be scheduled so these parts and all others can be made and shipped on time. The CSR might have to consult with the supervisor of that area in the shop. The CSR then puts a job packet together (Figure A-4). The job packet will include a current revision of the blueprint with all of the part specifications. The packet may include

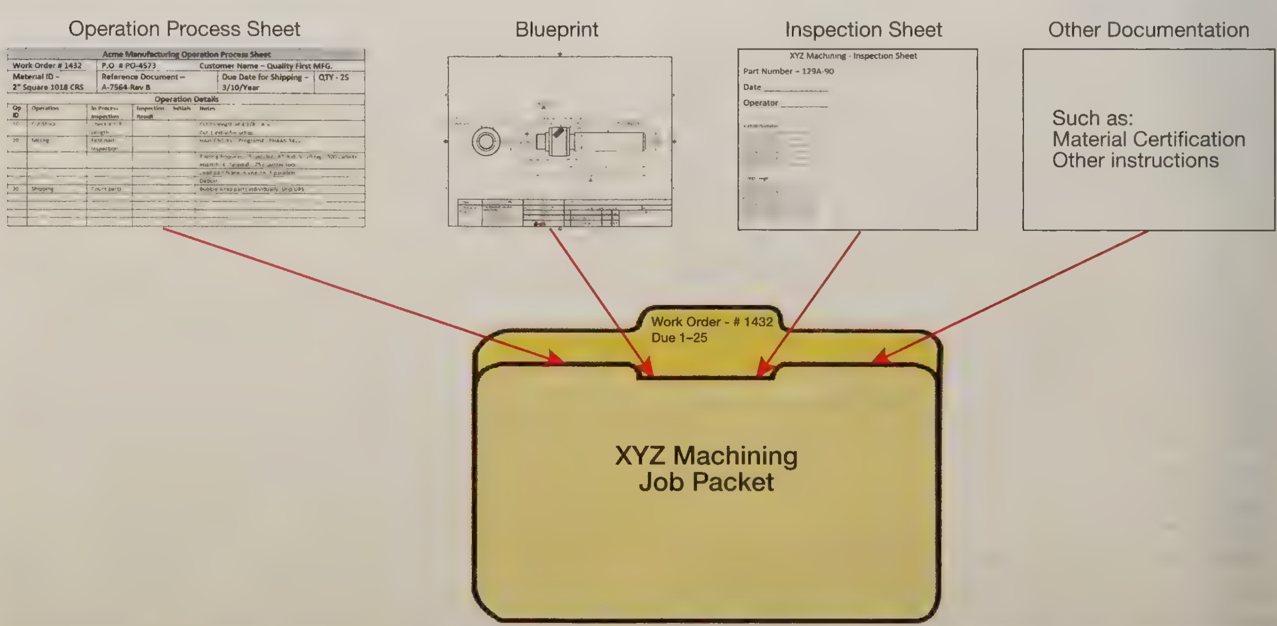



Figure A-4 Job Packet.

inspection sheets if special inspections are required. XYZ has a person who does process plans. The process planner develops an operation process sheet for the job. The process planner might also develop the CNC program for the parts, although the machinists program their own parts in many shops. If XYZ had run these parts before for ACME, the program would have already been written and the program number and machine would be specified on the operation process sheet.

Figure A-4 shows an example of the types of things that might go into a job packet. Job packets may also be called shop packets.

## Process Plans

A process plan details all of the things that need to be done to manufacture a part (Figure A-5). They are step-by-step instructions that are done by the machinist. The steps detail each machining operation, inspections that need to be done, deburring operations, and so on. The process plan also references the blueprint and correct revision level that needs to be used. The process plan may list the CNC program to be used, the machine, and any special setup instructions. The process plan would also detail and special handling, packaging, and or shipping requirements.

Process plans are also called routings or routers.

## Reference Document

The reference document is typically the customer-supplied blueprint. This is very important information. The machinist must always check to make sure the blueprint is the current revision. In this example, the blueprint number is A-7564-Rev B. The blueprint number must be the same exact number and revision level or the parts will be wrong.

## Work Order Number

The work order number is an internal number. The company the machinist works for assigns a work order number to each order it accepts from customers. This number is used for internal tracking of all information about this part run.

## P.O. Number

This is the purchase number. This number ties the order to a particular customer and order. It is the number the company will use to get paid by the customer after delivery of the parts.

## Material Specification

This is where the material for this part is specified. This specification must match the material specified by the blueprint.

## Due Date for Shipping

A machine shop must meet their customers' requirements. One of the most important is on-time delivery. A customer must have parts when they are needed. If a machine shop is not consistently on time with deliveries, the customer will find a new machine shop to work with.

**Figure A-5** An operation process plan.

<table>
<tr><th colspan="6">XYZ Manufacturing Operation Process Plan</th></tr>
<tr><td colspan="2">Work Order # 1432</td><td colspan="3">P.O. # PO-4573</td><td>Customer Name – ACME</td></tr>
<tr><td colspan="2">Material Spec. –<br>2″ Square 1018<br>CRS</td><td colspan="3">Reference Document –<br>A-7564-Rev B</td><td>Due Date for Shipping – 5/25/Year   QTY - 1000</td></tr>
<tr><td colspan="6">Operation Details</td></tr>
<tr><td>Op. ID</td><td>Operation</td><td>In-Process Inspection</td><td>Inspection Result</td><td>initials</td><td>Notes</td></tr>
<tr><td>10</td><td>Cut Stock</td><td>Check 4 1/8″ Length</td><td></td><td></td><td>Cut to length of 4 1/8 – 4 ¼<br>Cut 1 extra for setup.</td></tr>
<tr><td>20</td><td>Milling</td><td>First part Inspection</td><td></td><td></td><td>Haas CNC #3 – Program# - PHAAS-3412</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Tooling Required: .5 spotdrill, #7 drill, ¼ -20 tap, .500 carbide endmill, 4″ facemill, .75 chamfer tool.</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Load part blank in vise on .5 parallels</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Deburr</td></tr>
<tr><td>30</td><td>Shipping</td><td>Count parts</td><td></td><td></td><td>Bubble wrap parts individually. Ship UPS</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

## Operation

Operation is used to describe the operation that will be performed in this step. Note that there may be several steps and operations to be performed. In this example, there are only three operations. The first is to cut 25 blanks of 2″ square 1018 CRS (cold roll steel) to a length of 4 1/8″ to 4 $\frac{1}{4}$″. The note also calls for an extra blank to be cut for setting up a first piece.

## SELF-TEST

1. Develop a personal career plan. What job would you like to start your career in? What would you like to be doing in five years? Fifteen years?
2. List five things you can do to achieve your 15-year goal.
3. Companies are looking for people with good attitude and work ethic. List at least five things that describe the attributes of good attitude. List at least five things that describe the attributes of work ethic.
4. How does a company get jobs to do?
5. Name some considerations that go into a bid.
6. What is a process control plan?
7. What is a router?
8. What typically is included in a job packet?

UNIT TWO

# Manufacturing Competitiveness and Improvement

OBJECTIVES

After completing this unit, you should be able to:

- Explain at least three techniques for improving competitiveness.

## MANUFACTURING COMPETITIVENESS

Manufacturing is very competitive. A large percentage of manufacturing is done in job shops. They must bid on jobs to get work. The shop with the lowest bid that meets specifications will generally get the work. One of the techniques that manufacturers have been adopting to increase their efficiency is *lean manufacturing*.

Lean manufacturing is a technique that views the investment of a company's resources for any reason other than the creation of value for the customer to be wasted. The goal is to reduce or eliminate costs that do not create value for the customer. Customer value could be defined as any process that the customer would be willing to pay for. Many of the concepts and techniques of lean manufacturing have been around for a very long time.

Lean manufacturing is concerned with producing the product with fewer resources. Many of the concepts are based on principles from the Toyota Production System (TPS). The TPS was based on reducing waste and it identified seven principal wastes.

### Overproduction

Overproduction is defined as making a product before it is actually required. Overproduction is very costly because it prevents the efficient flow of materials and adversely affects productivity and quality. Overproduction often hides the real problems and opportunities for improvement in manufacturing. The goal is to make only what can be sold or shipped immediately. This is often called just-in-time.

### Wait Time

If a product is not moving or is being worked on, waste occurs. In a typical company, more than 99 percent of a product's time in the plant might be spent in waiting to be processed. This is often because distances between work centers are excessive, production runs are too long, and material flow is often very inefficient. Waiting can be reduced by having each process feed directly into the next process.

### Unnecessary transportation

Transporting products between processes is a cost that does not add any value to the product. Excessive transportation and product handling can cause damage. When people have to excessively transport parts in a plant, it takes time from their real role of adding value to the product. This is another cost that adds no value.

### Excess Inventory

Excess inventory or work in progress (WIP) is a direct result of overproduction and waiting. Excess inventory hides problems on the plant floor. Excess inventory wastes floor space, increases lead times, and dramatically increases costs.

### Unnecessary Motion

Unnecessary motion by people or equipment is a waste. This waste is related to ergonomics and is seen in all unnecessary movement of people performing an operation or task.

### Over Processing

Over processing often involves the use of expensive, high-cost equipment where simpler tools would do the job. The use of high-cost technology often results in higher quantity runs to try and recover the high cost of the equipment. Toyota is famous for using low-cost automation and well-maintained, older machines. If a machine is needed to produce X number of parts, Toyota would typically by a low-cost machine to produce that many parts. If production demands increase, they would buy another low-cost machine to meet the increased demand. American manufacturers would typically buy a more expensive machine that could produce many more than the required parts. There is less risk involved with the Toyota method. When possible, companies should invest in smaller and more flexible equipment.

### Defective Product

Quality defects that cause scrap or rework are a huge cost to manufacturers. When scrap is produced, many additional costs occur. These additional costs include quarantining the defective product, reinspecting it, and rescheduling the line to reproduce the scrapped product. This results in the loss of capacity as the time and resources used to reproduce the product cannot be used to create additional product. The total cost of defects is often a very significant percentage of the total cost of manufacturing.

An eighth waste has recently been added: underutilization of employees. Enterprises often hire employees to physically produce products but do not utilize their brain. Manufacturers must utilize their employees' creativity to eliminate the seven wastes and increase productivity.

## LEAN MANUFACTURING TOOLS FOR IMPROVEMENT

Lean manufacturing is a set of tools that assist in the identification and elimination of waste. When waste is eliminated, quality improves, and production time and cost are reduced. Some of the tools that are utilized in lean manufacturing include: Five S, Value Stream Mapping, Kanban (pull systems), and Poka-Yoke (error-proofing).

### The Five S Improvement Tool

The term *Five S* comes from the Japanese. The five Japanese words used to describe the method all begin with the letter s.

**Sorting (Seiri)** All unnecessary parts, tools, and instructions should be eliminated. All tools, materials, instructions, and so on in the work area and overall plant should be thoroughly examined. Only essential items should be kept. Essential tools should be easily accessible in the work station. Everything that is nonessential should be stored or discarded.

**Stabilizing or Straightening Out (Seiton)** This technique stresses that there should be a place for everything and everything should be in its place. There should be a place for each item in a station and it should be clearly labeled. Parts, tools, supplies, and equipment should be located close to where they are needed. Everything should be arranged to promote efficient work flow.

**Cleaning or Shining (Seiso)** Clean the workspace and equipment, and then keep it clean and organized. At the end of each shift, clean the work area and be sure everything is restored to its place. Spills, leaks, and other messes also then become a visual signal for equipment or process steps that need attention. Maintaining cleanliness must be an integral part of the daily work.

**Standardizing (Seiketsu)** All work practices should be consistent and standardized. Work stations for a particular operation should be exactly the same. Employees with the same role should be able to work in any station. The same tools should be in the same location in every station.

**Sustaining the Practice (Shitsuke)** The new standards that have been implemented as a result of the previous tools must be reviewed, maintained, and improved. After the first four S's have been established, they must continue to be the new way to operate. This new way must be sustained. The plant must not be allowed to slide back to the old ways of operating. Everyone must also commit to continue looking for ways to improve.

### Value Stream Mapping

Value stream mapping is a lean manufacturing tool that can be used to analyze and design the flow of materials and information required to bring a product to a customer. It originated at Toyota.

#### Implementation Steps

1. Identify the product to be studied.
2. Draw a state value stream map based on the shop floor that reflects the current steps, waits, and information flows required to deliver the product. This can be done by drawing it on paper or with special value stream mapping software.
3. Assess the efficiency of the current value stream map in terms of improving flow by eliminating waste.
4. Develop the redesigned value stream map.
5. Implement the redesign.

Shigeo Shingo was a Japanese industrial engineer who is one of the world's leading experts on manufacturing and the TPS. Shigeo Shingo suggested that the value-adding steps be drawn horizontally across the center of the value stream map and the non–value-adding steps be drawn vertically at right angles to the value stream.

This makes it easy to distinguish the value stream from the wasted steps. Shingo calls the value stream the process and the non–value streams the operations. Shingo viewed each vertical line as the story of a person or workstation. He viewed the horizontal line as the story of the product being created. Value stream mapping is a very visual and easy to understand tool to study and improve a process.

### Kanban

Kanban is not an inventory control system. It is a scheduling system that helps determine what to produce, when to produce it, and how many to produce.

In the 1940s, Toyota studied supermarkets to try and apply store and shelf-stocking techniques to the factory floor. Toyota observed that in a supermarket, customers get what they need at the needed time, and in the needed quantity. Toyota saw that a supermarket only stocks what it thinks will sell, and customers only buy as many as they need because they are not worried about getting additional products in the future. Toyota saw a process as being a customer of the processes that preceded it. The customer (worker) goes to the store to get the parts they need, and the store restocks with additional product like a store would.

Kanban uses the rate of demand to control the rate of production. Demand is passed from the end customer through the chain of customer (worker) processes. Toyota first applied this technique in 1953 in their main machine shop.

Imagine that one of the components needed to make the product is a ¼−20 bolt and it arrives in a box. There are 100 of the bolts in a box. The worker might have two boxes of bolts available. When the first box is empty, the assembler installing the bolts would take the card that was attached to the box and send it to the bolt making department. The assembler would then begin to use the bolts from the second box of bolts. The card would serve as an order for another box of 100 bolts. The box of bolts would be made and sent to the assembler. A new box of bolts would not be produced until a card is received. In this way the demand drives the rate of production.

Kanban is a pull-type production system. The number of bolts that are produced depends on the actual demand. In this example, the demand is the number of cards received by the bolt manufacturing area from the customer (assembler).

**Poka-Yoke** Poka-Yoke is a Japanese word that means mistake-proofing or fail-safing. A Poka-Yoke is any mechanism in a manufacturing process that helps an operator avoid mistakes. For example, the addition of a pin in a fixture to prevent the part from being mislocated would be a Poka-Yoke. Poka-Yoke attempts to eliminate product defects by preventing, correcting, or warning the operator an error is about to occur. Shigeo Shingo first used the term Poka-Yoke as part of the TPS.

A Poka-Yoke technique alerts the operator when a mistake is about to be made, or the Poka-Yoke device actually prevents the mistake from being made.

## Summary of Lean Manufacturing

Toyota's belief is that *lean* is not the tools, but the actual reduction of three types of waste: non–value-adding work, overburden, and unevenness of production. The tools are used to expose problems and improve processes.

Lean manufacturing attempts to get the correct things to the correct place at the correct time in the correct quantity to achieve an efficient work flow. Lean manufacturing also attempts to minimize waste and make processes flexible and able to react to change. For lean manufacturing techniques to be effective, they must be understood and be actively supported by the employees who build the product and add the value.

## SELF-TEST

1. How is lean manufacturing supposed to make a company more efficient and more profitable?
2. What was the basis of improvement in the Toyota Production System?
3. The Toyota Production System originally listed seven wastes. An eighth was added. What is it and what does it mean for you in your career?
4. What is the basis of the Five S tool?
5. How can Value Stream Mapping improve a process?
6. What is Kanban?
7. What is Poka-Yoke?

UNIT THREE

# Shop Safety

## OBJECTIVES

After completing this unit, you should be able to:

- Identify common shop hazards.
- Identify and use common shop safety equipment.
- Explain the classes of fires that are applicable to a machine shop.
- Given a fire extinguisher, explain what types of fires it can be used on.
- Demonstrate safe working practices in the shop.
- Explain Lockout/Tagout.

## SAFETY FIRST

We generally do not think about safety until it is too late. Safety is often not thought about as you do your daily tasks. Often you expose yourself to needless risk because you have experienced no harmful effects in the past. Unsafe habits become almost automatic. You may drive your automobile without wearing a seat belt. You know this to be unsafe, but you have done it before and so far, no harm has resulted. None of us really likes to think about the possible consequences of an unsafe act. However, safety can and does have an important effect on anyone who makes his or her living in a potentially dangerous environment. An accident can end your career as a machinist. Accidents are always unexpected! You may spend several years learning the trade and more years gaining experience. Years spent in training and gaining experience can be wasted in an instant if you have an accident, not to mention a possible permanent physical handicap for you and hardship on your family. Safety is an attitude that should extend far beyond the machine shop and into every facet of your life. You must constantly think about safety in everything you do. Safe habits must be developed and utilized. Safety glasses are just one example. You must develop the habit to wear them at all times in the shop to the point that you feel naked without them.

## PERSONAL SAFETY

### Grinding Dust, Hazardous Fumes, and Chemicals

Grinding dust is produced by abrasive wheels and consists of extremely fine metal particles and abrasive wheel particles. These should not be inhaled. Many grinding machines have a vacuum dust collector (Figure A-6). Grinding may be done with coolants that aid in dust control. You should wear an approved respirator if you are exposed to grinding dust. Change the respirator filter at regular intervals. Grinding dust can present a great danger to health.

Some metals, such as zinc, give off toxic fumes when heated above their boiling point. When inhaled, some of these fumes cause only temporary sickness, but other fumes can be severe or even fatal. The fumes of mercury and lead are especially dangerous, as their effect is cumulative in the body and can cause irreversible damage. Cadmium and beryllium compounds are also very poisonous. Therefore, when welding, burning, or heat-treating metals, adequate ventilation is an absolute necessity. This is also true when parts are being carburized with compounds containing potassium cyanide. These cyanogen compounds are deadly poisons, and every precaution should be taken when using them. Kasenit, a trade name for a nontoxic carburizing compound, is often found in school shops and in machine shops.

There may also be chemical hazards in the machine shop; lubricating oils, cutting oils, coolants, solvents, and some types of degreasing agents may be used. Any of these chemical agents can cause both short- and long-term health problems. Cutting oils may smoke when heated and give off noxious fumes. Inhaling any type of smoke can have short- and long-term health risks. Coolants may cause contact dermatitis, a skin irritation problem, and prolonged exposure can cause other long-term health problems. You should seek chemical safety data regarding these products and determine what health problems that short- and long-term exposure can cause. Chemical hazard awareness programs label chemicals to make employees aware of particular fire, health, and reactivity issues.

Figure A-6 Dust collector installed on a grinder.

## Material Safety Data Sheets (MSDS)

A material safety data sheet or MSDS contains information describing the properties of particular chemicals, materials, and other substances. Technical data are provided defining the chemical and physical properties of materials, such as melting point, boiling point, flash point, and any toxic elements that are likely to be present during processing or handling. Other items that may be included on an MSDS are proper disposal techniques, first-aid issues from exposure to hazardous materials, and protective equipment required to safely handle the material. Material safety data sheets are available from many different sources including the Occupational Safety and Health Administration (OSHA) and manufacturers' published information. MSDS sheets should be readily available in the shop. Modern industrial operations often use many hazardous materials. Safety in using, handling, and disposing of these materials has become extremely important.

## Eye Protection

Eye protection is a primary safety consideration in the machine shop. Machine tools produce hot, sharp metal chips that may be ejected from a machine at high velocity. Sometimes they can fly many feet. Furthermore, most

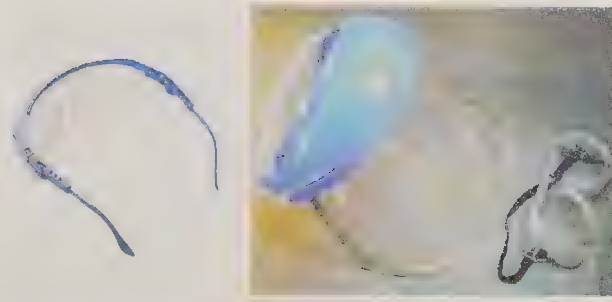


Figure A-7 Safety glasses, face shield, and safety goggles.

cutting tools are made from hard, brittle materials. They can occasionally break or shatter from the stress applied to them during a cut. The result can be flying metal particles.

Eye protection must be worn at all times in the machine shop. Several types of eye protection are available. Plain safety glasses are all that are required in most shops (see Figure A-7). These have shatterproof lenses that may be replaced if they become scratched. The lenses have a high resistance to impact.

Side shield safety glasses should be worn around any grinding operation. The side shield protects the side of the eye from flying particles. Side shield safety glasses may be of the solid or perforated type. The perforated side shield type fits closer to the eye.

Prescription glasses may be covered with safety goggles. The full-face shield may also be used (Figure A-7). Prescription safety glasses are available. In industry, prescription safety glasses are sometimes provided free to employees.

## Foot Protection

Generally, the machine shop presents a modest, but real hazard to the feet. There is always a possibility that you could drop something on your foot. Safety shoes with a steel toe shield to protect the foot are available. Some safety shoes also have an instep guard. Shoes must be worn at all times in the machine shop. A solid leather shoe is recommended. Sandals should not be worn as they expose the foot to hot chips produced in machining processes. Many shops provide rubber mats by machines that can dramatically reduce the fatigue on the feet caused by standing on a hard-concrete floor.

## Ear Protection

Machine shops are noisy environments. Hearing protection should be worn. Excess noise can cause permanent hearing loss. Usually, this occurs over a period of time, depending on the intensity of the exposure. Noise is considered an industrial hazard if it is continuously above 85 **decibels (dB)**. Decibel is the unit used for measuring the relative intensity of sounds. If the noise level is over 115 dB, even for short periods of time, ear protection must be worn (Figure A-8). Several types of sound suppressors and noise-reducing earplugs may be worn. Earmuffs or earplugs should be used wherever high-intensity noise occurs. Table A-1 shows the decibel level of various sounds; sudden sharp or high-intensity noises are the most harmful to the ears.

Figure A-8 Ear plugs.

Table A-1 Decibel Level of Various Sounds

| R | Sound |
|---|---|
| 130 | Painful, Jet engine on the ground |
| 120 | Airplane on the ground |
| 110 | Power saw at 3 feet |
| 100 | Motorcycle or snowmobile |
| 90 | Truck traffic |
| 80 | Telephone dial tone |
| 60–70 | Normal conversation at 3–5 feet |
| 30 | Whisper or a quiet library |
| 0 | Faintest audible sound |

## Clothing, Hair, and Jewelry

Shirts should be short-sleeved or long sleeves should be rolled up above the elbow. Shirts should be tucked in. If a shop apron is worn, it should be kept tied behind the back. If apron strings were to get entangled in the machine, you may be reeled in as well. Loose, hanging clothing is dangerous. A shop coat may be worn as long as long sleeves are rolled up above the elbow. Fuzzy sweaters should not be worn around machines. Polyester clothing is very susceptible to hot chips and should be avoided. Cotton clothing is a better choice.

If you have long hair, keep it secured properly. In industry, you may be required to keep your hair tied back so that your hair cannot become tangled in a moving machine. Long hair is easily caught up in moving tools such as drills and chucks. The result of this can be disastrous.

Remove your wristwatch and rings before operating any machine tool. These can cause serious injury if they are caught in a moving machine part.

## Hand Protection

No device will totally protect your hands from injury. Next to your eyes, your hands are the most important tools you have. It is up to you to keep them out of danger. Use a brush to remove chips from a machine (Figure A-9). Do not use your hands. Chips are razor sharp and can be extremely hot. Never grab chips as they come from a cut. Long chips are extremely dangerous. Long chips can be eliminated by sharpening your cutting tools properly. Chips should not be removed with a rag. The metal particles become embedded in the cloth and they may cut you. Furthermore, the rag may be caught in a moving machine. Gloves should never be worn around moving machinery. If a glove is caught in a moving part, it will be pulled in, along with the hand inside it.

Figure A-9 Use of a brush to remove chips safely.

Do not be careless around machines. Do not put your hands near moving machinery. Do not lean on a machine that is running. Do not lean over the back of a machine and talk to the employee who is running the machine. Accidents happen very quickly and they are never expected.

Various cutting oils, coolants, and solvents may affect your skin. The result may be a rash or an infection. Avoid direct contact with these products as much as possible, and wash your hands as soon as possible after contact.

## Lifting

Improper lifting (Figure A-10) can result in a permanent back injury that can limit or end your ability to earn a living and reduce your quality of life by restricting what you are able to do. Back injury can be avoided if you lift properly at all times. If you must lift a large or heavy object, get some help or use a hoist or forklift. Don't try to be a "superman" and lift something that you know is too heavy. It is not worth the risk. Most shops have lifting devices available for heavy objects. Objects within your lifting capability can be lifted safely by using the following procedure:

1. Keep your back straight.
2. Squat down, bending your knees.
3. Lift smoothly, using the muscles in your legs to do the work. Keep your back straight. Bending over the load puts an excessive stress on your spine.
4. Position the load so that it is comfortable to carry. Watch where you are walking when carrying a load.
5. If you replace the load back at floor level, lower it in the same manner in which you picked it up.

## Scuffling and Horseplay

The machine shop is no place for scuffling and horseplay. This activity can result in a serious injury to you or those around you. Practical joking is also hazardous. What might appear comical to you could result in a disastrous accident to

Figure A-10 The picture on the left shows the incorrect method to lift object. The picture on the right shows the correct method for lifting objects.

someone else. In industry, horseplay and practical joking are often grounds for firing an employee. Loud noises should also be avoided in the plant. Yelling, whistling, and making loud noises can startle an individual and may cause them to injure themselves.

### Injuries

If you should be injured, report it immediately to your instructor. In many schools and companies, there are incident report forms that must be filled out to report injuries to help fix the problem and help prevent it in the future.

## IDENTIFYING SHOP HAZARDS

A machine shop is not so much a dangerous place as it is a potentially dangerous place. One of the best ways to be safe is to be able to identify shop hazards before they result in an accident. By being aware of potential dangers, you can be very safe as you do your work in a machine shop.

### Compressed Air

Machine shops use compressed air to operate certain machine tools. Often, flexible air hoses hang throughout the shop. There is a large amount of energy stored in a compressed gas such as air. Releasing this energy presents an extreme danger. You may be tempted to blow chips from a machine tool using compressed air. This is not good practice. The air will propel metal particles at high velocity. They can injure you or someone on the other side of the shop. Use a brush to clean chips from the machine. Do not blow compressed air on your clothing or skin. The air may be dirty, and the force can implant dirt and germs into your skin. Air can be a hazard to ears as well. An eardrum can be ruptured.

Should an air hose break or the nozzle on the end come unscrewed, the hose will whip about wildly. This can result in an injury if you happen to be standing nearby. When an air hose is not in use, it is good practice to shut off the supply valve. The air trapped in the hose should be vented. When removing an air hose from its supply valve, be sure that the supply is turned off and the hose has been vented. Removing a charged air hose will result in a sudden venting of air. This can surprise you, and an accident might result.

### Housekeeping

Keep the floor and aisles clear of stock and tools. This will ensure that all exits are clear if the building should have to be evacuated. Material on the floor, especially round bars, can cause falls. Clean up oils or coolants that spill on the floor. Several products designed to absorb oil are available. Keep a broom handy when you are machining if chips are flying onto the floor. Keep the floor clean around the machine. Keep oily rags in an approved safety can (Figure A-11). This will prevent possible fire from spontaneous combustion.

### Fire Extinguishers

Fire extinguishers work by cooling the fuel, stopping the reaction, or by removing the oxygen from the fire. Fire extinguishers are used to spray a pressurized media out of a nozzle. The spray should not be aimed at the flames. The spray should be aimed at the fuel of the fire, which is at the bottom of the flames.

OSHA has identified five basic types of fires and specified types of extinguishers for each type of fire. Four of the five types of fire may be found in a machine shop.

**Class A** Class A fires involve common combustibles such as paper, cloth, wood, rubber, many types of plastics, and so on.

Figure A-11 A safety can for oily rags to prevent fires.

An extinguisher rated for a Class A fire uses pressurized water as the media. A Class A fire extinguisher should only be used on a Class A fire, never on any other type of fire.

**Class B** Class B fires involve oils, gasoline, lacquers, some types of paints, solvents, grease, and most other flammable liquids. Class B fire extinguishers use carbon dioxide or dry chemicals as the media.

**Class C** Class C fires are electrical fires. These can occur in wiring, energized electrical equipment, fuse boxes, computers, and so on. Class C fire extinguishers utilize carbon dioxide or a dry chemical as the extinguishing media.

There are fire extinguishers available that can be used for a Class A, B, or C fires. They are labeled for Class A, B, and C.

**Class D** Class D fires involve metals such as powders, flakes, or shavings of combustible metals such as magnesium, titanium, potassium, and sodium. These can be very dangerous fires. Class D fire extinguishers can contain a sodium chloride–based dry powder extinguishing agent, but most of the fire extinguishers labeled Class D have components that are geared to a specific metal.

**Class K** Class K fires involve combustible cooking fluids such as oils and fats. These are not applicable to a machine shop.

Know where all fire extinguishers are located in the plant. Know what type they are and what types of fires they can be used on. Know how they are operated. You should be fully aware of this information before they are needed. Precious minutes can be saved by knowing this ahead of time.

### Carrying Objects

If material is over 6 feet long, it should be carried in the horizontal position. If it must be carried in the vertical position, be careful of electrical buses, light fixtures, and ceilings. If the material is both long and over 40 lb in weight, it should be carried by two people, one at each end.

### Machine Hazards

There are many types of machine hazards. Each section of this book will discuss the specific dangers applicable to that type of machine tool. Remember that a machine cannot distinguish between cutting metal and cutting fingers. Do not think that you are strong enough to stop a machine should you become tangled in moving parts. You are not. When operating a machine, think about what you are going to do before you do it. Go over a **safety checklist**:

1. Do I know how to operate this machine?
2. What are the potential hazards involved?
3. Are all guards in place?
4. Are my procedures safe?
5. Am I doing something that I probably should not do?
6. Have I made all the proper adjustments and tightened all locking bolts and clamps?
7. Is the workpiece secured properly?
8. Do I have proper safety equipment?
9. Do I know where the stop switch is?
10. Do I think about safety in everything that I do?

## INDUSTRIAL SAFETY AND FEDERAL LAW

In 1970, Congress passed the Williams-Steiger Occupational Safety and Health Act. This act took effect on April 28, 1971. The purpose and policy of the act is "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources."

The Occupational Safety and Health Act is commonly known as OSHA. Prior to its passage, industrial safety was the individual responsibility of each state. The establishment of OSHA added a degree of standardization to industrial safety throughout the nation. OSHA encourages states to assume full responsibility in administration and enforcement of federal occupational safety and health regulations.

### Duties of Employers and Employees

Every employer under OSHA has the general duty to furnish places of employment free from recognized hazards causing or likely to cause death or serious physical harm. The employer has the specific duty of complying with safety and health standards as defined under OSHA. Each employee has the duty to comply with safety and health standards and all rules and regulations established by OSHA.

## Occupational Safety and Health Standards

Job safety and health standards consist of rules for avoiding hazards that have been proven by research and experience to be harmful to personal safety and health. These rules may apply to all employees, as in the case of fire protection standards. Many standards apply only to workers engaged in specific types of work. A typical rule might state that aisles and passageways shall be kept clear and in good repair, with no obstruction across or in aisles that could create a hazard.

## Complaints of Violations

Any employee who believes that a violation of job safety or health standards exists may request an inspection by sending a signed written notice to OSHA. This includes anything that threatens physical harm or represents an imminent danger. A copy must also be provided to the employer; however, the name of the person complaining need not be revealed to the employer.

## Enforcement of OSHA Standards

OSHA inspectors may enter a business or school at any reasonable time and conduct an inspection. They are not permitted to give prior notice of this inspection. They may question any employer, owner, operator, agent, or employee in regard to any safety violation. The employer and a representative of the employees have the right to accompany the inspector during the inspection.

If a violation is discovered, a written citation is issued to the employer. A reasonable time is permitted to correct the condition. The citation must be posted at or near the place of the violation. If after a reasonable time the condition has not been corrected, a fine may be imposed on the employer. If the employer is making an attempt to correct the unsafe condition but has exceeded the time limit, a hearing may be held to determine progress.

## Penalties

Willful or repeated violations may incur monetary penalties. Citations issued for serious violations incur mandatory penalties. A serious violation may be penalized for each day of the violation.

## OSHA Education and Training Programs

The Occupational Safety and Health Act provides for programs to be conducted by the Department of Labor. These programs provide for education and training of employers and employees in recognizing, avoiding, and preventing unsafe and unhealthful working conditions. The act also provides for training an adequate supply of qualified personnel to carry out OSHA's purpose.

## Lockout and Tagout Procedures

On October 30, 1989, the Department of Labor released "The control of hazardous energy sources (Lockout/Tagout)" standard. It is the Lockout/Tagout standard numbered 29 CFR 1910.147. The standard was intended to reduce the number of deaths and injuries related to servicing and maintaining machines and equipment.

The Lockout/Tagout standard covers the servicing and maintenance of machines and equipment in which the unexpected startup or energization of the machines or equipment or the release of stored energy could cause injury to employees. The standard covers energy sources such as electrical, mechanical, hydraulic, chemical, nuclear, and thermal. The standard establishes minimum standards for the control of these hazards.

Normal production operations are excluded from the lockout/tagout restrictions. Normal production operation is the use of a machine or equipment to perform its intended production function. Any work performed to prepare a machine or equipment to perform its normal production operation is called setup.

If an employee is working on cord and plug-connected electrical equipment for which exposure to unexpected energization or start up of the equipment is controlled by the unplugging of the equipment from the energy source, and the plug is under the exclusive control of the employee performing the servicing or maintenance, this activity is also excluded from requirements of the standard.

The Lockout/Tagout standard defines an energy source as any source of electrical, mechanical, hydraulic, pneumatic, chemical, thermal, or other energy. Machinery or equipment is considered to be energized if it is connected to an energy source or contains residual or stored energy. Stored energy can be found in pneumatic and hydraulic systems, capacitors, springs, and even gravity. Heavy objects have stored energy. If they fall they can cause injury.

Servicing and/or maintenance includes activities such as installing, constructing, setting up, adjusting, inspecting, modifying, and maintaining and/or servicing equipment. These activities include lubrication, cleaning or unjamming of machines or equipment, and making adjustments or tool changes, where personnel may be exposed to the unexpected energization or start up of the equipment or a release of hazardous energy.

Employers are required to establish (lockout/tagout) procedures and employee training to ensure that before any employee performs any servicing or maintenance on a machine or equipment where the unexpected energizing, startup, or release of stored energy could occur and cause injury, the machine or equipment shall be isolated, and rendered inoperative. Most companies impose strong sanctions on employees who do not follow the procedures to the letter. Many companies terminate employees who repeatedly violate the procedures. The procedures are designed to keep personnel safe. Make sure you follow procedures. You should also be aware of the penalties of not following them. The greatest penalty could be severe injury or death.

Employers are also required to conduct periodic inspections of the procedures at least annually to ensure that the procedures and the requirements of the standard are being followed.

Only authorized employees may lock out machines or equipment. An authorized employee is defined as being one who has been trained and has been given the authority to lock or tag out machines or equipment to perform servicing or maintenance on that machine or equipment.

An energy-isolating device is defined as being a mechanical device that can physically prevent the transmission or release of energy. A disconnect on an electrical enclosure is a good example of an energy-isolating device (see Figure A-12). If the disconnect is off, it physically prevents the transmission of electrical energy. Energy-isolating devices include the following: disconnects, manual electrical circuit breakers, manually operated switches by which the conductors of a circuit can be disconnected from all ungrounded supply conductors and, in addition, no pole can be operated independently; line valves (see Figure A-12); locks and any similar device used to block or isolate energy. Push buttons, selector switches and other control circuit type devices are not considered to be energy-isolating devices.

Due to the invisible and potentially fatal hazard of electrical energy, manufacturing companies developed **lockout/tagout** procedures for safely working on electrical equipment. When working on electrical equipment, it is of critical importance to absolutely prevent the accidental energizing of an electrical circuit. In lockout/tagout procedures, the source of the power is turned off and the control switches, circuit breakers, or main switches are physically locked out, often using a keyed lock. The circuit is also tagged and signed off by the electrician or other maintenance workers and can be unlocked and reenergized only by the person directly responsible for the lockout/tagout procedure. Make sure that you follow lockout/tagout procedures. Failure to follow them may cause serious injury or death.

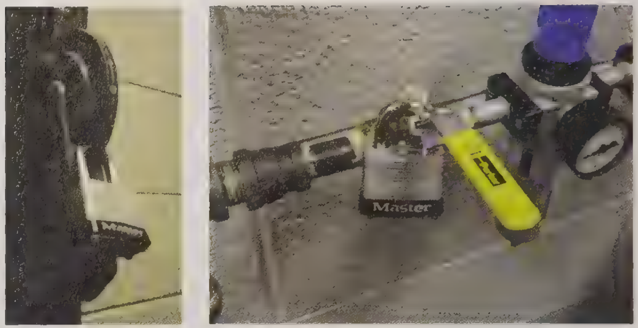



**Figure A-12** Electrical disconnect on the left and a pneumatic disconnect on the right (*Courtesy of Fox Valley Technical College*).

Most companies also have severe penalties up to and including, being fired for not following lockout/tagout procedures.

## SELF-TEST

1. What is the primary piece of safety equipment in the machine shop?
2. What are side shields and what are they designed to do?
3. Describe proper dress for the machine shop.
4. What can be done to control grinding dust?
5. What hazards exist from coolants, oils, and solvents?
6. Describe proper lifting procedure.
7. Describe at least two compressed-air hazards.
8. Describe good housekeeping procedures.
9. How should long pieces of material be carried?
10. List at least five points from the safety checklist for a machine tool.
11. Describe the purpose of lockout/tagout procedures.

## INTERNET REFERENCES

Information on industrial safety, lockout/tagout and safety equipment:

http://www.osha.gov

http://www.seton.com

# Threads and Fasteners

Many precision-machined products are useless until assembled into a machine, tool, or other mechanism. This assembly requires many types of fasteners and other mechanical hardware. In this unit you will be introduced to many of these important hardware items.

## OBJECTIVES

After completing this unit, you should be able to:

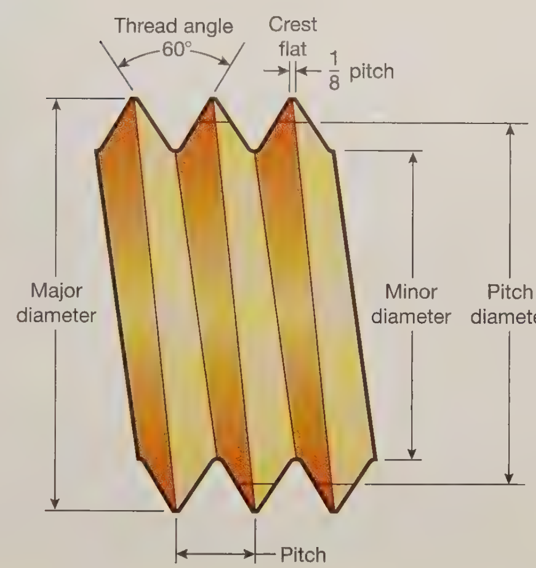
- Identify threads and threaded fasteners.
- Identify thread nomenclature on drawings.
- Discuss standard series of threads.
- Identify and describe applications of common mechanical hardware found in the machine shop.

## THREADS

This unit will introduce types of fasteners and their proper use. Threads are mainly used as fastening devices. Threads are also used for adjustment, measurement, and the transmission of power. The thread is an extremely important mechanical device. It derives its usefulness from the principle of the inclined plane, one of the six simple machines. Almost every mechanical device is assembled with threaded fasteners. One of the fundamental tasks of a machinist is to produce external and internal threads using machine tools and hand tools.

## THREAD FORMS

There are a number of thread forms. In later units you will examine these in detail, and you will have the opportunity to make several of them on a machine tool. The most common is the unified thread form (Figure A-13). The unified thread form is an outgrowth of the American National Standard form. It was developed to help standardize manufacturing in the United States, Canada, and Great Britain.




| | |
|---|---|
| UNC | National Coarse |
| UNF | National Fine |
| UNS | National Special |

**Figure A-13** Unified thread form.

In 1948, representatives from America, Canada, and Great Britain agreed on a common standard for threads. It utilized the best of both standards and was called the Unified Screw Thread System.

America has not adopted the metric system. Great Britain adopted the metric system in 1965. The International Standards Organization (ISO) adopted an international screw thread standard in 1969. The ISO metric standard is the most widely used in the world. Unified threads, a combination of the American National and the British Standard Whitworth forms, are divided into the following series: Unified National Course (UNC); Unified National Fine (UNF); and Unified National Special (UNS).

## IDENTIFYING THREADED FASTENERS

*Unified coarse* and *unified fine* refer to the number of threads per inch of length on standard threaded fasteners. A specific diameter of bolt or nut will have a specific number of threads per inch of length. For example, a $\frac{1}{2}$ − inch − 13 Unified National Coarse bolt will have 13 threads per inch of length. This bolt is identified by the following marking:

$\frac{1}{2}$ in. − 13 UNC

The $\frac{1}{2}$ inch is the **major diameter**, and 13 is the number of threads per inch of length. A $\frac{1}{2}$ inch diameter Unified National Fine bolt will be identified by the following marking:

$\frac{1}{2}$ in. − 20 UNF

The $\frac{1}{2}$ inch is the major diameter and 20 is the number of threads per inch.

The Unified National Special threads are identified in the same manner. A $\frac{1}{2}$ inch diameter UNS bolt may have 12, 14, or 18 threads per inch. These are less common than the standard UNC and UNF. There are many other series of threads used for different applications. Information and data on these can be found in machinists' handbooks. You might wonder why there needs to be a UNC and a UNF series. A fine thread is stronger in harder materials like steels and a coarse thread is stronger in softer materials like aluminum. The choice of coarse versus fine series also has to do with the application. For example, an adjusting screw may require a fine thread, while a common bolt may require only a coarse thread.

### Thread Terminology

Some of the more commonly used thread terms are:

Thread Angle—The angle of the thread is the included angle between the sides of the thread (see Figure A-13). For example, the thread angle for Unified Screw Thread forms is 60 degrees.

Major Diameter—Commonly known as the outside diameter (see Figure A-13). On a straight screw thread, the major diameter is the largest diameter of the thread on the screw or nut.

Minor Diameter—Commonly known as the root diameter (see Figure A-13). On a straight screw thread, the minor diameter is the smallest diameter of the thread on the screw or nut.

Number of Threads—Refers to the number of threads per inch of length.

Pitch—Is the distance from a given point on one thread to a corresponding point on the next thread.

Lead—Lead and pitch are closely related concepts. Lead is how far a thread advances by one complete rotation of the screw (360 degrees). For example, if we turn a bolt one revolution clockwise, the distance it would move into the nut would be the lead of the thread. If a bolt has 10 threads per inch, the lead would be equal to 1 inch/10 or .100 inch. One complete revolution of the bolt would advance the bolt into the nut .100 inch. Lead and pitch are normally the same for a thread. Lead and pitch would be different if the threads are not a single thread. For example, the lead on a double thread would be twice as much as the pitch.

## CLASSES OF THREAD FITS

Some applications can tolerate loose threads, while other applications require tight threads. For example, the head of your car's engine is held down by a threaded fastener called a stud bolt, or simply a stud. A stud is threaded on both ends. One end is threaded into the engine block. The other end receives a nut that bears against the cylinder head. When the head is removed, it is desirable to have the stud remain screwed into the engine block. This end requires a tighter thread fit than the end of the stud accepting the nut. If the fit on the nut end is too tight, the stud may unscrew as the nut is removed.

Unified thread fits are classified as 1A, 2A, 3A, or 1B, 2B, 3B. The A symbol indicates an external thread. The B symbol indicates an internal thread. This notation is added to the thread size and number of threads per inch. Let us consider the $\frac{1}{2}$-inch diameter bolt discussed previously. The complete notation reads:

$\frac{1}{2}$ − 13 UNC 2A

On this particular bolt, the class of fit is 2. The symbol A indicates an external thread. If the notation had read:

$\frac{1}{2}$ − 13 UNC 3B

it would indicate an internal thread with a class 3 fit. This could be a nut or a hole threaded with a tap. Taps are a common tool for producing an internal thread.

Classes 1A and 1B have the greatest manufacturing tolerance. They are used where ease of assembly is desired and a loose thread is acceptable. Class 2 fits are used on the largest percentage of threaded fasteners. Class 3 fits will be tight when assembled. Each class of fit has a specific tolerance on major diameter and pitch diameter. These specifications can be found in machinists' handbooks and are required for the manufacture of threaded fasteners.

## STANDARD SERIES OF THREADED FASTENERS

Threaded fasteners range from very small machine screws through very large bolts. Fasteners under $\frac{1}{4}$-inch diameter are given a number. Common UNC and UNF series threaded fasteners are listed in Table A-2. Above size 12, the major diameter is expressed in fractional form. Both series continue up to about 4 inches.

### Metric Threads

With all of the importation of foreign products, metric threads have become much more common.

Table A-2 UNC and UNF Threaded Fasteners

| UNC | | | UNF | | |
|---|---|---|---|---|---|
| Size | Major Diameter (inches) | Threads/ Inch | Size | Major Diameter (inches) | Threads/ Inch |
| | | | 0 | .059 | 80 |
| 1 | .072 | 64 | 1 | .072 | 72 |
| 2 | .085 | 56 | 2 | .085 | 64 |
| 3 | .098 | 48 | 3 | .098 | 56 |
| 4 | .111 | 40 | 4 | .111 | 48 |
| 5 | .124 | 40 | 5 | .124 | 44 |
| 6 | .137 | 32 | 6 | .137 | 40 |
| 8 | .163 | 32 | 8 | .163 | 36 |
| 10 | .189 | 24 | 10 | .189 | 32 |
| 12 | .215 | 24 | 12 | .215 | 28 |
| $\frac{1}{4}$ inch | .248 | 20 | $\frac{1}{4}$ inch | .249 | 28 |
| $\frac{5}{16}$ inch | .311 | 18 | $\frac{5}{16}$ inch | .311 | 24 |
| $\frac{3}{8}$ inch | .373 | 16 | $\frac{3}{8}$ inch | .373 | 24 |
| $\frac{7}{16}$ inch | .436 | 14 | $\frac{7}{16}$ inch | .436 | 20 |
| $\frac{1}{2}$ inch | .498 | 13 | $\frac{1}{2}$ inch | .498 | 20 |
| $\frac{9}{16}$ inch | .560 | 12 | $\frac{9}{16}$ inch | .561 | 18 |
| $\frac{5}{8}$ inch | .623 | 11 | $\frac{5}{8}$ inch | .623 | 18 |
| $\frac{3}{4}$ inch | .748 | 10 | $\frac{3}{4}$ inch | .748 | 16 |
| $\frac{7}{8}$ inch | .873 | 9 | $\frac{7}{8}$ inch | .873 | 14 |
| 1 inch | .998 | 8 | 1 inch | .998 | 12 |

The metric thread form is similar to the unified and based on an equilateral triangle. The root may be rounded and the depth somewhat greater. An attempt has been made through international efforts (ISO) to standardize metric threads. The ISO metric thread series now has 25 thread sizes with major diameters ranging from 1.6 to 100 mm.

Metric thread notation takes the following form:

$$M\ 10 \times 1.5$$

M is the major diameter and 1.5 is the thread pitch in millimeters. This thread would have a major diameter of 10 mm and a pitch (or lead) of 1.5 mm. ISO metric thread major diameters and respective pitches are shown in Table A-3.

## ISO METRIC THREADS CLASSES OF FIT

Numbers and letters after the pitch number in the notation specify the tolerance for both the pitch and the major diameter of external threads and the pitch and the minor diameter of internal threads. The numbers indicate the amount of tolerance allowed. The smaller the number, the smaller the amount of tolerance allowed. The letters indicate the position of the thread tolerance in relation to its basic diameter. Lowercase letters are used for external threads, with the letters e indicating a large allowance, g a small allowance, and h no allowance. Conversely, uppercase letters are used for internal threads, with a G used to indicate a small allowance and an H used to indicate no allowance.

Table A-3 ISO Metric Threads

| Diameter (mm) | Pitch (mm) | Diameter (mm) | Pitch (mm) |
|---|---|---|---|
| 1.6 | .35 | 20.0 | 2.5 |
| 2.0 | .40 | 24.0 | 3.0 |
| 2.5 | .45 | 30.0 | 3.5 |
| 3.0 | .50 | 36.0 | 4.0 |
| 3.5 | .60 | 42.0 | 4.5 |
| 4.0 | .70 | 48.0 | 5.0 |
| 5.0 | .80 | 56.0 | 5.5 |
| 6.3 | 1.00 | 64.0 | 6.0 |
| 8.0 | 1.25 | 72.0 | 6.0 |
| 10.0 | 1.50 | 80.0 | 6.0 |
| 12.0 | 1.75 | 90.0 | 6.0 |
| 14.0 | 2.00 | 100.0 | 6.0 |
| 16.0 | 2.00 | | |

The tolerance classes 6H/6g are used for general-purpose applications. They are comparable to the Unified National 2A/2B classes of fit. The designation 4H5H/4h5h is approximately equal to the Unified National class 3A/3B.

### Taper Pipe Threads

Standard taper pipe threads (NPT) are unlike standard threads in the way they are cut and in their use. Taper pipe threads are one of the more challenging thread-cutting operations. Cutting taper pipe threads requires greater accuracy than standard threads. Pipe threads are designed to mechanically seal a threaded joint for pressure and to prevent leakage. To create the mechanical seal, 100 percent of the thread height must be cut by the tap to maintain the standard thread profile. The NPT standard limits for both external and internal are identical, so that hand-tight engagement can result in thread flank contact only or crest and root contact only. Wrench tightening normally produces an assembly with crest and root clearances. Excessive tightening with a wrench without the use of some kind of tape or chemical sealer is not advisable.

Taper threads are also unlike standard threads in their designations. A machinist looking at a $\frac{1}{4}$–18 NPT would immediately notice that the outside diameter of the tap is much bigger than $\frac{1}{4}$ of an inch. This is due to the fact that the tap size designation refers to the inside diameter of the standard iron pipe it is designed to fit. Another major difference between taper pipe tapping and standard thread tapping is the way in which the machinist must control the thread diameter. Since the tap is tapered, the machinist can control the thread diameter by adjusting the depth that the tap threads into the hole. To get the proper thread depth, a machinist drives the tap into the work 12 full turns. More turns may result in the tapped hole being too large. Less turns may result in the tapped hole being too small. There is no one particular class of fit for NPT threads, such as 3A or 3B. Proper taper thread gauging is the only acceptable method for determining proper depth for taper pipe tapping. One method of monitoring tap depth is to wrap a piece of wire or tape around the tap as a line to serve as a depth indicator. This practice works well to get you "close." This trick works well for hand tapping when cutting fluids are used.

## COMMON EXTERNALLY THREADED FASTENERS

Common mechanical hardware includes threaded fasteners such as bolts, screws, nuts, and thread inserts. All these are used in a variety of ways to hold parts and assemblies together.

### Bolts and Screws

A general definition of a *bolt* is an externally threaded fastener that is inserted through holes in an assembly. A bolt is tightened with a nut (Figure A-14, right). A *screw* is an externally threaded fastener that is inserted into a threaded hole and tightened or released by turning the head (Figure A-14, left). From these definitions, it is apparent that a bolt can become a screw or vice versa. This depends on how it is used. Bolts and screws are the most common of the threaded fasteners. Threaded fasteners are used to assemble parts quickly, and they also make disassembly possible.

The strength of an assembly of parts depends to a large extent on the diameter of the screws or bolts used. In the case of screws, strength depends on the amount of thread engagement. *Thread engagement* is the distance that a screw extends into a threaded hole. The minimum thread engagement should be a distance equal to the diameter of the screw used; preferably, it should be a minimum of $1\frac{1}{2}$ times the screw diameter. Should an assembly fail, it is better to have the screw break than to have the internal thread stripped from the hole. It is generally easier to remove a broken screw than to drill and tap for a larger screw size. With a screw engagement of $1\frac{1}{2}$ times its diameter, the screw will usually break rather than strip the threads in the hole.

Machine bolts are made with hexagonal or square heads. These bolts are often used in the assembly of parts that do not require a precision bolt. The body diameter of machine bolts is usually slightly larger than the nominal or standard size of the bolt. Body diameter is the diameter of the unthreaded portion of a bolt below the head. A hole that is to accept a common bolt must be slightly larger than the body diameter. Common bolts are made with a class 2A unified thread and come in both UNC and UNF series. Hexagonal head machine bolt sizes range from $\frac{1}{4}$-inch diameter to 4 inches. The size of the head on a square-head machine bolt is typically $1\frac{1}{2}$ times the thread diameter.

Stud bolts (Figure A-15) have threads on both ends. Stud bolts are used where one end is semipermanently screwed into a threaded hole. A good example of the use of stud bolts is in an automobile engine. The stud bolts are tightly held in the cylinder block, and easily changed nuts hold the cylinder heads in place. The end of the stud bolt screwed into the tapped hole has a class 3A thread, while the nut end is a class 2A thread. Studs are also widely used to hold vises and or parts down on machine tables.

Machine screws are made with either coarse or fine thread and are used for general assembly work. Machine screws are available in many sizes and lengths (Figure A-16). Several head styles are also available (Figure A-17). Machine screw sizes fall into two categories. Fraction sizes range from diameters of $\frac{1}{5}$ to $\frac{3}{4}$ inch. Screws that are under $\frac{1}{4}$-inch diameter are identified by numbers from 0 to 12. A No. 0 machine screw has a diameter of .060 inch (60 thousandths of an inch). For each number above zero, add .013 in. to the diameter.

**Figure A-14** On the left a fastener is used as a screw and on the right the screw is used as a bolt because it is used with a nut.

**Figure A-15** Stud bolts, T-nuts, and a clamping nut (*Courtesy of Fox Valley Technical College*).

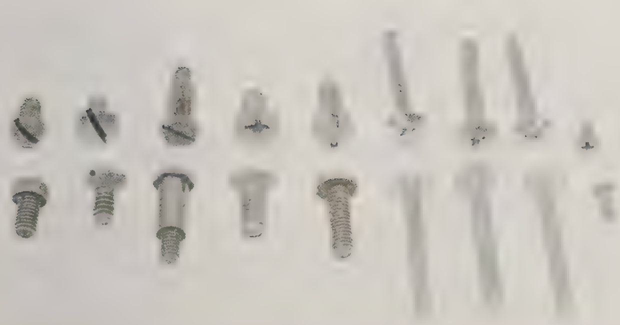


Figure A-16 Machine screw head styles.

Figure A-17 Various cap screws. From the left: a stainless-steel socket-head cap screw, a regular socket-head cap screw, a button-head cap screw, and a flat-head cap screw (*Courtesy of Fox Valley Technical College*).

**EXAMPLE**

Find the diameter of a No. 6 machine screw:

$$\text{No. 0 diameter} = .060 \text{ in.}$$

$$\begin{aligned}\text{No. 6 diameter} &= .060 \text{ in.} + (6 \times .013 \text{ in.})\\ &= .060 \text{ in.} + .078 \text{ in.}\\ &= .138 \text{ in.}\end{aligned}$$

Machine screws 2 inches long or less typically have threads extending all the way to the head. Longer machine screws have a $1\frac{3}{4}$-inch thread length.

Machine screws (Figure A-16) are made with a variety of different head shapes and are used where precision bolts or screws are needed. Machine screws are made with coarse, fine, or special threads. Machine screws with a 1-inch diameter have a class 3A thread. Those with greater than a 1-inch diameter have a class 2A thread. The strength of screws depends mainly on the kind of material used to make the screw. Materials that screws are made from include aluminum, brass, bronze, low-carbon steel, medium-carbon steel, alloy steel, stainless steel, titanium, and various plastics.

## Socket Head Cap Screws

Socket head screws are made with a variety of different head shapes and are used where precision bolts or screws are needed. Socket head screws are manufactured to close tolerances. Cap screws can have round heads, low heads, flat heads, button head, or can be in a shoulder screw configuration (see Figure A-17).

Socket head cap screws are the strongest of the head styles. The height of the head is equal to the shank diameter.

## Low Head Cap Screw

These are designed for applications in which head height is limited. These are not as strong as the regular head. The head height is approximately half the shank diameter.

## Flat Head Cap Screw

These are designed for flush mount applications. Note that the inch and metric screws have different countersink angles. You must use the correct countersink or the screw may fail.

## Button Head Cap Screw

These are well suited to holding thin materials because of the large head. They are good for tamper proofing because of the hex drive style makes it less susceptible to tampering with a screwdriver. Also good for applications where a regular screw (slotted or Phillips) is prone to stripping.

## Socket Shoulder Screw

These are typically used as pivot points or axles for other parts to rotate around. The shoulders are ground to tight tolerances.

## Bolt Grades and Torque Factors

In some instances, bolts need to be fastened with the correct amount of pressure (torque). In these instances, the manufacturer of the product will specify a certain torque be applied to a particular fastener. Insufficient torque will usually result in parts working loose. Overtightening, on the other hand, can cause stress or warping which also might disturb alignment on assemblies. The "armstrong" (overtightening) method of tightening fasteners can also cause broken castings, broken bolts, or stretching of the fastener.

Steel has excellent elasticity. Elasticity is the ability to stretch slightly, like a spring, and then return to its original shape. Any fastener must reach its limits of stretching to exert clamping force. But also, like a spring, an overstretched fastener takes on a set, loses its elasticity, and cannot snap back to its original shape. Proper torqueing will prevent this condition.

A popping or snapping sound is sometimes heard during the final tightening of a fastener. This popping sound indicates that the fastener is undergoing set. When a new fastener is being used and the popping occurs, the remedy is to back it off and retighten to the proper torque specifications. When an old fastener is being used and you hear popping, take the fastener out, and clean the bolt and the internal threads out completely. The safer, more economical thing to do is replace the old fastener with a new one.

## SCREW STRENGTH GRADES

The selection of the right grade of fastener is just as important as proper torqueing. The strength grades of bolts are identified by the markings on the heads. The grade indicates the strength of the fastener. Figure A-18 shows a few examples of grade markings. Use a manufacturer's chart as a guide for the proper torque of fasteners.

### Metric Strength Property Classes

The correct terminology for the grade of a metric fastener is property class. The metric system designates strength capabilities via property classes rather than grades. The numbering system is simple. Figure A-19 shows an example of the strength class marking on a metric bolt. The number that appears before the decimal, when multiplied by 100, will provide the approximate minimum tensile strength of the bolt. In this example, the 8 in 8.8 multiplied by 100 tells the user that this bolt has an approximate minimum tensile strength of 800 MPa (Mega (million) Pascals). The

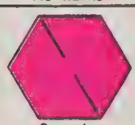
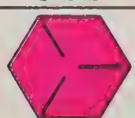
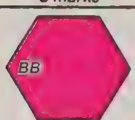
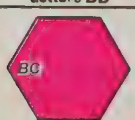
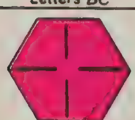
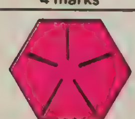
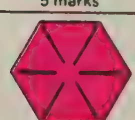
| Bolt head marking | SAE – Society of Automotive Engineers<br>ASTM – American Society for Testing and Materials<br>ASTM Definitions | Material | Minimum tensile strength in pounds per square inch (PSI) |
|---|---|---|---|
|  No marks | SAE grade 1<br>SAE grade 2<br>Indeterminate quality | Low carbon steel<br>Low carbon steel | 65,000 PSI |
|  2 marks | SAE grade 3 | Medium carbon steel, cold worked | 110,000 PSI |
|  3 marks | SAE grade 5<br>ASTM – A 325<br>Common commercial quality | Medium carbon steel, quenched and tempered | 120,000 PSI |
|  Letters *BB* | ASTM – A 354 | Low alloy steel or medium carbon steel, quenched and tempered | 105,000 PSI |
|  Letters *BC* | ASTM – A 354 | Low alloy steel or medium carbon steel, quenched and tempered | 125,000 PSI |
|  4 marks | SAE grade 6<br>Better commercial quality | Medium carbon steel, quenched and tempered | 140,000 PSI |
|  5 marks | SAE grade 7 | Medium carbon alloy steel, quenched and tempered, roll threaded after heat treatment | 133,000 PSI |
|  6 marks | SAE grade 8<br>ASTM – A 345<br>Best commercial quality | Medium carbon alloy steel, quenched and tempered | 150,000 PSI |

**Figure A-18** Fastener strength grade chart.

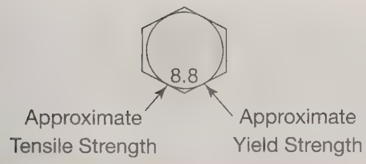



**Figure A-19** Strength class marking for metric bolts (*Courtesy of Fox Valley Technical College*).

**Pascal** (symbol: **Pa**) is the unit of pressure, stress, and tensile strength, named after the French physicist, mathematician, inventor, and philosopher Blaise Pascal. It is a measure of force per unit area, defined as one newton per square meter.

The number which appears after the decimal, when multiplied by 10, will provide the approximate yield strength percentage in relation to the minimum tensile strength. For the 8.8 bolt, the 8 after the decimal point tells the user that the yield strength of the bolt is approximately 80 percent of the first number: 800 MPa. Thus, the 8.8 bolt has a yield strength of approximately 640 MPa.

There are nine common metric property classes: 4.6, 4.8, 5.8, 8.8, 9.8, 10.9, and 12.9. In the United States, property classes 8.8.3 and 10.9.3 also defined. The 3 after the second decimal point indicates the fastener is made of weather resistant steel. Hex head bolts M5 and larger have the property class marked on the head of the bolt. Fasteners smaller than M5, and those with slotted or recessed heads do not have to be marked.

Setscrews are used to lock pulleys or collars on shafts. Setscrews can have square heads with the head extending above the surface; more often, the setscrews are slotted or have socket heads. The heads of slotted or socket head setscrews are usually set below the surface of the part to be fastened. A pulley or collar with the setscrews below the surface is much safer for persons working around it. Socket head setscrews may have hex socket heads or spline socket heads. Setscrews are manufactured in number sizes from 0 to 10 and in fractional sizes from $\frac{1}{4}$ to 2 inches. Setscrews are usually made from carbon or alloy steel and hardened.

Setscrews can have various point configurations (Figure A-20). The flat point setscrew will make the least amount of indentation on a shaft and is used where frequent adjustments are made. A flat point setscrew is also used to provide a jam screw action when a second setscrew is tightened on another setscrew to prevent its release through vibration. The oval point setscrew will make a slight indentation as compared with the cone point. With a half-dog or full-dog point setscrew holding a collar to a shaft, alignment between shaft and collar will be maintained even when the parts are disassembled and reassembled. This is because the shaft is drilled with a hole of the same diameter as the dog point. Cup-pointed setscrews will make a ring-shaped depression in the shaft and will give a slip-resistant connection. Square head setscrews have a class 2A thread and are usually supplied with a coarse thread. Slotted and socket head setscrews have a class 3A UNC or UNF thread.

**Figure A-20** Setscrew points.

Thread-forming screws form their own threads and eliminate the need for tapping. These screws are used in the assembly of sheet metal parts, plastics, and nonferrous material. Thread-forming screws form threads by displacing material with no cutting action. These screws require an existing hole of the correct size.

Thread-cutting screws make threads by cutting and producing chips. Because of the cutting action these screws need less driving torque than thread-forming screws. Applications are similar to those for thread-forming screws. These include fastening sheet metal, aluminum, brass, die castings, and plastics.

## COMMON INTERNALLY THREADED FASTENERS

### Nuts

Common nuts (Figure A-21) are manufactured in as many sizes as bolts are. Most nuts are either hex (hexagonal) in shape. Nuts are identified by the size of the bolt they fit, not by their outside size. Common hex nuts are made in different thicknesses. A thin hex nut is called a *jam nut*. It is used where space is limited or where the strength of a regular nut is not required. Jam nuts are often used to lock other nuts. Regular hex nuts are slightly thinner than their size designation. A $\frac{1}{2}$-inch regular hex nut is $\frac{7}{16}$-inch thick. A $\frac{1}{2}$-inch heavy hex nut is $\frac{31}{64}$-inch thick. A $\frac{1}{2}$-inch-high hex nut measures $\frac{11}{16}$ inch in thickness. Other common nuts include various stop nuts or locknuts. Two common types are the elastic stop nut

**Figure A-21** Common nuts.

and the compression stop nut. They are used in applications where the nut might vibrate off the bolt. Wing nuts and thumb nuts are used where quick assembly or disassembly by hand is desired. Other hex nuts are slotted or castle nuts. These nuts have slots cut into them. When the slots are aligned with holes in a bolt, a cotter pin may be used to prevent the nut from turning. Axles and spindles on vehicles have slotted nuts with cotter pins to prevent wheel bearing adjustments from slipping.

Cap or acorn nuts are often used where decorative nuts are needed. These nuts also protect projecting threads from accidental damage. Nuts are made from many different materials, depending on their application and strength requirements.

## INTERNAL THREAD INSERTS

Thread inserts can be used when an internal thread is damaged or stripped and it is not possible to drill and tap for a larger size. A thread insert retains the original thread size; however, it is necessary to drill and tap a somewhat larger hole to accept the thread insert.

One common type of internal thread insert is the key–lock type. The thread insert has both external and internal threads. This type of thread insert is screwed into a hole tapped to the same size as the thread on the outside of the insert. The four keys are driven in using a special driver (Figure A-22). This holds the insert in place. The internal thread in the insert is the same as the original hole.

A second type of thread insert is also used in repair applications as well as in new installations. Threaded holes are often required in products made from soft metals such as aluminum. If bolts, screws, or studs were to be screwed directly into the softer material, excessive wear could result, especially if the bolt was taken in and out a number of times. To overcome this problem, a thread insert made from a more durable material may be used. Stainless steel inserts are frequently used in aluminum (Figure A-23). This type of thread insert requires an insert tap, an insert driver, and a thread insert (Figure A-24). After the hole for the thread insert is tapped, the insert driver is used to screw the insert into the hole (Figure A-25). The end of the insert coil must be broken off and removed after the insert is screwed into place. The insert in the illustration is used to repair spark plug threads in engine blocks.

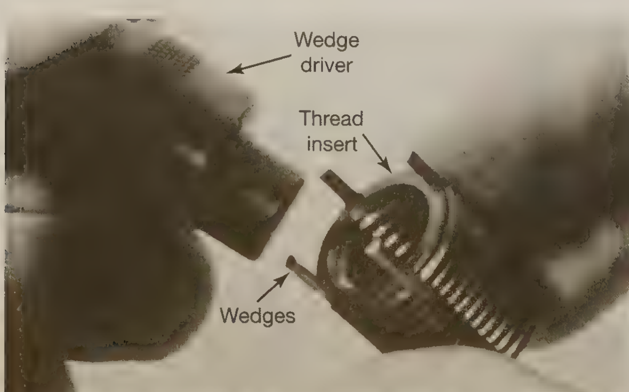



**Figure A-22** Key–lock internal thread insert.

**Figure A-23** Stainless steel thread insert used in an aluminum valve housing.

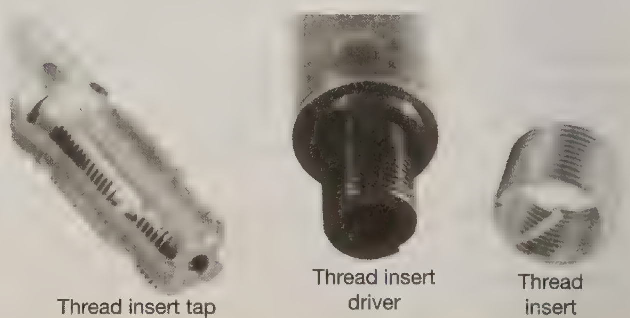



**Figure A-24** Thread insert tap, driver, and repair insert for spark plug hole repair.

**Figure A-25** Thread insert driver.

# WASHERS, PINS, RETAINING RINGS, AND KEYS

## Washers

Flat washers (Figure A-26) are used under nuts and bolt heads to distribute the pressure over a larger area. Washers also prevent the marring of a finished surface when nuts or screws are tightened. Washers can be manufactured from many different materials. The nominal size of a washer is intended to be used with the same nominal-size bolt or screw. Standard series of washers are narrow, regular, and wide. For example, the outside diameter of a $\frac{1}{4}$-inch narrow washer is $\frac{1}{2}$ inch the outside diameter of a $\frac{1}{4}$-inch regular washer is almost $\frac{3}{4}$ inch and the diameter of a wide $\frac{1}{4}$-inch washer measures 1 inch.

Lock washers (Figure A-27) are manufactured in many styles. The helical spring lock washer provides hardened bearing surfaces between a nut or bolt head and the components of an assembly. The spring-type construction of this lock washer will hold the tension between a nut and bolt assembly even if a small amount of looseness should develop. Helical spring lock washers are manufactured in series: light, regular, heavy, extra duty, and hi-collar. The hi-collar lock washer has an outside diameter equal to the same nominal-size socket head cap screw. This makes the use of these lock washers in a counterbored bolt hole possible. Counterbored holes have the end enlarged to accept the bolt head. A variety of standard tooth lock washers are produced, the external type providing the greatest amount of friction or locking effect between fastener and assembly. For use with small head screws and where a smooth appearance is desired, an internal tooth lock washer is used. When a large bearing area is desired or where the assembly holes are oversized, an internal–external tooth lock washer is available. A countersunk tooth lock washer is used for a locking action with flat head screws.

## Pins

Pins (Figure A-28) find many applications in the assembly of parts. **Dowel pins** are heat-treated and precision ground. Their diameter varies from the nominal dimension by only plus or minus .0001 inch (1/10,000th of an inch). Dowel pins are used where accurate alignments must be maintained between two or more parts. Holes for dowel pins are reamed to provide a slight press fit. Reaming is a machining process during which a drilled hole is slightly enlarged to provide a smooth finish and accurate diameter. Dowel pins only

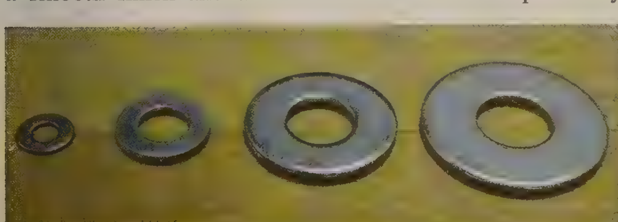


**Figure A-26** A few examples of flat washers (*Courtesy of Fox Valley Technical College*).

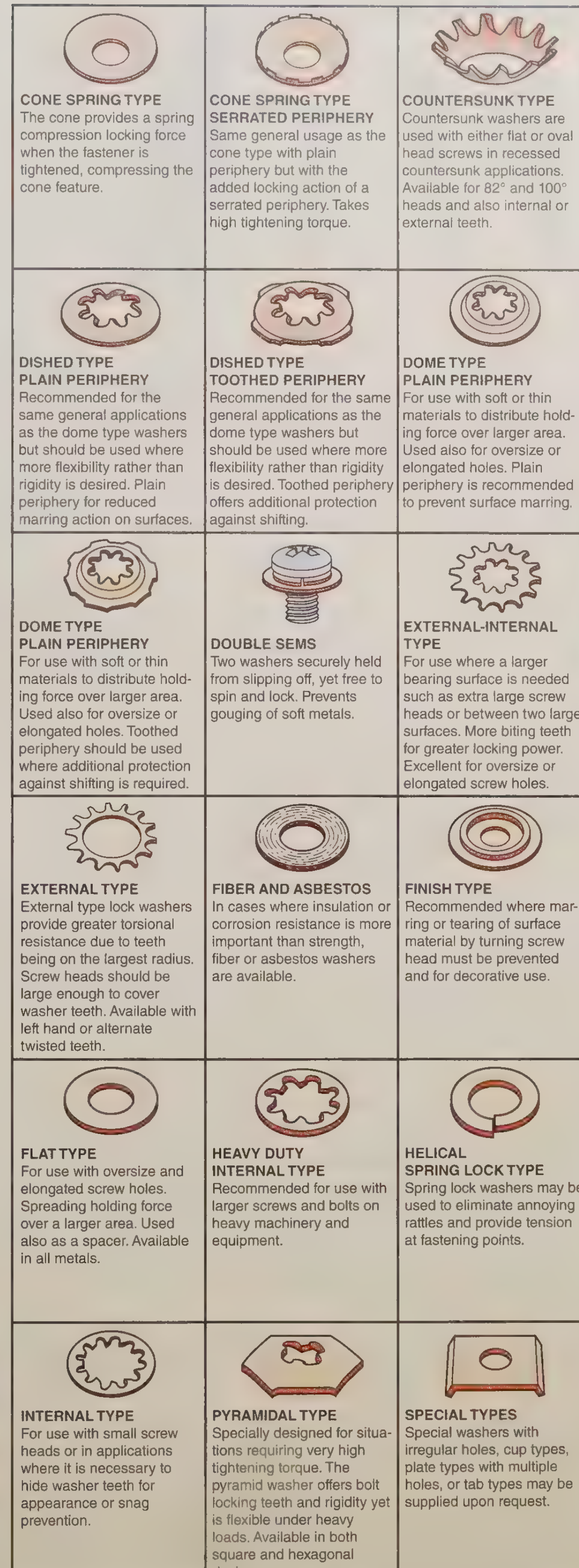



**Figure A-27** Lock washers.

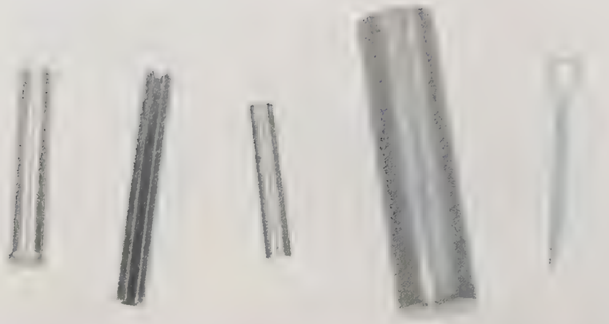


Figure A-28 Pins.

locate. Clamping pressure is supplied by the screws. Dowel pins may be driven into a blind hole. A blind hole is closed at one end. When this kind of hole is used, provision must be made to let the air that is displaced by the pin escape. This can be done by drilling a small through hole or by grinding a narrow flat the full length of the pin.

One disadvantage of dowel pins is that they tend to enlarge the hole in an unhardened workpiece if they are driven in and out several times. When parts are intended to be disassembled frequently, **taper pins** can provide accurate alignment. Taper pins have a taper (diminishing diameter) of $\frac{1}{4}$ inch per foot of length and are fitted into reamed taper holes. If a taper pin hole wears larger because of frequent disassembly, the hole can be reamed larger to receive the next larger size of taper pin. Diameters of taper pins range in size from $\frac{1}{16}$ inch to $\frac{11}{16}$ inch measured at the large end. Taper pins are identified by a number from $\frac{7}{0}$ (small diameter) to number 10 (large diameter) as well as by their length. The large end diameter is constant for a given size pin, but the small diameter changes with the length of the pin. Some taper pins have a threaded portion on the large end. A nut can be threaded on the pin and used to pull the pin from the hole much like a screw jack. This facilitates removal of the pin.

A **grooved pin** is either a cylindrical or a tapered pin with longitudinal grooves pressed into the pin body. This causes the pin to deform. A grooved pin will hold securely in a drilled hole even after repeated removal.

**Roll pins** can also be used in drilled holes with no reaming required. These pins are manufactured from flat steel bands and rolled into cylindrical shape. Roll pins, because of their spring action, will stay tight in a hole even after repeated disassembly.

**Cotter pins** are used to retain parts on a shaft or to lock a nut or bolt as a safety precaution. Cotter pins make quick assembly and disassembly possible.

## Retaining Rings

Retaining rings are fasteners that are used in many assemblies. Retaining rings can be easily installed in machined grooves, internally in housings, or externally on shafts or pins (Figure A-29). Some types of retaining rings do not require grooves but have a self-locking spring-type action. The most common application of a retaining ring is to provide a shoulder to hold and retain a bearing or any other part on an otherwise smooth shaft. They may also be used in a bearing housing (Figure A-30). Special pliers are used to install and remove retaining rings.

## Keys

**Keys** (Figure A-31) are used to prevent the rotation of gears or pulleys on a shaft. Keys are fitted into key seats in both the shaft and the external part. Keys should fit the key seats

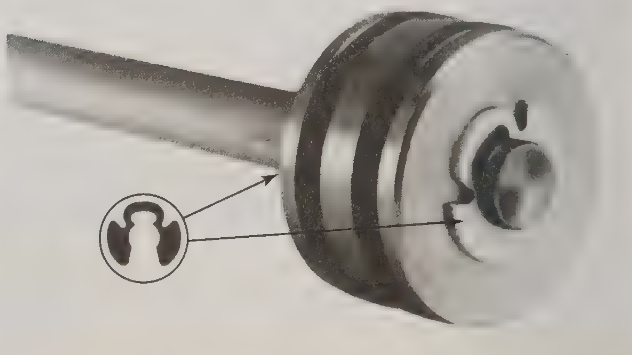


Figure A-29 External retaining ring used on a shaft (Rotor Clip Company, Inc.).

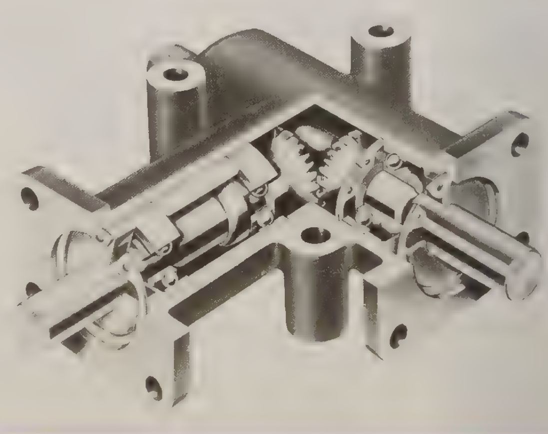


Figure A-30 Internal retaining rings used to retain bearings (Rotor Clip Company, Inc.).

Figure A-31 Keys. A square key, a Woodruff key, a rectangular key, and a gib-head taper key.

rather snugly. **Square keys**, where the width and the height are equal, are preferred on shaft sizes up to a $6\frac{1}{2}$-inch diameter. Above a $6\frac{1}{2}$-inch diameter, rectangular keys are recommended. Woodruff keys, which almost form a half circle, are used where relatively light loads are transmitted. One advantage of **Woodruff keys** is that they cannot change their axial location on a shaft because they are retained in a pocket. A key fitted into an end-milled pocket will also retain its axial position on the shaft. Most of these keys are held under tension with one or more setscrews threaded through the hub of the pulley or gear. Where extremely heavy shock loads or high torques are encountered, a taper key is used. **Taper keys** have a taper (diminishing diameter) of $\frac{1}{8}$ inch per foot. When a tapered key is used, the key seat in the shaft is parallel to the shaft axis, and a taper to match the key is in the hub. Where only one side of an assembly is accessible, a gib-head taper key is used instead of a plain taper key. When a gib-head taper key is driven into the key seat as far as possible, a gap remains between the gib and the hub of the pulley or gear. The key is removed for disassembly by driving a wedge into the gap to push the key out.

## SELF-TEST

1. Define the term pitch diameter.
2. Name two ways to measure a thread.
3. What is the rule of thumb for the length of internal thread to maximize the strength of the bolt? (In other words, that the bolt will break before the threads pull out.)
4. Describe when class two fits are used.
5. Describe UNC and UNF.
6. What is the formula for calculating the OD of a machine screw? What are setscrews used for?
7. When are stud bolts used?
8. Describe the strength classification system and marking for bolts.
9. Explain two reasons why flat washers are used.
10. What is the purpose of a helical spring lock washer?
11. When is an internal–external tooth lock washer used?
12. When are dowel pins used?
13. When are taper pins used?
14. When are roll pins used?
15. What are retaining rings?
16. What is the purpose of a key?
17. When is a Woodruff key used?
18. When is a gib-head key used?

# Blueprint Reading Fundamentals

From earliest times, people have communicated their thoughts through drawings. The pictorial representation of an idea is vital communication between the designer and the people who produce the final product. The drawing can also provide an important testing phase for an idea. Many times, an idea may be rejected at the drawing board or CAD stage before a large investment is made.

**OBJECTIVES**

After completing this unit, you should be able to:

- Find information in a title block.
- Explain terms such as surface finish, isometric, oblique, first angle projection, and third angle projection.
- Make isometric and oblique sketches of objects.
- Find information on blue prints.

Almost anything can be represented by a drawing. It is important that the designer be aware machining methods and limitations. On the other hand, a machinist must fully understand all the symbols and terminology on the designer's drawing. The machinist must be able to understand the drawings to transform the ideas of the designer into useful products.

The name "blueprint" originated from one of the first processes used to make copies of drawings. One of the first processes developed to duplicate drawings produced white lines on a blue background, hence the name "blueprint."

## TITLE BLOCK

The title block is normally located in the lower-right corner (Figure A-32). The title block contains the drawing number, the name of the part or assembly, and the material to be used. It also includes the scale of the drawing, drafting record, authentication, date, and may include more information depending on the complexity of the part.

### Drawing Number

Each blueprint has a drawing number in the title block (Figure A-32). On blueprints with more than one sheet, the information in the number block shows the sheet number and the number of sheets in the series. For example, note that the title blocks shown in Figure A-32 shows sheet 1 of A complex part or assembly might have several sheets.

### Revision Block

If a revision has been made, there will be a revision block on the drawing, as shown in Figure A-32. Note that each revision is numbered and the revisions are shown with the number on the actual drawing where the feature was changed. The revision block may be attached to the title block or be in a separate location on the print. All revisions in this block are identified by a number and a brief description of the revision. A revised drawing is shown by the addition of a letter to the original number as shown in the figure. When the print is revised, the revision will use the next available letter. For example, if the first revision was labelled A, the next revision will be labelled B. The letter is used to identify the current revision of the drawing.

### Reference Number

Reference numbers that appear in the title block refer to numbers of other blueprints. On some prints you may see a notation above the title block such as "34512 RH shown; 34512-1 LH opposite." RH means right hand, and LH means left hand. Note that both the right-hand and left-hand parts carry the same number, but the left-hand part number has a "–1."

### Zone Number

Zone numbers serve the same purpose as the letters and numbers on the borders of maps. They are used to locate a particular feature on a drawing. It makes it easier to convey information when you are communicating with

# Index

Note: Page numbers in *italics* refer to figures and illustrations.