Fourth Edition

Machining and CNC Technology

Michael Fitzpatrick
Keith Smith

Mc Graw Hill Education

Machining and CNC Technology

Fourth Edition

Michael Fitzpatrick
Everett Community College
Community and Corporate Education
Keith Smith
Shoreline Community College

McGraw Hill Education

MACHINING AND CNC TECHNOLOGY, FOURTH EDITION
Published by McGraw-Hill Education, 2 Penn Plaza, New York, NY 10121.

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 21 20 19 18

ISBN 978-1-259-82744-0 (bound edition)
MHID 1-259-82744-5 (bound edition)
ISBN 978-1-260-04785-1 (loose-leaf edition)
MHID 1-260-04785-7 (loose-leaf edition)

Portfolio Manager: *Thomas M. Scaife, Ph.D.*
Product Developer: *Tina Bower*
Marketing Manager: *Shannon O'Donnell*
Content Project Managers: *Jane Mohr, Rachael Hillebrand, and Sandy Schnee*
Buyer: *Laura Fuller*
Design: *Matt Backhaus*
Content Licensing Specialist: *Melissa Homer*
Cover Image: ©*Mike Fitzpatrick*
Compositor: *MPS Limited*

All credits appearing on page or at the end of the book are considered to be an extension of the copyright page.

Library of Congress Cataloging-in-Publication Data

Fitzpatrick, Michael, 1945- author.
Machining and CNC technology/Michael Fitzpatrick.
Fourth edition. | New York, NY : McGraw-Hill Education, [2019] |
Includes index.
LCCN 2017048119 | ISBN 9781259827440 (acid-free paper) |
ISBN 1259827445 (acid-free paper)
LCSH: Machining—Handbooks, manuals, etc. |
Machine-tools—Numerical control—Handbooks, manuals, etc.
LCC TJ1165 .F566 2018 | DDC 671.3/5—dc23 LC record available at
https://lccn.loc.gov/2017048119

While there were countless others along the way, these people made all the difference in my career and life. Without them I question whether this book would have been.

To Linda, my wife,
for never complaining about the time taken from us to do this, for believing, giving, and forgiving.

To Jan Carlson
for demonstrating with acts, what a caring professional should be, and especially for the encouraging space to grow.

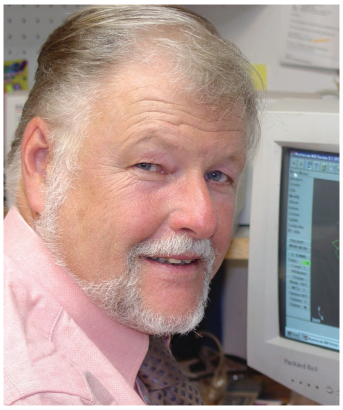
Gene Haas
and the Gene Haas Foundation
for the total support of machinist education worldwide. You make me proud to be an American machinist. Thanks for the HTEC Network, Gene.

This page intentionally left blank

Contents

Mc Graw Hill Education
5011444

About the Authors


Courtesy Mike Fitzpatrick

Mike Fitzpatrick—Journey Machinist, Tool and Die Maker As if it was yesterday, I remember carrying my new toolbox down the aisle at Kenworth Trucks of Seattle. Scotty, the crusty drill press operator, stepped away from his machine and planted himself right in front of me. Without a welcome, he raised his bushy eyebrows, poked two fingers into my chest, and said, "You see all these men here?" He waited. At 18, I recall only nodding, unable to speak. He went on: "Each one of us will show you everything we know if you pay attention. We'll give you lifetimes of experience, but know this, lad, it comes with an obligation. Someday you'll pass it on."

Having served a machinist apprenticeship at Kenworth Trucks and a tool and die apprenticeship at Boeing, I have 14,000 hours of formal trade education in two very different industries and at the workbench of many craft-masters. I began teaching machining part-time, then moved to full-time many years ago. I can call myself a journeyman! And a veteran teacher. I am fulfilling Scotty's challenge—learn the trade well then at mastery pass it forward! I am so very honored to be your teacher in print alongside Keith Smith.


Courtesy Keith Smith

Keith Smith—Instructor of Machining It has been an honor and pleasure to be invited by Mike to work on this edition of *Machining and CNC Technology.* I first met Mike when I began teaching at Shoreline Community College. Before that, I had worked many years in the machining trade, first as a manual machinist, then as a CNC machinist, and eventually a programmer. Mike has been a mentor to me in my teaching career, and I feel like I have come full circle by being able to make a contribution to his book. This book stands out among others because it recognizes and anticipates changes taking place in manufacturing. My own experience has shown me this is not a static industry but one that is dynamically evolving. Hopefully this text will always be able to reflect the exciting changes taking place in the manufacturing of machined parts.

Preface

Programmed machine tools now represent most machine operation and, of greater impact to you, of new jobs. *Entry-level people usually start in the shop as CNC operators.* Flexible and friendly, the machines and programming systems are so quick and easy to learn that they are now practical even for one-of-a-kind work such as mold making and die work, as well as production. *Schools integrate and teach CNC as an entry-level subject—starting from the first lesson on the first day.*

This book was specifically written to serve this type of modern student. To do so, subjects have been grouped into four large career partitions:

Part 1 Introduction to Manufacturing

Manufacturing is a world of its own. Chapters 1 through 7 are designed to open the door. They provide the background needed to fit into the shop, to understand the rules, to read and interpret the drawings, to be comfortable with extreme accuracy, and especially to be safe.

Part 2 Introduction to Machining

Chapters 8 through 15 teach how to cut metal the right way. These lessons assume that you will eventually perform them on CNC equipment but will probably practice first on manually operated machines because they are a simple, safe place to learn setups and operations.

Part 3 Introduction to Computer Numerical Control Machining

Now we get to the text core: how to apply Parts 1 and 2 to setting up, programming, and running CNC machine tools. In Chapters 16 through 23, we will learn how to professionally manage a CNC world. Because they move at lightning speed with lots of power behind them, safety must be integrated into everything we study.

Part 4 Advanced and Advancing Technology

Chapters 24 through 28 set the tone for your career after graduation. The best is yet to come, so let's get started!

So, many thanks to those who are using our book to start your manufacturing careers. It's an honor to be your instructors. Here's what we can pass on about our trade.

The Fourth Edition has been revised to include a number of new features:

- **New chapters on Mastercam and SolidWorks with student downloads of test software**
- **Multiaxis setups and operations**
- **An index to help you map this book to any national machining standard** Recognizing the growing trend toward standardized instruction, this textbook is now skill mapped and indexed to help fit it to any national machining standard. The full index can be found on the Online Learning Center at www.mhhe.com/fitzpatrick4e, and the three-digit codes will help you cross-reference the index with the material in the book. A **glossary of terms** can also be found in the Online Learning Center.
- **More on 3-D metal printing** Still an emerging technology, will it fall within the machinist job title? Where will it be in 10 years?
- **Interactive chapter feature** There have been many advances in mobile technology since the last edition, and this new textbook incorporates many of them. Students can now use their mobile devices to view interesting websites, videos, and articles when they scan the special codes throughout the book. Think of these **Xcursions** as a virtual field trip of material that will enhance student understanding of the text.

Acknowledgments

Our deepest gratitude goes to these major contributors, without whom this book would not have been possible:

CNC Software, Inc. Mastercam *Mark Summers, President; Dan Newby, Training Director*

Thank you, Mark, for believing in education, and Dan, for your editing and guidance, and many thanks to your entire team for improving our trade and supporting education worldwide.

CGTech *(Irvine, California) Scott Michalek, CGTech Sales Engineer (recently retired); Bryon Jacobs, Marketing Manager*

Special thanks to Scott, Bryon, and everyone at CGTech who provided assistance putting together the chapter on program verification.

Renishaw, Inc. *Rafael Herrera, Marketing Specialist*

Your time, effort, and energy helped illustrate the impact that probe technology has on the machining industry.

3DX Industries, Inc. *(Ferndale, Washington) Roger Janssen President & CEO, CFO*

Thank you for your support and help with updating the additive manufacturing unit of this book.

Milwaukee Area Technical College *(Milwaukee, Wisconsin) Dale Howser and Patrick Yunke, Lead Instructors*

Offering a nationally recognized, 2-year tool-and-die-making diploma. MATC graduates learn die and mold making and qualify for Wisconsin's apprenticeship certificate. Thus, they often serve full apprenticeships in the highly paid tooling area of manufacturing.

Dale Howser Sr.: Apart from 28 years of journeyman toolmaking experience, with 15 years of teaching these subjects, Dale holds degrees in tool and die making from Milwaukee Area Technical College and in Vocational Education from Stout University. He also develops and works on educational materials for the Precision Metalforming Association and Wisconsin's Apprenticeship programs.

Patrick Yunke: A graduate of Wisconsin's Madison Area Technical College die-making program and Stout University for Vocational Education, Patrick brings many years of experience in all aspects of precision die, metal, and plastic mold making to MATC, where he has taught for 15 years. He has also been a consultant to industry for manufacturing and custom educational programs.

Many thanks to you both for your expertise and for supplying great photos from your beautifully organized shop.

NTMA—National Tooling and Machining Association *Dick Walker, President*

Many thanks for being at the root of this new book in the beginning, for investing time and energy in it, and for the 45 drawings donated from your training materials.

NTMA Training Centers, California *Max Hughes, Dean of Instruction*

Thanks, Max, for the assistance with the CNC portion of this book.

Haas Automation, Inc. *(Oxnard, California) Scott Rathburn, Marketing Manager, Sr. Editor CNC Machining*

Thank you, Scott, for supporting education, educators, programs and especially aiding and encouraging students.

Boeing Commercial Airplane Co. *Apprentice Instructor*

Thank you for giving me the best education possible when I began my career, and to Tim for your ongoing support of quality apprenticeship, for help in planning and executing this book, and for being a lifelong friend.

Brown and Sharpe Corp. *(Rhode Island) Metrology Equipment*
For your commitment to education in metrology in technical schools and colleges.

Kennametal Inc. *Kennametal University, dedicated to finding better methods and to educating wherever machining is taught or applied.*
Thanks for the data, advanced tooling photos, text, and charts.

Iscar Metals *Bill Christensen, Advanced Tooling Photos and Text*
Advancing knowledge through research and education; thank you, Bill, for the HSM article.

Sandvik Coromant
Thank you for photos from *Modern Metal Cutting*.

SME—Society of Manufacturing Engineers
Westech Machine Tool and Productivity Exposition

In addition, I would like to thank the following instructors who reviewed this textbook and provided suggestions for improvement:

Bob Dixon *Walters State Community College*

Bret Holmes *Ogden Weber Applied Tech Center*

Mike Wyckoff *Grand Rapids Community College*

Mike Cannon *Pensacola State College*

Dean Duplessis *Northern Maine Community College*

Mark Dodge *Nashua Community College*

Arthur Martz Thomas Wertman *Kaplan Career Institute*

Jim Kitchen *Pensacola State College*

Samuel Obi *San Jose State University*

Andrew Zwanch *Johnson College*

Patrick Mason *Morehead State University*

Michael Mattson *Clackamas Community College*

Dexter Hulse *University of Cincinnati-Batavia*

Richard Buhnerkemper *Gateway Technical—Elkhorn*

Thanks to the following individuals for recommending companies for the "Made Right Here" opening segments in this book:

Gerald Berry *Wayne County Community College District*

Herbert Skinner *Southeast Technical Center*

Ismail Fidan *Tennessee Tech University*

Erica Matthew *Florida Career College*

Teje Sult *Jackson State University*

M*achining and CNC Technology,* Fourth Edition, provides the most up-to-date approach to Machine Tool technology available, with totally integrated coverage of manual and computer numerical control–based equipment.

Every other chapter opens with a **Made Right Here** profile. This profile contains a photo and a brief text describing a company or product manufactured today. It is meant to inspire students and show them all of the opportunities available to them in the industry.

Courtesy Dennis Paulson and Straightline Precision Industries, Inc.

In July 1996, my father, Mike Paulson, my brother, DJ, and I started a small machine shop called Straightline Precision Industries, Inc. We started with a small manual mill and lathe in our garage with the intention of doing general machining and repairs. In 1999, we

Xcursion. How much torture did your safety glasses endure to get that Z87 approval? For more information and video of the ballistic testing of safety glasses, scan here.

XCURSIONS are special codes students can scan using their mobile devices to view interesting videos, websites, and articles. An icon in the chapter alerts students to scan the code to access the additional material.

The **Terms Toolbox Challenge** allows students to review the vocabulary terms using their mobile devices. Students can scan the code to access the flashcard-like exercise.

TERMS TOOLBOX

Chips Metal particles of waste removed from the workpiece by machining.

Natural fibers Cotton or wool cloth, which tends to resist hot chip damage and melting, thus protecting the wearer from burns.

Synthetic fibers Plastic cloth such as nylon and polyester, which tends to melt when hot chips touch it.

Z87 or Z87.1 The mark found on safety glasses approved for shop work, which means they will protect your eyes from the front and side in a dangerous environment.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick4e.

TRADE TIP

Besides using letters to track revisions, in your shop, drawing revisions can also be tracked by number or by the date on which they were updated.

KEYPOINT

When receiving a job, always verify that

A. The part number matches the W/O.
B. The drawing revision level and work order revision level agree.

SHOPTALK

Replacement Parts Some shops produce replacement parts for older products—*not the latest version!* In that case, detective work must be done. The changes made over time must be backtracked from the current Rev level back to the ones ordered. Each change must be investigated to see if it is compatible with the latest parts. Will they interchange, or does the planner need to modify them to fit the older product? These can be incredibly complex research issues that must be done before releasing the job to the shop. The good news is that beginning machinists never have to do them! After the planner solves the issues, he or she writes a work order covering the steps needed to make the older version of the part, guiding you to make the right parts.

MOTIVATIONAL CHAPTER FEATURES such as *Key Points, Trade Tips,* and *Shoptalk* are included to show students the practical side of the subject.

All topics in the textbook have been **indexed for programs needing to offer standard skills certificates.** The complete index can be found on the instructor side of the Online Learning Center (www.mhhe.com/fitzpatrick4e). The topics are noted in text with a three-digit numbering system.

TERMS TOOLBOX

Nominal dimensions The desired target value.

Tolerance The amount of acceptable variation from nominal.

Bilateral Tolerance that extends both plus and minus values from nominal only.

Unilateral Tolerance that extends one direction plus or minus from nominal.

Limits Tolerance expressed as a maximum and minimum value.

2.2.1 Bilateral Tolerances

Bilateral tolerances are easy to understand but not always easy to accomplish. That's how we earn our pay! For example, on the engineering drawing you read that a hole diameter specification is to be 0.6250 diameter; then, in the table on drawing, you see the tolerance for a four-place number is "±0.0010."

Question: So, what size range would be acceptable?
Answer: 1.624 in. on the low and 1.626 in. on the high.

Expressing it as a plus/minus range is called a **bilateral tolerance,** meaning its acceptable range extends both directions from nominal.

2.2.2 Unilateral Tolerance

Expressing the tolerance in one direction from nominal is a **unilateral tolerance.** Look at the 1.50-in. width dimension in Fig. 2-5.

$$01.50 \frac{+.000}{-.010}$$

And now what is the range? Answer 1.500 to 1.490 in.

You cannot machine the width larger than 1.50 in., but ten thousandths smaller is okay.

2.2.3 Limits

Sometimes the designer will express the tolerance as **limits** of size; for example, the bottom width:

2.995 in.
2.305 in.

That means there is no specific quality target—any result within the limited range is okay.

Final point: No matter how it's expressed, your task will be to machine and measure the controlled feature well within the tolerance!

Figure 1-7 Hair does catch on moving machinery. Keep it out of harm's way. ©McGraw-Hill Education/Photography by Prographics

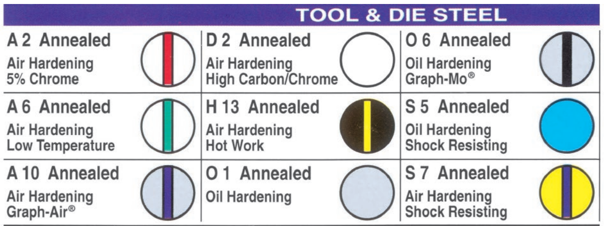


Figure 1-13 Correctly stored and color-code-identified raw materials. Source: Pacific Machinery & Tool Steel Co.

Full-color **photos and illustrations** make concepts easier for students to understand and apply to the information presented.

THE ONLINE LEARNING CENTER (WWW.MHHE.COM/FITZPATRICK4E) contains a wealth of resources for instructors, including an Instructor's Manual with teaching tips and handouts and enhanced PowerPoint slides with videos.

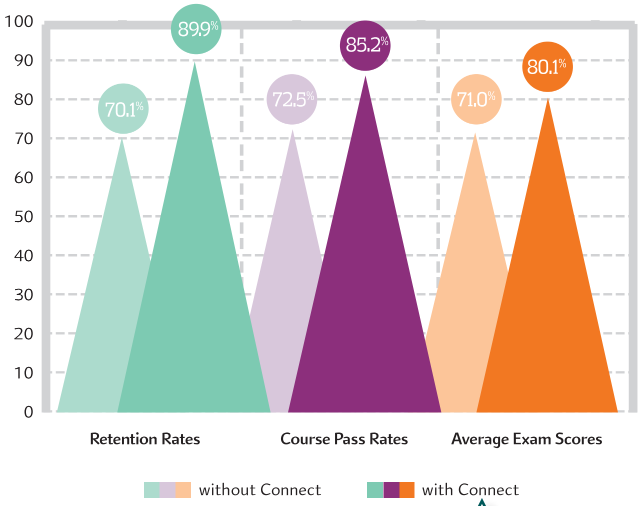
McGraw-Hill Connect® is a highly reliable, easy-to-use homework and learning management solution that utilizes learning science and award-winning adaptive tools to improve student results.

Homework and Adaptive Learning

- Connect's assignments help students contextualize what they've learned through application, so they can better understand the material and think critically.
- Connect will create a personalized study path customized to individual student needs through SmartBook®.
- SmartBook helps students study more efficiently by delivering an interactive reading experience through adaptive highlighting and review.

Over **7 billion questions** have been answered, making McGraw-Hill Education products more intelligent, reliable, and precise.

Connect's Impact on Retention Rates, Pass Rates, and Average Exam Scores



Using **Connect** improves retention rates by **19.8** percentage points, passing rates by **12.7** percentage points, and exam scores by **9.1** percentage points.

73% of instructors who use **Connect** require it; instructor satisfaction **increases** by 28% when **Connect** is required.

Quality Content and Learning Resources

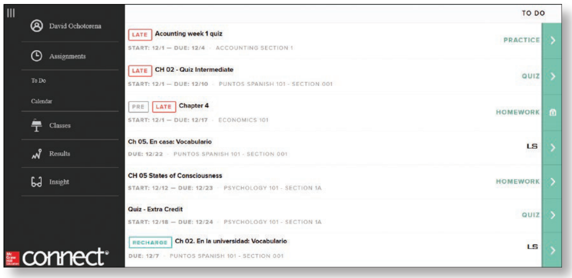
- Connect content is authored by the world's best subject matter experts, and is available to your class through a simple and intuitive interface.
- The Connect eBook makes it easy for students to access their reading material on smartphones and tablets. They can study on the go and don't need Internet access to use the eBook as a reference, with full functionality.
- Multimedia content such as videos, simulations, and games drive student engagement and critical thinking skills.

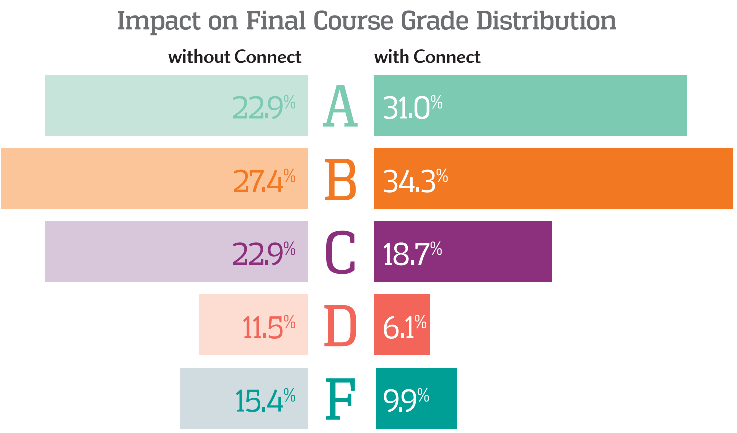
©McGraw-Hill Education

Robust Analytics and Reporting

©Hero Images/Getty Images

- Connect Insight® generates easy-to-read reports on individual students, the class as a whole, and on specific assignments.
- The Connect Insight dashboard delivers data on performance, study behavior, and effort. Instructors can quickly identify students who struggle and focus on material that the class has yet to master.
- Connect automatically grades assignments and quizzes, providing easy-to-read reports on individual and class performance.





More students earn **As** and **Bs** when they use **Connect**.

Trusted Service and Support

- Connect integrates with your LMS to provide single sign-on and automatic syncing of grades. Integration with Blackboard®, D2L®, and Canvas also provides automatic syncing of the course calendar and assignment-level linking.
- Connect offers comprehensive service, support, and training throughout every phase of your implementation.
- If you're looking for some guidance on how to use Connect, or want to learn tips and tricks from super users, you can find tutorials as you work. Our Digital Faculty Consultants and Student Ambassadors offer insight into how to achieve the results you want with Connect.

Part 1

Introduction to Manufacturing

This book is about getting a job in a machine shop. But it's also about keeping that job and advancing career responsibility and pay. For career success, you need to know what is expected of you from the very first day. Like any workplace, there are tasks, procedures, and rules to be followed. Some are formal skills or rules; some are informal and generally accepted by your fellow workers.

Part 1 is designed to impart basic manufacturing knowledge and skills and to clarify trade expectations to help you in the following ways:

Chapter 1 Know how to look, act, and be professional

Chapter 2 Understand, use, and speak the precision numbers of the trade

Chapter 3 Read early lab drawings and be ready for more engineering drawing instruction

Chapter 4 Identify and use geometric dimensioning and tolerancing (GDT) found on drawings

Chapter 5 Work with the materials, documents, and processes before and after the machining occurs

Chapter 6 Use five basic measuring tools, the right way always with the best repeatability

Chapter 7 Use specialized measuring tools when the five basic tools aren't the right choice

For supplemental information on performing part layout and knowing when it's right or wrong for the job, go to **www.mhhe.com/fitzpatrick4e.**

Chapter 1

Professionalism in Manufacturing

Units

INTRODUCTION

This book represents a manufacturing world where computer-aided design/computer-aided manufacturing (CAD/CAM) and computer numerical control (CNC) have changed everything. Planned by a group of industry leaders and instructors, we used today's job market and tomorrow's career needs as our guide. To make room for the new subjects needed for career success, every effort was made to eliminate old technologies and skills no longer relevant to mainstream employment. Our goal was to equip you, the beginning machinist, with the competencies to get and keep that vital first job.

But we also knew that students often breeze past the usual opening chapters to get to the "real training." So why start with a chapter on professionalism and safety?

Because a critical part, perhaps the most critical part, of your training has nothing to do with measuring, reading prints, and running programs on machines, yet getting it right will have everything to do with your success! It might be called work ethic, team spirit, or job readiness. It's often called attitude on an employee evaluation or a grade report. No matter what you call it, it adds up to how you walk the walk of a skilled craftsperson. A large part of the separation between ordinary and skilled workers is a professional attitude.

Although a whole lot more could be said on the subject, these units are enough to get started fitting into a machine shop environment and starting the lifelong process of being a skilled professional. Taken to heart, the message of this chapter will make a real difference in your career.

Unit 1-1 Dressing for Career Success

Introduction: In Fig. 1-1, which person would you want making precision parts for your new car or outboard motor? In truth, they might all be good machinists but—well, you get the picture. The concern here isn't styles of clothing or grooming; it's about being right for a precision shop environment.

Figure 1-1 Which machinist looks right for the job—and more important, for a career? ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

TERMS TOOLBOX

Chips Metal particles of waste removed from the workpiece by machining.

Natural fibers Cotton or wool cloth, which tends to resist hot chip damage and melting, thus protecting the wearer from burns.

Synthetic fibers Plastic cloth such as nylon and polyester, which tends to melt when hot chips touch it.

Z87 or Z87.1 The mark found on safety glasses approved for shop work, which means they will protect your eyes from the front and side in a dangerous environment.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick4e.

1.1.1 Getting Ready for the Work Environment—Eye Protection Always

Figure 1-2 shows several types of eye protection. Most shops supply one or more varieties. The best choice is the one you find comfortable and tend to leave on 100 percent of the time! Many prefer full-vision, wraparound lenses because they are all clear material so you don't see a frame.

KEYPOINT

Safety glasses will bear the mark **Z87** or **Z87.1** on the earpiece if they have passed strict testing and are acceptable for shop work.

Xcursion. How much torture did your safety glasses endure to get that Z87 approval? For more information and video of the ballistic testing of safety glasses, scan here.

Clear or Yellow Lens Color

Either clear or yellow lens color is acceptable. Yellow lenses offset the blue of common fluorescent lighting, and many feel that the correction boosts their ability to read precision tools. Never select dark glasses unless you must work near electric welding flashes because they dull your ability to see details.

Prescription Eyewear

Most wraparound safety glasses can be worn over prescription glasses. But the law requires prescription glass lenses to be made from tempered glass or high-impact plastic, so it is acceptable to wear them alone as long as side shields are added. It's a fact that many eye injuries occur from the side rather than straight on, so shatterproof front lenses aren't enough protection by themselves.

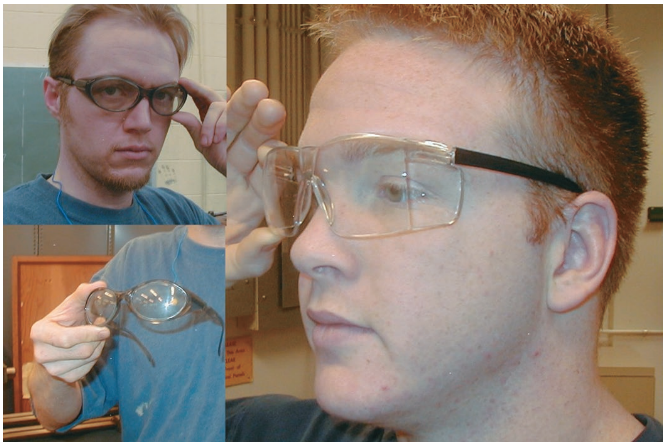


Figure 1-2 The best choice for eye protection is the one you find most comfortable and tend to leave on. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

Extreme Danger Areas

When performing tasks such as disk grinding with lots of flying debris, protect your eyes by adding a full-face shield over safety glasses.

Just Do It!

Be a trendsetter—wear safety glasses even when others don't. Modern CNC equipment usually has containment shielding so the operator feels safe from flying metal particles, but don't forget you must occasionally walk through the shop and pass by other unprotected machines. Make safety glasses a habit by putting them on when entering the shop. Here's an attitude check: You've got it right when you feel strange without your safety glasses. No kidding, I've gone home still wearing them! If those provided aren't comfortable, then find an industrial safety supplier and buy a pair just right for you—that's the kind of pro we're talking about.

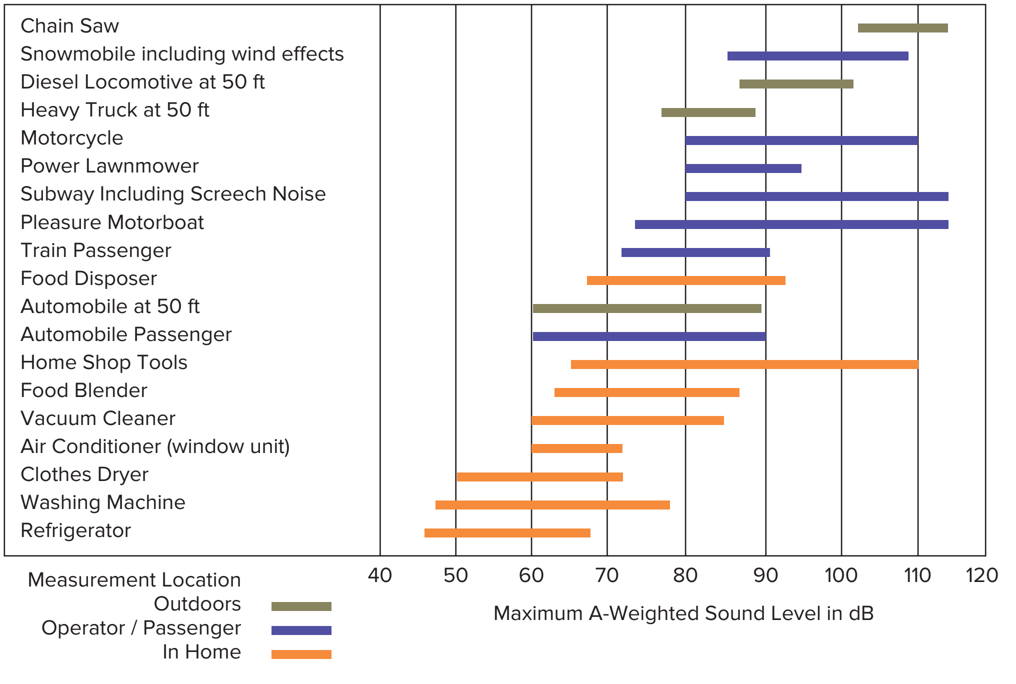
1.1.2 Hearing Protection

Machine shops can be noisy places. Some operations are loud enough to cause hearing loss over time. Prevent permanent damage right now while your hearing is good. Get in the habit of wearing ear protection (Fig. 1-3) where noise gets above moderate—see the chart. The two common types of hearing protection are expandable foam inserts that fit every ear shape and the muff type that fit over your ears.

Figure 1-3 Machinists protect their hearing when shop noise is loud or high pitched. ©McGraw-Hill Education/Photography by Prographics

> **TRADE TIP**
>
> **Hearing Is Your Primary Control** Protecting your hearing is more than personal. Just as when driving a car, the machinist almost always hears a problem developing before seeing it, especially on fast CNC equipment.

Typical Range of Common Sounds



Source: Protective Noise Levels, EPA, 1979, pg. 5.

Earplugs remove the loud spikes but allow controlled hearing. For extreme situations, earmuffs are supplied by your employer. Either way, don't give away your most immediate control sense by not protecting it. And by the way, to control your machine it is important to not use personal music earphones—sorry, but they're not acceptable when running a machine.

1.1.3 Shop Clothing

The main danger of loose clothing is that it can be caught by moving machinery—but you already knew that. Although Fig. 1-4 was set up, really being caught in a machine is no fun—think about it! Wear nothing loose—sleeves, necklaces, untucked shirts—nothing! Well-fit **natural fibers** such as cotton or wool, without pockets or tie cords hanging out, are essential.

Figure 1-4 Seriously, loose clothing does get caught in moving machinery! ©McGraw-Hill Education/Photography by Prographics

Figure 1-5 Two hot chips melted onto this nylon windbreaker while the center one went completely through to possibly burn the person within! Courtesy Mike Fitzpatrick

Why Natural Fibers?

The shavings made when cutting metal are called **chips**. They're hot, as much as 1,000°. While today's CNC machines won't operate with the safety guard open, many older machines will. Flying hot chips must be dealt with. As we study machine operation we'll see several ways to control them, but one action the pro takes is the kind of fabrics worn on the job.

When hot chips contact **synthetic fibers** such as polyester, rayon, or nylon, they stick, then melt through (Fig. 1-5). So your shirt or pants are ruined and the hot metal is held against your skin. Ouch! Not only that, but that makes it hard to concentrate on the task at hand.

An apron or shop coat can be a good choice. But be aware that not all are designed for machining. Some are made for lab work, where machinery won't grab loose ties or pockets. Find one with internal pockets and no loose belts tied in front. Long sleeves are not smart for obvious reasons. A professional approach is to keep a short-sleeved work shirt in your locker.

How About Shoes?

Your work shoes have three safety aspects. I'll bet the third one will surprise you. Work shoes provide the following:

- Protection for your feet from falling objects
- Nonslip soles designed for a shop where chips, coolants, and oils are often on the floor
- Protection from fatigue

Athletic shoes are a poor choice. Even though comfortable, they aren't designed to stand up to a shop environment.

Steel Toes Shoes or boots with steel toe caps are better than shoes without and may be required on the job.

No matter how careful you are, there's always the inevitable falling heavy object. Don't fall for the old tale that someone knows someone who had his or her toes severed by the steel insert collapsing when something really heavy fell on it. Think about it: If the thing was that heavy, it would have done the same damage with or without the steel protection!

SHOPTALK

Quality Could Be Linked to Good Work Shoes or Boots As a machinist, you're going to be on your feet all day, usually on concrete. Guess when most folks make the most mistakes. That's right, at the end of the day when they're tired. Good-quality work shoes offset some of the problems and help keep your mind sharp.

No Accessories

Jewelry catches on moving machinery (Fig. 1-6). Here's another aspect you may not know: Jewelry also conducts electricity and heat. In addition to the safety aspect, jewelry should be left in your locker.

Hair Up

Think about this: Would you reach up and pull a handful of hair out of your scalp? Painful but that would be just a few hairs! So now, imagine a machine wrapping up most of your hair along with a patch of scalp. No kidding! I've seen it happen twice with my own eyes (Fig. 1-7). It gets caught up by static electricity produced during machining and is blown by the air currents swirling around moving tools. A hair band, a bandana, or a hat is right to wear when your hair is long enough to be caught.

That's it. With these dress-for-success guidelines, you're ready to step into the shop and, if you see the bigger picture, into a career.

Figure 1-6 Jewelry is dangerous. It catches on machines and chips and conducts heat and electricity. ©McGraw-Hill Education/Photography by Prographics

Figure 1-7 Hair does catch on moving machinery. Keep it out of harm's way. ©McGraw-Hill Education/Photography by Prographics

UNIT 1-1 REVIEW

Replay the Key Points

- Eye protection is best if it's comfortable.
- Safety glasses will bear the mark Z87 or Z87.1 on the earpiece if they have passed strict testing and are acceptable for shop work.
- Ear protection is necessary in many work areas.
- Well-fitting coats or aprons made of natural fibers are best.
- Footwear must be designed for shop use and comfort.

- Athletic shoes, although comfortable at first, do not stand up to the shop environment.
- Any loose item is a danger, including jewelry and hair.

Respond

1. Are yellow-tinted safety glasses acceptable in the shop? Are brown- or green-tinted glasses acceptable?
2. Describe the two reasons to avoid synthetic fibers and wear natural fiber clothing when running machines.
3. What are three aspects of footwear with regard to safety?
4. Why is hearing such a vital issue for a machinist?
5. For what two reasons does long hair become tangled in moving machines?

Unit 1-2 Handling Materials

Introduction: Working in a machine shop requires the use of many materials. Some are technical chemicals with specific precautions and earth issues. Some are consumables meant to be used up but not wasted. Others are heavy and expensive. This unit lays out the ways to handle them all—like a pro. Doing so is an excellent way to demonstrate a well-tuned attitude.

TERMS TOOLBOX

Choker strap A nylon strap that cinches tightly around heavy objects with a strong eye loop on each end to be attached to the crane.

Heat lot number The original quality control number for a specific metal bar.

Intervertebral disk (disk) The flexible cushion between spinal vertebrae that can be damaged by the wrong lifting techniques.

Jib crane A heavy lifting device that may be fastened to a wall or column to swing in an arc or on portable rollers and often called a cherry picker.

Traceability The ability to link a given bar of metal from "birth" all the way to its final shape and individual serial number.

1.2.1 Lifting Heavy Materials

Always Use a Machine If You Can!

After all, we are *machinists*. The very last thing we use to get a job done is muscle power (Fig. 1-8). In most facilities, you will find one or more of these devices:

- Overhead cranes moving on rails
- Rolling lift tables
- Floor jacks for flat pallets of workpieces and boxes
- Forklift trucks
- Portable **jib cranes**, often called "cherry pickers"
- Jib cranes fastened to a column to pivot around a circular area

a. b. c.

Figure 1-8 Smart machinists use equipment, not muscle, to lift heavy objects. ©McGraw-Hill Education/Photography by Prographics at Milwaukee Area Technical College

Use Your Legs (and Your Head), Not Your Back

However, there comes a time when lifting by muscle power is the only way to get the job done. At these times, the wise machinist asks for help. Two lifters are better than one. In North America, it's estimated that two of five adults suffer from back pain that could have been prevented.

Here's the point: It doesn't happen later in life; it starts right now—today! Unlike the common view, common back injuries don't actually happen catastrophically—during one bad lift! They are the product of lifting wrong over a long time. Everyone has heard about the straight back, bent legs method. It's best, but why?

To understand, let's look at your spine as a piece of machinery: A human lifter is a crane of sorts. In Fig. 1-9, the person on the left has turned her back into a long lever with the pivot point right at her lower back. *This wrong action causes pressure in the range of hundreds of pounds per square inch right on the lower back.* In contrast, the person on the right, bent at the knees, is focusing the pressure on his leg muscles, not his back.

Disks in Your Back

Now focus on that pressure point, the lower back. Your spine is well engineered with cushions between the vertebrae, called **intervertebral disks** (or just **disks**). They provide flexibility and they absorb shock. They also keep the vertebrae apart so nerves are not pinched as you move. Disks are critical and can be damaged (Fig. 1-10). When they are damaged, it can really hurt and even immobilize you!

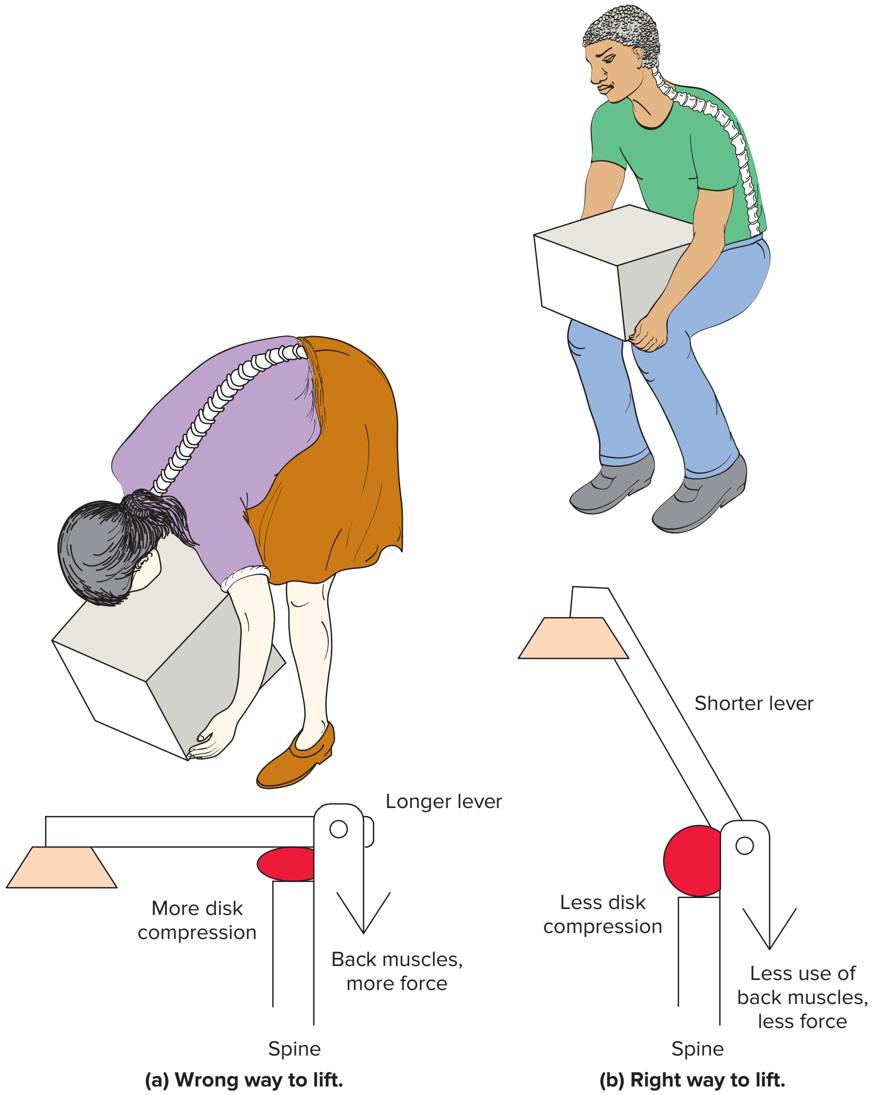


Figure 1-9 Lifting the wrong way and the right way. The worker on the left is setting up a painful future! Note that the spinal disk is under a lot more pressure because she is bending her back, not her knees.

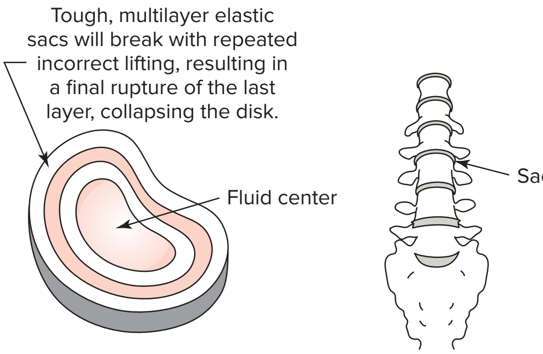


Figure 1-10 A spinal disk is a tough, multilayered shock absorber. But lifting incorrectly can cause progressive damage, leading to a disaster in the future.

The disks are tough, fluid-filled sacs with several layers containing the fluid center. Lifting wrong overpressurizes them, resulting in a blowout. Here's the part most people do not know: When the disks first stretch and break, it's an inner layer or two that goes, and usually the injured person doesn't even know. The layers do not often break all at once! But, with continued bad technique, the last one finally ruptures, resulting in enough pain that the person cannot stand up straight!

KEYPOINT

Lifting wrong is not only the start of a painful future; it also creates a poor professional image.

Carrying Materials

Another aspect of handling heavy objects is carrying long bars of metal. Be cautious of the forward end—it's a ram! If the bar is too heavy to safely hand carry (beyond 40 pounds) or if it's over 8 feet long, there are two acceptable methods:

1. **Crane Carry—One Person**
   In the unbalanced carry, hold the bar with a nylon **choker strap** near the leading edge and pull the remaining bar along on the floor using the overhead crane. One person can perform this carry by being at the forward end. A choker strap is a strong nylon flat strap with loop ends that slip closed with pressure. Your instructor or shop lead will demonstrate this aspect of lifting.

2. **Two Person**
   For the balanced carry, choke the bar near the middle and carry it with both ends off the floor. This requires a second person to walk at the leading edge, to prevent hitting people or objects (Fig. 1-12).

Figure 1-11 Use a crane and choker to haul heavy bars, while an assistant helps control the metal bar! ©McGraw-Hill Education/ Photography by Prographics at Milwaukee Area Technical College

WARNING: Crane Overswing

A suspended heavy bar is a mass in motion that can't "stop on a dime." It will swing forward when you stop pushing or driving the crane forward. Anticipate a short swing forward upon stopping (Fig. 1-11).

Heavy lifting is a skill requiring knowledge of rigging (the lifting devices that contact the work), lift machines, and the physics of lifting. Due to the specialized skills and knowledge required, many shops employ a lifting crew. But this subject is also considered part of the machinist's duty. If you are the slightest bit unsure about how to lift or move an object, get help.

KEYPOINT

Never reach under or, worse, walk under a heavy object during a lift.

Figure 1-12 Two people hand carry long bars by preventing the leading edge from harming people and objects. ©McGraw-Hill Education/Photography by Prographics at Milwaukee Area Technical College

1.2.2 Storing Metals

Our school has received many donations of expensive metal from local shops because careless workers cut the color-coded identification off the bar end or lost the identification tag. Once gone, the bar is useless in most cases, especially when the shop makes people-moving products. In situations where lives could be at stake, once the **heat lot number** (the original manufacturing quality control number) is lost, the metal is not only worthless; it's also illegal to use!

When the design specs must be followed exactly, as in making airplane parts, for example, a continuous history must be traceable from the foundry to final part number. This is known as **traceability**. A specific part will have a specific number assigned to it, called the serial number (S/N). The manufacturer must be able to provide documents tracing the S/N to the heat lot of the metal's original manufacturer. Material can be tested in an independent lab and then recertified, but that's more costly than just buying more metal!

One of several good methods of storing metals is a rack. Note that the bars cannot fall out of the safety storage rack and that short bars are not kept here. "Shorts" are kept on smaller shelves where they won't fall through. Note that they are sorted by type and alloy such that the color-coded identification is facing out (Fig. 1-13). Later, we'll take a look at material identifications and alloys.

KEYPOINT

These are not small details. You must have exactly the right material for the design, and it often must be kept in storage for a specific job.

UNIT 1-2 REVIEW

Replay the Key Points

- Always use a lifting device for your first choice.
- If physical lifting is absolutely necessary, get help—all should bend their knees.

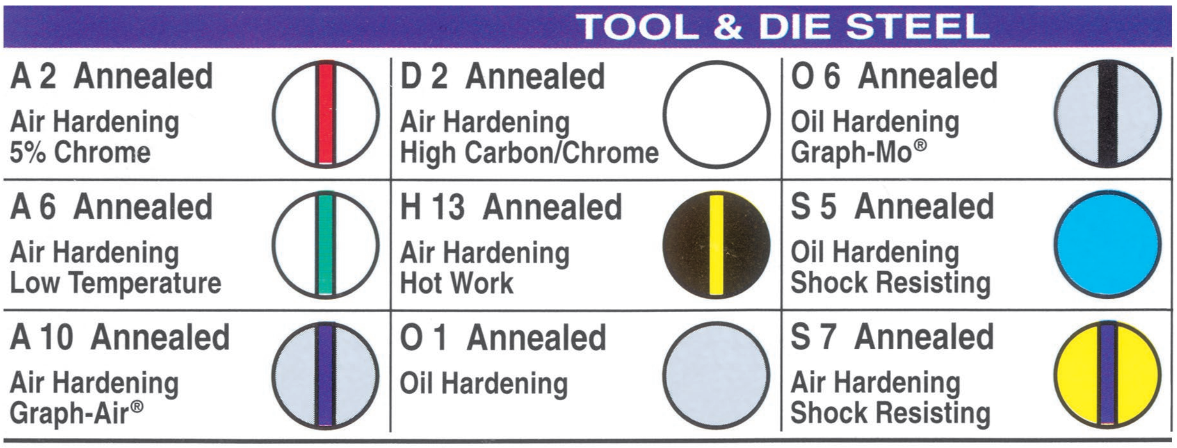


Figure 1-13 Correctly stored and color-code-identified raw materials. Source: Pacific Machinery & Tool Steel Co.

- Carry long bars safely by protecting the leading edge.
- Store long bars in a safety rack and short pieces away from the rack on shelves designed for this purpose.
- Mind the color coding and/or stamps—*never cut them off the bar.*

Respond

1. Name at least three shop lifting aids other than human muscle?
2. A choker strap can be used to carry long material through the shop as long as the forward end of the bar is high in the air. Is this statement true or false? If it's false, what could make it true?
3. Why is material identification important for many types of work?
4. Describe a disk in your spine.
5. Where must short bars be stored?

Unit 1-3 Handling Shop Supplies

Introduction: Today's professional must know the rules when handling materials. Beyond the cost of waste and a ruined planet, the fines for ignoring the rules can cost dollars and company image. Machinists must use chemicals and consume materials with an awareness of the issues concerning each. That means

- CONSERVE, REUSE, RECYCLE, and DISPOSE RESPONSIBLY.

TERMS TOOLBOX

Hydrostatic bearings Found on modern CNC machines, these require an exact oil viscosity to separate two sliding components apart as they move.

Safety Data Sheet (SDS) The product of the federal "Right to Know" act that ensures that workers must be provided the information needed to handle materials safely—found on Safety Data Sheets.

Spindle oil Lubricant designed to prevent rolling friction.

Viscosity The rated property of lubricants to resist thinning out and flow rate.

Way oil A lubricant used to control sliding friction in machines (the part that slides is called the machine's ways).

1.3.1 Your Right (and Obligation) to Know about Shop Chemicals

Promanagement means knowing hazards a material might have and taking the right actions. Those issues and the correct use of each chemical are found in documents called **Safety Data Sheet (SDS)** (Fig. 1-14). Mandated by federal law, manufacturers of chemicals must supply these sheets, and employers must have them on file for all to read.

In general, machine shop chemicals are not overly dangerous. Still, some will ignite, or skin can react, and some produce fumes. Many involve precaution.

The six precautions are

- Fire hazard
- Chemical stripping of skin oils—direct contact
- Fume toxicity and oxygen exclusion (displaces breathing oxygen)
- Eye irritation
- Allergic reactions
- Contamination of other fluids or chemicals, with possible side reactions

For example, we sometimes use acetone to clean and remove dyes from parts. Using the data sheet (SDS) in Fig. 1-14, we find the following:

- Acetone must be stored in a fire-resistant container.
- It should not be in contact with skin or eyes.
- You must avoid breathing excessive or concentrated acetone fumes.

So, using acetone requires a fireproof container. Wear chemical-resistant gloves and work in a place where air circulates—never a small room with closed doors and windows.

KEYPOINT

Although shop chemicals are generally not extremely dangerous, each has its own set of precautions and procedures found in its own SDS. Each also has a correct disposal procedure that must be followed. Knowing is your right and obligation.

1.3.2 The Five Kinds of Shop Chemicals

1. Lubricants
2. Coolants
3. Solvents/coatings
4. Cleaning products
5. Gasses (compressed and liquefied)

SAFETY DATA SHEET

1. IDENTIFICATION

Product identifier	ABC Cleaner
Other means of identification	
Product code	XXXXX
Recommended use	Cleaner
Recommended restrictions	None known.
Manufacturer/Importer/Supplier/Distributor information	
Company name	ABC Company
Address	123 Main Street Anywhere, USA 12345
Telephone	
General Information	123-45-6789
Technical Assistance	123-45-6789
Customer Service	123-45-6789
24-Hour Emergency (CHEMTREC)	123-45-6789 (US) 123-45-6789 (International)

2. HAZARD(S) IDENTIFICATION

Physical hazards	Flammable aerosols	Category 1
	Gases under pressure	Compressed gas
Health hazards	Acute toxicity, oral	Category 3
	Skin corrosion/irritation	Category 2
	Serious eye damage/eye irritation	Category 2A
	Reproductive toxicity (the unborn child)	Category 2
	Specific target organ toxicity, single exposure (oral)	Category 1 (eyes, central nervous system)
	Specific target organ toxicity, single exposure	Category 3 narcotic effects
	Specific target organ toxicity, repeated exposure	Category 2 (liver, lung, kidney, brain)
	Aspiration hazard	Category 1
Environmental hazards	Not classified.	
OSHA defined hazards	Not classified.	

Label elements

Signal word	Danger
Hazard statement	Extremely flammable aerosol. Contains gas under pressure; may explode if heated. Toxic if swallowed. May be fatal if swallowed and enters airways. Causes skin irritation. Causes serious eye irritation. Causes damage to organs (eyes, central nervous system) by ingestion. May cause damage to organs (liver, kidney, lung, brain) through prolonged or repeated exposure. May cause drowsiness or dizziness. Suspected of damaging the unborn child.

05079 Version #: 03 Revision date: 09-14-2016 Issue date: 08-11-2014 SDS US 1 / 12

Figure 1-14 An SDS sheet. When in doubt, read these bulletins. It's your right to know.

You might be called on to use compressed gasses for welding and brazing. We also use liquefied nitrogen for deep chilling when shrinking metal parts for special assemblies. But these tasks are beyond beginners, so we do not study gas safety here. However, be aware there are some highly specialized skills needed to use them. That leaves the other four categories.

1.3.3 Using Lubricants the Right Way

Other than fire hazard, today's machine lubricants are safe and *benign* (not toxic).

TRADE TIP

You Should Know! Fast, modern CNC machines are fussy about getting the exact oil for the duty. An expensive machine can be damaged by adding the wrong lube nearly as fast as not adding any at all. Of highest priority: Oil thickness and resistance to flow, called **viscosity**, are absolutely critical—both from the standpoint of the precision action of the machine and to prevent wear.

Special Oils Must Be Identified and Kept Clean

Several application-specific lubricants are necessary, especially where there is a variety of CNC machines. Both sliding and rotating equipment must have lubrication, but faster machines equipped with high-tech **hydrostatic bearings** depend on an exact thickness of oil between moving components. Components actually "float" on a predictable thickness of oil much like an air hockey puck. Introducing the wrong oil causes a double problem: It can create inaccurate machine movements, but even worse, a thinner film than that required can let metal touch and rub with sure damage to follow!

KEYPOINT

Keep oilcans labeled and stored in a marked, fire-protected area with their tops closed to avoid contamination (Fig. 1-15).

Figure 1-15 Specialized lubricants must be stored in fireproof surroundings and kept free from contamination. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

Sliding Lubricants and Rolling Action Lubes

Oils are used in two very different ways: to prevent either sliding friction or rolling friction. The sliding type oil is called **way oil** because the machine parts it lubricates are also called "ways" (discussed in lathe and mill training coming up). Way oil is thicker than spindle oil. Even thicker yet, grease is occasionally used to prevent sliding friction in some older machines, but it's far less common today. However, if the machine needs grease, then using way oil would be a big mistake!

For bearings that rotate, **spindle oil** is the correct lubricant. There are more kinds of spindle oils than ways due to the wide differences in the kinds of spindle bearings. This is the area where you must be doubly sure to have exactly the right oil. Some bearings are made of ceramic composites, whereas others are ceramic/steel, and still others are steel alone. Some spindles are refrigerated to maintain perfect accuracy, while others aren't. Spindle accuracy and tool life depend on lubrication.

KEYPOINT

Never leave open oilcans in the work area or even in the storage area. They become contaminated with chips and dirt. They could even catch on fire from heated flying chips.

How Do You Know Which Lube to Use?

Lubrication instructions are usually found on a metal plate fastened to the machine, right at the input point. If no plate or other tag is visible, look it up in the owner's manual (Fig. 1-16). Or just ask.

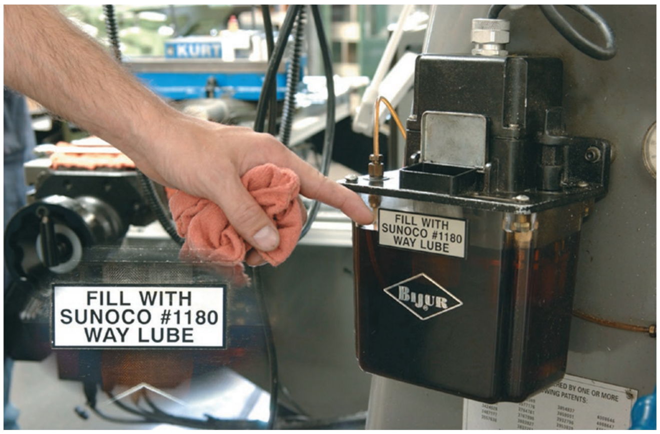


Figure 1-16 Be absolutely certain to add the right oil, especially on CNC equipment! ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

SHOPTALK

Pros Do It! It's often the little things that identify the pro. Here are a few examples. When putting oil in a machine, clean the funnel and spout and do not pour oil while chips are flying. When finished with the fill, wipe the oilcan top before storing it so that it won't collect dirt. Last, put the can in the cabinet with the label turned out for the next user.

1.3.4 Using Cutting Fluids (Coolants)

Later in Chapter 8 you will learn the technology of coolants, also called cutting fluids. Here we'll look at them as shop chemicals. Coolants often make machining safer and faster. Most of today's coolants are water-based fluids that are either flooded or sprayed over the cut area. When used correctly, tools last longer, productivity increases, and horsepower is reduced along with excess heat. Today most shops mix coolants such that one dilution can be used throughout the shop, but others prefer to custom mix for a specific application. For example, a thicker mixture is needed for milling, but a thinner one works best for grinding. The important issues for coolants are as follows:

- If a vapor or spray is produced in the machine operation, it must not be inhaled. Containment barriers and a breathing mask are two good solutions.
- The undiluted syrup used to make coolant is ultracostly. A barrel of the unmixed syrup can cost a week's wages for a journeyman!
- Coolants must be maintained by checking density and adding fresh water because the heat from machining evaporates the water and thickens the dilution ratio.
- Coolants become contaminated with lube oils from the equipment and dirt from machining, called "tramp oil." Tramp oil must be skimmed or filtered out.
- Coolants can be revitalized by chemical treatment and filtration, but at some point coolants must be disposed of. When the time comes, disposal must be done in the right, legal way!

Coolants come in three forms: synthetic, organic, and special threading compounds. *Synthetic coolant* is the most common, especially for CNC work. Synthetics are nonclinging, meaning that they run off the workpiece easily; thus, parts come away clean from the machine, and the shop stays cleaner, too. Synthetics last longer in the machine compared to older organic oils. *Organic coolants* can rot due to bacterial action, over time. Finally, even though their main ingredient is water, synthetic coolants prevent rust on machines and on steel or iron parts similar to antifreeze mixed with water in your car's engine block.

TRADE TIP

Knowing Coolant Ratios While there is a general shop ratio usually around 40 to 1 for most products, different applications may require an exact dilution ratio. For example, a given coolant might work best at 25/1 for milling but 45/1 for grinding. Too much syrup adds nearly no benefit but adds needless cost. But more important, too little degrades the performance of the mix, and it even rusts the machines! Cutting different metals on the same machine can even require differing ratios: Steel can be successfully cut with thinner coolant mixes than titanium, for example.

Highly engineered synthetics (Fig. 1-17) are designed to be both nonallergenic to people and nonreactive to metals.

Cutting oils and cutting compounds (Fig. 1-18) are lubricants that tend to cling to the work, called the wetting property. Different from synthetics, these oils and compounds stay on the tool or work by design. Each has its use. They are either brushed or poured on during the operation. A few of these products are designed for thread machining and are exceptionally effective, but they're also expensive! They pay for themselves in results, but please don't waste them. If not used sparingly, they can contaminate the water-based coolants in the machine reservoir, which becomes tramp oil.

Figure 1-17 Synthetic coolants are highly designed shop chemicals that are mixed with water to make machining more efficient and safer. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

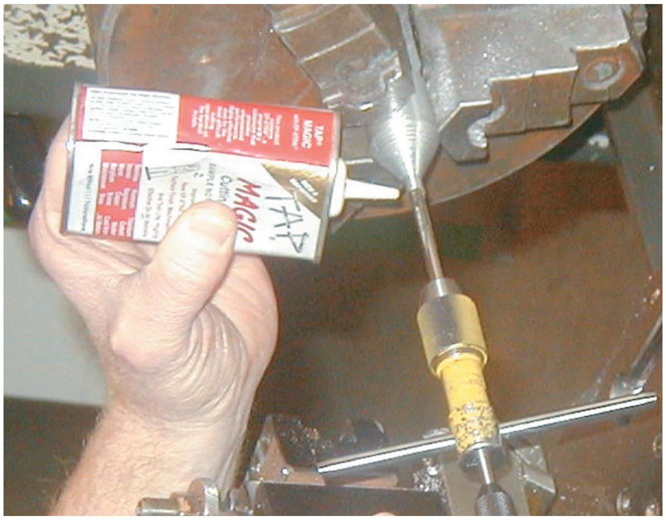


Figure 1-18 Thread-cutting compound makes a huge difference in thread quality and tool life, but it is expensive.

1.3.5 Recycling and Disposing of Waste

All responsible persons working with chemicals today must understand how to sort and dispose of them. That, too, can be found in the SDS sheet. Very few chemicals can be released as is back into the environment.

Most coolants, solvents, and oils must be turned over to a company equipped to either burn or chemically neutralize them based on the type. This is a very specialized operation that is regulated by state and federal agencies. Not surprisingly, it can be more expensive to dispose of chemicals than to buy them. Recycling within the shop whenever possible makes good sense. Your shop will undoubtedly sort the various kinds of scrap and have a well-defined waste program.

UNIT 1-3 REVIEW

Replay the Key Points

- Know the correct use and potential hazards of all shop chemicals.
- Store all chemicals and oils in designated containers and areas.
- Be absolutely certain that you're using the right lube for the application.
- Two kinds of coolants are used in the shop: Synthetic coolants are syrups mixed with water, and cutting oils and compounds are wetting lubricants for cutting metal.
- Always ask for supervision or read the SDS sheet if in doubt about how to handle a chemical.

Respond

1. We find information about shop chemicals on SDS sheets. Is this statement true or false? If false, what will make it true?
2. Synthetic coolants are mixed at dilution ratios of water to syrup from
   A. 20 to 1 up to 50 to 1
   B. 10 to 1 up to 20 to 1
   C. 1 to 20 up to 1 to 50
   D. 1 to 10 up to 1 to 20
3. Machine lubrication falls into two general types (other than grease used on old machines). Name them.
4. Without looking back, name as many precautions as you can recall with regard to shop chemicals (there are six).
5. The sliding parts of machines that must have a specific kind of lubrication are called________.

Unit 1-4 Maintaining Equipment and the Work Environment

Introduction: Our next professionalism subject is not unlike taking care of your car. We all want to believe a clean car gets better mileage but more to the pro point, a messy car says a lot about the driver! Organization equals efficiency. Need proof? When working on your car, how much time do you spend looking for that wrench you just used a few minutes ago?

While the mileage issue might be false, long life and precision results on machine tools are true if they are maintained with care. Operating a new CNC machine means management has trusted you with the value of a dozen or more high-dollar automobiles and, more, with the profit that can be made with it if it keeps running.

TERMS TOOLBOX

Axis lock (override) One of the options a machinist might have to prevent any possibility of a machine moving while cleaning chips from the bin.

Chip breaking The action of breaking chips into easier-to-handle short segments.

Flow glass A glass window in an older machine that indicates the pump is working as oil flows over the window.

Lean manufacturing The study of organizing and managing an efficient work environment.

One-shot lubricator A manual lubrication pump found on smaller machine tools such as school machines.

Sight glass Functions like a dipstick by allowing the fluid level to be seen and compared to a line.

The following duties fall on the machinist. Done well they keep your machine and shop humming. We'll look at three categories:

1. Keeping chips under control
2. Doing under-the-hood checks: lubrication, coolants, and air pressure
3. Maintaining your work area

1.4.1 Removing and Handling Chips

Chips are the ever-present challenge for machinists. They come off the work in two varieties: short and long. Short broken pieces are the ones we try to produce because they're less dangerous and easier to clean up. The long ones can be nasty since they can snag and cut hands. But whatever the chip shape, here is a list of possible hazards to control (Fig. 1-19):

- Chips are *hot* right after they are made—they may be up to 1,000° Fahrenheit in standard machining and even higher when special ceramic cutters are used.
- Chips are *sharp*—as sharp as a razor at times—sharper actually since the edge may be only a few microns wide due to the way they are sheared off the workpiece!
- Chips *fly like bullets*—as much as 150 miles per hour on manually operated machines but up to 250 or more for CNC high-speed machining!
- Chips are *strong*. The long string type can catch and drag the unwary machinist into machines—this is the greatest danger. They can also cut deeply if drawn across your skin.
- Chips are *slippery* on bare concrete floors.

Thinking of resigning? Hold on, with some preparation and prevention, these nasty critters can be tamed and controlled. There are lots of ways that we'll learn as we study drilling, milling, and turning.

Figure 1-19 Long, stringy chips are strong *razor wires* that catch clothing and cut skin. All chips, even the safer "C" shapes on the right, can be dangerously hot. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

Two Different Ways to Clean Up Chips

For now, let's talk about getting them out of the area. There are two ways we remove chips from machinery, depending on what the machine is doing:

- When the machine is operating and making chips
- When it's stopped; for example, when the chip bin is full at shift change or at the end of the job

For safety, each requires a very different action on your part.

Machine Not Running Chips pile up fast (Fig. 1-20). Many CNC machines feature some form of automatic removal system, while others require the machinist or helper to intervene by blowing, raking, or brushing them away. We dispose of chips as we go but sometimes they get ahead of us and even the automatic chip conveyors get backed up. Whatever the reason, it's time to stop machining and get them out of the way. That means cleaning the chip bin, which almost always puts some part of your body at risk if the machine were to start.

Lock It Up or Lock It Out

Before reaching in to clear chips out, be absolutely sure the machine is locked or blocked from accidental startup, in case you bump it on or someone else might start it by accident (Fig. 1-21). Many CNC machines feature an **axis lock (override)** function. Other machines

Figure 1-20 Chips can pile up quickly and must be removed from the machine. Courtesy Mike Fitzpatrick

Figure 1-21 Lock it out or lock it up—never perform maintenance on a machine that can be started accidentally.

such as manual lathes require throwing the main power switch. But that might be a disaster on an older computer-driven machine because of the loss of data and/or setup positions.

KEYPOINT

Never reach into a machine to remove chips unless it is locked up or out. If you must go to the back of the machine, tell someone you are there so it can't be accidentally started.

If neither locking out nor turning off is possible, then do the following:

A. Turn CNC axis overrides to zero whereby no movement will occur.
B. Place a sign over the panel: "*Operator Cleaning Chip Bin*."
C. Tell fellow machinists you are cleaning in the back or out of sight.

TRADE TIP

Chip Breaking There are two ways of breaking stringy chips into safe little packets. In the first, using heavier machining action forms thicker, stiffer chips that cannot take the bending action of being removed from the parent metal. They then break into small "C" shapes. The other answer is using a cutting tool with a chip breaking dam (Fig. 1-22). The obstruction redirects the flowing chip such that it snaps off. We'll see more on both techniques in tool geometry later.

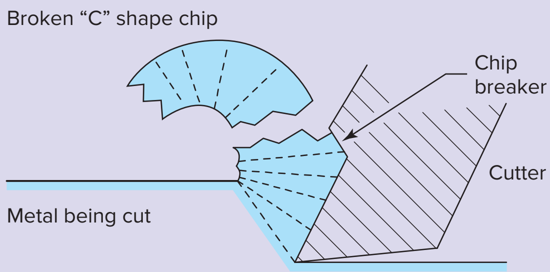


Figure 1-22 A chip breaker bends the flowing chip so quickly that it snaps off into small "C" shapes rather than a long string.

Now with the machine safely locked up or locked out, with no possible machine movement, put on gloves and rake the chips out safely. If you are assisting other machinists (you aren't the machine operator), be absolutely sure that the person who is the operator knows you are working in the machine chip bin.

Clearing Chips from Operating Machines

This is a very different procedure from the standpoint of safety. It's often necessary to clear away chips from machines while they're being made. This is a machinist's prime duty. Here are the details:

- If your machine is moving *do not wear gloves.* Lacking sensitivity, gloves put your hands at increased risk of being caught in the machine.
- Never reach in the machine with your hand or a gripping tool such as a pliers or vise grip. Can you guess why? Because you can't let go fast enough if the chips or machine catch the gripping tool.

Here are four safe ways to remove chips from moving machines:

- A sturdy brush
- Coolant stream
- Compressed air
- A chip rake or chip hook

The brush is a safe, self-explanatory tool used on drills and mills but not lathes and CNC operations since your hand is too close to the action. Although they sometimes get "eaten" by the machine, you can't hold on tightly enough to a brush to get hurt. A brush is the first choice of beginning machinists in training where chip volume is low.

SHOPTALK

Recycling Metal Chips Is Good to Mother Earth Most modern shops recycle as part of an environmental effort and because of cost savings, too. Larger chunks of metal are kept separated from the chips since each is handled differently at the recycling center and has different values. Correct sorting ensures value. The wing spar in Fig. 1-23 started out weighing over 500 pounds but when finished weighed only 8 pounds—96 percent of the weight became chips. Recycled aluminum chips require *80 percent less energy* to remelt and pour back into useful aluminum again compared to refining raw material from the earth.

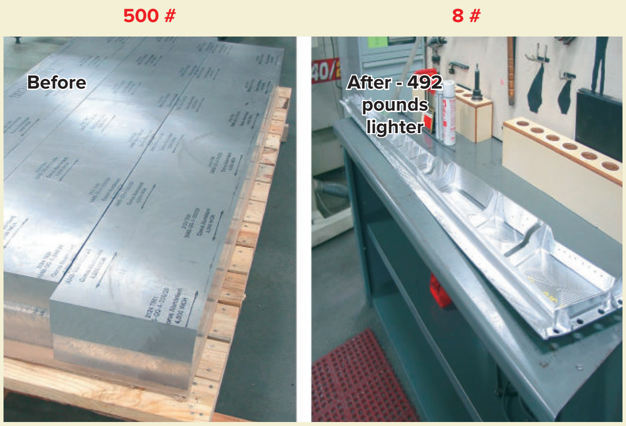


Figure 1-23 Sorting chips from scrap metal, then recycling each improves profitability plus it saves 80 percent of the energy required to mine and then refine raw metal. Courtesy of Aerospace Manufacturing Technologies (AMT)/Arlington, WA

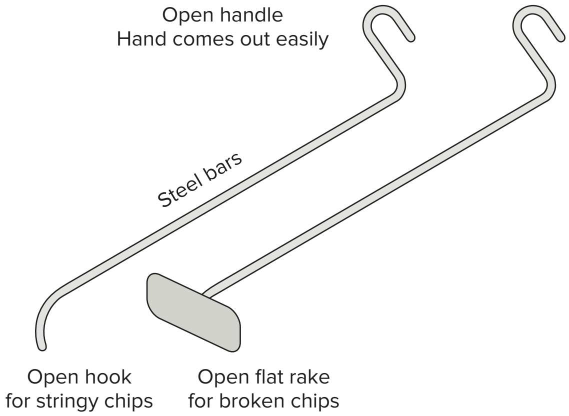


Figure 1-24 Chip hooks and chip rakes feature open handles designed to not get caught in moving machinery.

Figure 1-25 Compressed air is a good chip removal and cleanup tool when correctly used. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

Using a Chip Hook or Chip Rake

The longer chip hook pulls long, stringy chips out of the machine, while a rake removes broken chips. Both tools are made with handles that can't grab your hand should the business end accidentally get caught in the machine. The handle should not turn back into a closed loop. Figure 1-24 shows the right shape. Notice, too, that the hook end is not a full 90° either. The open hook tends not to catch on the machine and also to release the chips easily.

Compressed Air

Nearly every shop uses compressed air to power hand tools, to actuate machine actions such as pneumatic clamps, and also for cleanup work. Air is a safe and efficient tool used for chip removal in modern machining. But it can be misused against both people and machines. Use these two pro guidelines to stay out of trouble (Fig. 1-25).

Guide 1. Personal Danger—Never blow off chips from your skin or clothing or point the air at fellow workers! You can embed chips in skin or even inject air under the skin. It is possible to introduce air into veins and arteries, where serious consequences can occur. It should be obvious: Never point the airstream, with or without ejected chips, at someone or at other machines. At the *very least*, damage to computers, delicate measuring tools, and your reputation can occur. When using air on a manually operated machine it's best to place a guard wall behind or beside it to protect others.

Guide 2. Machine Safety—Never point compressed air at seals on the machine. All machine tools are equipped with seals designed to keep dirt and metal chips away from bearings and precision flat sliding surfaces. However, these tough seals are not able to stop pressurized air. Air can force chips under the seals, defeating their ability to stop further invasion.

KEYPOINT

A carelessly air-injected chip in a machine seal lifts the seal, thus defeating its usefulness. The embedded chips can also scratch precision surfaces.

Used correctly, compressed air works well to keep chips out of the immediate machining area, especially when the machine is moving. An airstream enables chip ejection without holding any solid object between you and the machine. It can't get caught and pull you into the machine. However, air cleaning and chip ejection are controversial. Many shops have an air policy.

KEY POINT

Ask First
Although it's used commonly, be aware that due to the potential for machine damage some shops have a strict rule against using air as a chip cleanup tool.

TRADE TIP

Coolant Air Substitute Where air is banned for chip control, try a directed coolant stream with less velocity but more mass. It can do the job every bit as well with no danger to seals. Plus the hand-aimed stream can improve tool life since the operator can concentrate coolant right when and where it's needed during heavy machine cuts. This tip works especially well on CNC machines with strong coolant systems and full containment guards to catch the splashing. A tee-fitting put in the coolant delivery hose is connected to any flexible hose and garden nozzle. This little accessory works wonders—try it!

1.4.2 Maintaining the Work Area

As boring as a list might be, it can't be avoided here if you are to know what the other machinists will expect of you when you enter the craft. Here are a few unwritten rules on how to keep your shop lean and mean:

- As much as possible, keep measuring tools away from the machine and in their case.
- When laying measuring tools or wrenches down, never lay them on sliding machine parts such as lathe ways. Do put a shop towel under them on your workbench.
- Keep clutter such as rags, metal scraps, and especially old paperwork picked up. Keep personal items to a minimum, too.
- Keep chips swept and picked up.
- If you see something that needs maintaining, fix it or report it, but don't ignore it.

Checking Machine Fluid Levels

Oils are consumed and coolant levels fall due to splashing, evaporation, and small amounts leaving on the work itself, called *clinging*. Nearly all newer CNC machines feature sensors and low-fluid alarms, but not all are so equipped and no manually operated machines have this protection. To determine fluid levels in these machines, there might be a dipstick or a **sight glass**, such as the one in Fig. 1-26. This is simply a little glass window into the side of the reservoir. Add the lubricant or coolant to the indicated full line.

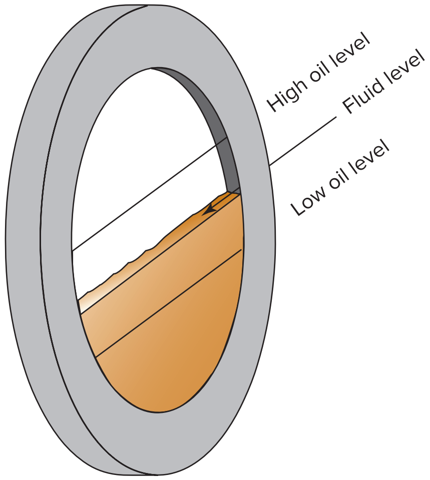


Figure 1-26 Sight glasses are small windows in the machine's oil sump that show the fluid level.

TRADE TIP

After wiping the oil and dirt from exposed, precision sliding surfaces, remember to replace with a wipe or spray of clean oil of the correct type. While these surfaces will be automatically lubricated by the next motion of the machine, however, the oil is absent unless you put it there for the first movement.

Lubrication Flow Glasses

When maintaining older machine tools, you must know the difference between a sight glass for checking fluid levels and a **flow glass** for coolants and lubrication. A *sight glass* has a line on the clear window; its purpose is to see critical fluid levels. It's like a dipstick, telling you how much oil or coolant to add.

No line on the glass or around the window's outside rim means it is a *flow glass*. It's a foolproof way of seeing that the fluid pump is working. A flow glass shows when oil is moving. When the pump is working, the oil flows down over this glass.

KEYPOINT

Caution, machines may have more than one sump with different oils in each.

On many smaller machines like those used in a typical machining course, there is probably a central, manual lubricating oil pump for sliding surfaces. Its handle must be lifted or pumped each time you step up to the machine and once each hour of operation. This is sometimes referred to as a **one-shot lubricator** (Fig. 1-27).

Figure 1-27 A one-shot central lubricator. Use at least once per half day or on the schedule set by your instructor. ©McGraw-Hill Education/Lake Washington Technical College, Kirkland, WA

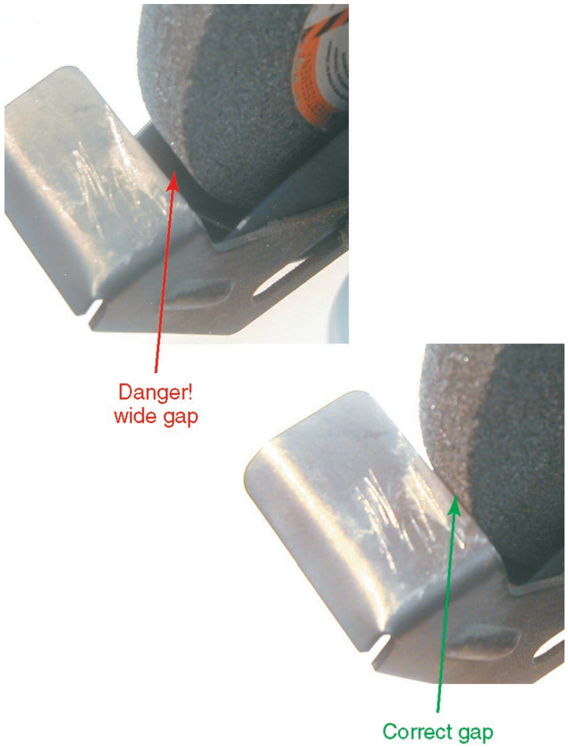


Figure 1-28 Due to grinding wheel wear, this tool rest gap has become dangerously wide and must be adjusted closer to the wheel to avoid pulling in small parts and fingers! Courtesy Mike Fitzpatrick

Adjustments to Equipment

Naturally, there are many routine adjustments that must be made on machining equipment—to walk the walk, don't walk away from them. Make adjustments when they need to be done and on a schedule, too. Safety guards, for example, or eye shields, and doors that close for containment, chuck guards, limit switches, and belts—they're everywhere in a machine shop, and they are part of your job.

Tool rests on bench grinders (Fig. 1-28) are a perfect example. As the grinding wheel is used, the gap widens. To minimize the pinch point created between the grinding wheel and rest, keep adjusting it to a minimum of 1/16 in. or less. Zero clearance is acceptable because items cannot be pulled into the gap, but it could result in the tool rest being eventually worn away.

1.4.3 Managing the Workplace—Lean and Green

Along with the machines and tools of the trade, the work area is also a tool that requires attention and proper care. A recognized trait of professional machinists is the pride they show in the way they organize and maintain their work area. But the subject involves more than pride—if managed correctly, tasks go faster and have more reliable results.

There are several names for the science of efficient work areas and environments, but the most common is **lean manufacturing**. The heart of lean manufacturing is finding the most efficient, logical way to organize and manage a working space. Using the lean concepts we count the steps and minutes required to complete a task, then do whatever it takes to reduce them. After observing the task, or a process and the people doing it, we ask what tools and supplies are needed and whether they can be placed closer to the task. Once provided, a system is created to keep them there consistently.

So you can see that lean focuses on common sense applied to shop procedures. Another aspect of lean lies in reducing unused inventory and clutter—old tools, leftover materials, that item "you might need sometime"—called the 5S process. While there's a lot more to the science, it starts with people having exactly what they need to do a job right where they need it and eliminating clutter. It also means returning tools to their place throughout the shift—not just at quitting time.

Figure 1-29 A lean shadow board and machine. Courtesy Tyee Aircraft, Everett, WA

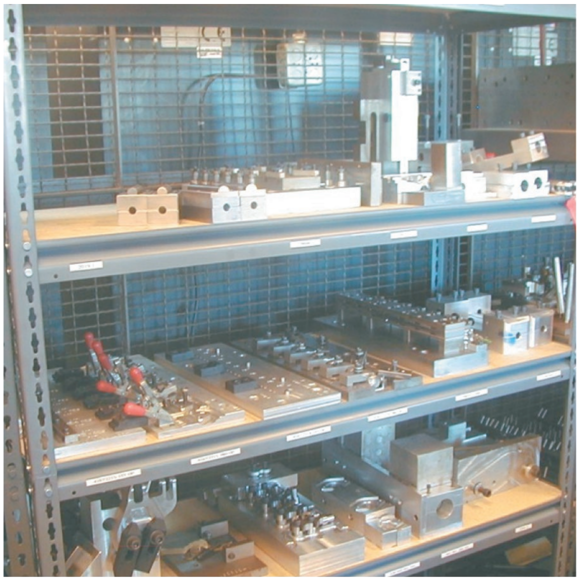


Figure 1-30 Machine accessories must be stored and transported correctly. Make sure they are on shelves made for heavy storage. Courtesy Tyee Aircraft, Everett, WA

Lean people constantly control the space in which they work. It's a habit.

A picture says it all (see Fig. 1-29). Your company may sponsor workshops where teams work together to get their area up to this level of efficiency. But there's nothing wrong with you becoming a committee of one! Start with your toolbox and the immediate area in which you work. Here are a few more ways to keep the workspace humming.

Safely Storing Machine Accessories

Machine accessories are precise, heavy, and expensive. Use lifting equipment to move them to avoid back injury and to minimize the chance of dropping them. Store them on shelves made for the load they represent and set them back from the edge (Fig. 1-30). If the stored item is a machine accessory or finished metal part prone to rusting and if it will not be used for some time, a light coat of protective oil is in order before storage.

The 5S Process to Become Lean

The obvious goal of becoming a lean machine shop (or company) is to be more efficient, thus profitable, by identifying and eliminating several categories of waste:

- People time
- Unused inventory
- Process time
- Inefficient processes
- Overproduction

But in a much greater sense, it's a way to change the essential culture of how you go about manufacturing. Shops wishing to become lean follow a set of steps called the *5S process:*

Sort (Inventory everything)

To be certain of upcoming decisions to surplus or not, a team surveys tools, parts, inventory, and fixtures; then determines which are useful and which must be eliminated. They then surplus the unneeded, unused, and clutter! This is not an easy step, but it is necessary!

Straighten (Organize)

Everything—tools, supplies, and instruction—gets a specific location such as a shadow board or labeled shelf. Figure 1-29 is as close to the point of use as possible. This phase is also about creating a culture of putting it back continuously—not just at the end of the day or week.

Sweep (Make it look lean) (see Fig. 1-30)

This is as much a visual kickoff to the newly improved shop as it is a lean-making tool in itself. Clean, paint, label where things go—make the shop shine! Completing the sweep, add to the lean culture that everyone keeps it that way! Taken as a whole, the sweep phase is a celebration of the new you.

Standardize (Make it permanent and ingrained)

This is where you solidify all the changes—create third-order change, not just paint and labels. Lean becomes the shop norm—planning and scheduling upkeep and preventive maintenance, for example, assigning responsibility, anything that makes your decision to be lean a permanent change with 100 percent buy-in from all workers.

Sustain (Set up schedules and audits—reevaluate)

Now lean is a way of doing your job. Schedule and post audits about how it's going. The objective is to be on and stay on track and to get even leaner as you learn. This is the long-term investment: Investigate and improve systems and culture—encourage each other, and celebrate success by recognizing improvements in quality, costs, and customer satisfaction!

ISO 14001 to Become Environmentally Responsible—Green

Reacting to several earth-related issues facing us all, the International Standards Organization (ISO) has developed standards that help organizations take a proactive approach to managing environmental issues. ISO 14000 sets the standard and 14001 guides implementation.

The ISO 14000 family of environmental management standards can be implemented in any type of organization in either public or private sectors—from companies to administrations to public utilities. ISO is helping to meet the challenge of climate change with standards for

- Greenhouse gas accounting
- Verification and emissions trading
- Carbon footprint measurement of products

ISO develops informative documents to facilitate the fusion of business and environmental goals by encouraging the inclusion of environmental aspects in product design. ISO offers a wide-ranging portfolio of standards for sampling and testing methods to deal with specific environmental challenges (see Fig. 1-31). It has developed some 570 international standards for monitoring:

Figure 1-31 The basics of ISO. Source: International Organization for Standardization, ISO Central Secretariat.

- Quality of air, water
- Soil, as well as noise, radiation
- Control of the transport of dangerous goods
- The technical basis for environmental regulations

Xcursion. Become an informed machinist, and sign up for the ISO newsletter and view their informative presentations.
Scan here.

ISO Environmental Standards 14000 and 14001 for business, government, and society as a whole make a positive contribution to the world we live in—and are accepted in 160 countries. They ensure vital features such as quality, ecology, safety, economy, reliability, compatibility, interoperability, conformity, efficiency, and effectiveness. They facilitate trade, spread knowledge, and share technological advances and good management practice.

ISO develops only those standards that are required by the market. This work is carried out by experts on loan from the industrial, technical, and business sectors who have asked for the standards and have subsequently put them to use. These experts may be joined by others with relevant knowledge, such as representatives of government agencies, testing laboratories, consumer associations, and academia, and by nongovernmental or other stakeholder organizations that have a specific interest in the issues addressed in the standards.

1.4.4 Fire Prevention and Safety

You will be given specific training in your school lab and on the job about fire prevention. Here are a few rules for safely controlling a shop fire:

1. Know where the exits are located in your shop.
2. Never attempt to fight a fire without knowing how you can escape. Fight a fire with your exit clear.
3. Know which kind of extinguisher fights which kind of fire:

   A = Common burning objects—wood, paper—anything that leaves an **A**sh.
   B = Volatile liquids—lubricants, gasoline—anything that goes **B**ooom!
   C = Electrical fires—anything with an energized **C**ircuit.

Remember: Never attempt to fight an electrical fire with an extinguisher not designed for the purpose. Turn the power off before attempting to fight an electrical fire.

A	Common Combustibles	Wood, paper, cloth, etc.
B	Flammable liquids and gasses	Gasoline, propane, and solvents
C	Live electrical equipment	Computers, fax machines (see note!)
D	Combustible metals	Magnesium, lithium, titanium
K	Cooking media	Cooking oils and fats

Figure 1-32 Notice the flammable metals category—titanium and especially magnesium and the new symbols.

Most shops employ A-B-C extinguishers, but read the label to be certain (Fig. 1-32)—you can get it wrong with unwanted results!

4. Be certain you CAN extinguish the fire—schools may have specific rules on this.
5. Above all else—be certain that all persons have been informed and evacuated—your first concern before extinguishing the fire!
6. Be certain that someone calls the EMS fire department immediately—don't wait until you KNOW you can't control the fire. This is a critical step—do it simultaneously with the effort to control the fire. (Author: "I speak from experience; the fire department doesn't mind being told that the emergency is under control—while racing to the fire, they like to hear a radio call to 'lower your code to an inspection.' But they do mind finding they could have controlled the fire if called in time!")
7. Review the PASS process for fighting a fire:

   Pull the pin.

   Aim at the base source of the flame.

   Squeeze the trigger.

   Sweep over the whole source to exclude oxygen from reaching any area.

UNIT 1-4 REVIEW

Replay the Key Points

- Depending on whether the machine is working or stopped, safe chip removal actions are very different. Identify or describe them.
- Air is a safe chip removal and cleanup tool, but some shops ban its use in this capacity.
- Lubrication is technical and often the machine operator's responsibility. Using the wrong oil can damage technical equipment almost as soon as using none at all!
- Savvy machinists keep their eyes open for conditions that need attention, and they fix problems themselves.

Respond

1. Why is air not always permitted as a cleanup tool?
2. Gloves are acceptable when removing long, stringy chips. Is this statement true or false? If false, what makes it true?
3. Why are flow glasses not found on modern CNC machines?
4. Name the four safe methods of removing chips from moving machinery.
5. Complete this sentence: Shop-made chip hooks and rakes are made such that ______________.
6. List and describe the 5S process.
7. What is the ISO standard that aids shops in becoming environmentally responsible?

CHAPTER 1 REVIEW

Terms Toolbox! To review key terms, please go to **www.mhhe.com/fitzpatrick4e.**

Unit 1-1

No part of Chapter 1 has been filler material. Demonstrating a professional attitude in the way you dress for the shop environment is one of the best tools you can develop to show your instructor and employer early on that you are on your way to becoming a top gun.

Unit 1-2

Back injuries are a serious concern for any machinist. Once you damage your back, it can become a lifelong disability. Pay close attention to the guidelines in this unit for handling and moving shop materials safely.

Unit 1-3

I once took my CNC class on a tour of a local shop. As we walked in I saw an apprentice I had previously trained, putting away a 5-gallon oilcan. Not realizing we were watching her, she carefully wiped the top, then rotated it so the label could be read. Only then did she close the door to the fireproof cabinet. I was truly proud but also noticed her supervisor nod toward me with approval!

It's details like that—taking care of shop supplies, knowing their value, and using them responsibly along with having a good respect for machine accessories and tools—that give the beginner the walk of a journeyman. They will be noticed or, more important, when they are ignored, they get noticed even faster.

Unit 1-4

Maintaining a well-organized work environment is an important step in keeping the workplace safe. It is much easier to spot potential problems in a clean and organized space than a dirty and cluttered one.

Keeping your machines in good repair with all safety guards in place is an important way to create a safe working environment. Equipment that does not work properly can lead to disastrous accidents.

QUESTIONS AND PROBLEMS

1. Describe a well-dressed machinist. Use at least five dos and two don'ts. (Unit 1-1)
2. True or false? It's okay to listen to music with a personal player as long as you leave one earphone out to be able to hear your machine. If it is false, why? (Unit 1-1)
3. List the best to worst ways to lift heavy objects. (Unit 1-2)
4. Name two (of three) professional precautions for storing metal bars. (Unit 1-2)
5. Explain why we use the bent knees lifting technique in 10 words or less. (Unit 1-2)
6. What would you expect to find on an SDS sheet? (Unit 1-3)
7. Lubricants fall into two general groups, to prevent ____________ and ____________ friction. (Unit 1-3)
8. True or false? It's okay to substitute lubricants as long as the new one has a higher viscosity than the required oil so it prevents friction better than the original. If it is false, why? (Unit 1-3)
9. Why do we not wear gloves around moving machinery? (Unit 1-4)
10. True or false? Pressurized air is permitted as a cleanup and chip removal tool in all modern shops. If it is false, why? (Unit 1-4)

CRITICAL THINKING

11. A bar of spring steel has been misplaced, but you have found another that you are sure is the same material. Can it be substituted for the job? Is there a way to maintain the traceability? (Unit 1-2)
12. True or false? Dark glasses impair vision, and they are never worn in the machine shop. If it is false, why? (Unit 1-1)

CNC QUESTIONS

13. Your CNC mill has stopped after completing a part cycle and a red light flashes while your operator's panel tells you that the way lubricant is low. Name three or more professional steps needed to get the machine up and running again. (Unit 1-2)

14. Why do you suppose the machine completed the cycle in Question 13 before it shut down due to low supply of a vital fluid? (Unit 1-2)

15. Why must a specific lubricant be used in most modern CNC bearings? (Unit 1-3)

CHAPTER 1 ANSWERS

ANSWERS 1-1

1. Yes for yellow lenses; no for dark unless working near incidental welding light. Note: Dark lenses will not protect your eyes from looking directly at a welding flash; they only protect from incidental light reflected off walls and ceiling.
2. Natural fibers stand up to hot chips so they don't melt or burn the wearers—breaking their concentration.
3. Traction, foot protection, and fatigue
4. Besides the joy of hearing, it's your prime control of the process.
5. Air currents and static electricity

ANSWERS 1-2

1. Three or more: overhead cranes moving on rails, rolling lift tables, floor jacks for pallets and tub skids, forklift trucks, portable jib cranes often called "cherry pickers," jib cranes fastened to a column to pivot around a circular area
2. False. The forward end high makes it out of your reach and out of your control.
3. For two reasons: Once the ID is lost, the metal cannot be proven without a lab test as to what alloy it is. Traceability demands that there be a trail from original manufacturer all the way to a specific part. Losing the ID means that it is gone.
4. A fluid center surrounded by several layers of tough skin
5. On a shelf where they cannot fall through

ANSWERS 1-3

1. True
2. A
3. Sliding (way oil) or rolling (spindle oil)
4. The precautions are fire hazard, chemical stripping of skin oils—direct contact, fume toxicity and oxygen exclusion (displacing oxygen), eye irritation, allergic reactions, contamination of other fluids or chemicals with possible side reactions.
5. Ways

ANSWERS 1-4

1. It may be banned due to potential damage to machine seals.
2. False. Use gloves only when the machine is not moving.
3. They are equipped with oil level sensors and alarms.
4. Chip hooks/rakes, airstream, coolant stream, brushes
5. Neither end can catch on machines or hands.
6. Sort (Inventory everything)
   Straighten (Organize)
   Sweep (Make it look lean)
   Standardize (Make it permanent and ingrained)
   Sustain (Set up schedules and audits—reevaluate)
7. ISO 14000 sets standards; ISO 14001 guides for implementing.

Answers to Chapter Review Questions

1. Do wear eye protection, shoes designed for the shop, hearing protection, tight-fitting clothing of natural fibers, a shop apron or coat. Don't wear jewelry or gloves or leave long hair uncontrolled. Any shop coat or apron should not have loose ties or pockets.
2. False. Any disturbance to hearing impairs machine control.

3. Mechanical devices (crane, shop lift, forklift, etc.); two or more people working together, all using correct technique; one person using the bent knee method
4. Never store short bars in the long bar rack where they could fall through. Store them with their ID visible and never cut the color code or stamp from the bar.
5. To prevent excessive pressurization and damage to disks in the spine
6. Instructions for the safe use and disposal of specific chemicals plus storage and special precautions
7. Sliding and rolling friction
8. False. The viscosity of a lubricant is determined by its purpose. Using the wrong lubricant can lead to expensive repairs.
9. Gloves desensitize your hands, which tends to help get fingers caught in machinery.
10. While air is used by many as a cleanup tool, it can also cause damage to machine seals and other items in the area. It may be banned for this purpose in many shops.
11. The short answer is *no*, at least not by you. However, if the heat lot for the new bar is on record and its specification matches the lost bar, then the paperwork can be cut to make the substitution—the traceability thread is not lost this way.
12. It's mostly true. But we sometimes must work around electric welding. Then they are okay to prevent incidental light damage to eyes.
13. A. Determine the specific way lube that's right for that machine.
    B. After getting the right oil, make sure the funnel and can are clean before opening the oil port on the machine (to avoid contamination of the reservoir).
    C. Fill until the sight glass line shows the reservoir is full.
    D. Close the can and return it to the storage area (to prevent fire hazard and to keep the can from being contaminated).
14. Modern CNC machines tell the operator when necessary fluids are low long before they reach the critical point. Therefore, the control allows finishing a cycle before stopping.
15. They depend on an exact viscosity for accuracy as well as long life.

Chapter 2

Math Skills Self-Review

Units

2-1 Understanding Precision (pages 27–31)
- Say decimal inches using the language of the shop
- Use measurements at one thousandth of an inch or smaller
- Convert between metric and imperial units (review)
- Appraise your needs for further review

2-2 Using Feature Tolerances (pages 31–32)
- Do a quick review

If you feel you need some math review for training and career, sample problems can be found at www.mhhe.com/fitzpatrick4e.

INTRODUCTION

Machining means math—lots of it. It doesn't matter whether you're a top toolmaker, a programmer, or a beginner, nearly all your actions in the shop will be based on numbers, and most must be calculated in some way. There's no escaping it. Every step from the design to final inspection requires math.

Today, calculators are as common in the machinist's toolbox as micrometers. This need for number skills is only going to increase as we commit further to technology. Are you ready, or would a little review be in order? Chapter 2 helps you answer that question and offers some hints about how to approach shop math. In addition, Chapter 2 is provided as a self-appraisal warmup. If after trying the problems your score is below expectation, then a refresher math course or some self-study is indicated. Here are the goals of Chapter 2 to get those gray cells humming.

Unit 2-1 Understanding Precision

Introduction: What does precision mean? The answer varies depending on the science or profession in which the word is used. In machining, it means cutting and measuring part features to within a few thousandths of an inch or decimal parts of a millimeter. Miss the target by too much or too little and the work is scrap! There is always a target and a limit as to how much variation is allowed—the allowable variation is called **tolerance** (see Unit 2-4).

Working constantly with small decimal numbers, machinists have developed their own way of pronouncing them. Besides sounding in-the-know, learning this trade lingo helps eliminate misunderstandings and, more importantly for the student, it greatly speeds up mastery of measuring tools, print reading, and machine operations.

TERMS TOOLBOX

Imperial The units based on Imperial England—the ruler that includes feet and inches.

SI—International System of Units The system of measurements based on metric values.

Tenth (of a thousandth) 0.0001 in.—to a machinist one tenth of our basic spoken unit, the thousandth of an inch; thus, it's a tenth in shop lingo.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick4e.

2.1.1 "Talking Precision"—Thousandths of an Inch

When working in inches we machinists refer to the inch as our working unit, but we speak as though it is the thousandth of an inch, and that's different from the regular nonprecision world. How do you pronounce *0.01 in.?*

KEYPOINT

In the shop, we pronounce inch decimals as though they were all extended to the third column, and 0.01 becomes *0.010 in.*

If you said either "one hundredth inch" or "point zero one inch," you were correct for general math, or when using metric tools and dimensions "point zero one" is correct. But when machining to inch dimensions, you will say "ten thousandths of an inch"! Or it might be shortened to ten thousandths. Or even "ten thou" in slang.

TRADE TIP

When a decimal inch number isn't extended to the third column, add the missing zeros to make it into thousandths of an inch.

TRY IT

A. 0.13 B. 0.013 C. 1.31 D. 0.2
E. 0.25 F. 0.303

ANSWERS

A. One hundred thirty thousandths of an inch—or one hundred thirty thousandths
B. Thirteen thousandths
C. One inch, three hundred ten thousandths
D. Two hundred thousandths
E. Two hundred fifty thousandths
F. Three hundred three thousandths

How Small Is a Thousandth of an Inch?

It's difficult to visualize 1 inch divided into one thousand parts (0.001 in.); however, here are some everyday examples:

A human hair is from 0.002 to 0.005 in. thick.
The paper this book is printed on will be from 0.003 to 0.004 in. thick.
A dime is about 0.04 in. (forty thousandths), and a ballpoint pen is around 0.310 in. in diameter—three hundred ten thousandths of an inch or shop-shortened to three hundred ten thousandths.

TRY IT

Pronounce the horizontal and vertical dimension on the part print in Fig. 2-1 and the hole diameter.

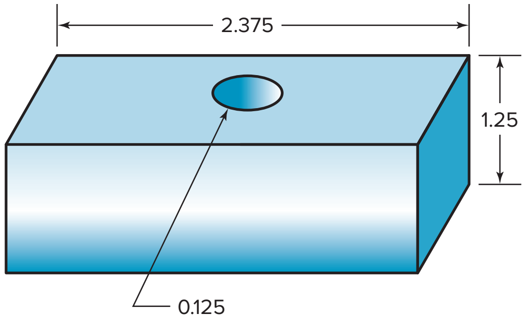


Figure 2-1 Say these dimensions to the thousandth of an inch.

ANSWERS

Two inches, three hundred seventy-five thousandths
One inch, two hundred fifty thousandths
One hundred twenty-five thousandths

2.1.2 Smaller Yet—Tenths of a Thousandth

Thousandths of an inch aren't precise enough for some designs, so we further divide them into 10 smaller parts. As a machinist, you will pronounce these as **"tenths."** Again, quite different from the outside world, not tenths of an inch (0.1) but tenths of our spoken base unit, the thousandth.

For example, *0.0001 in.* is one tenth of a thousandth.

A human hair might measure 0.0037 in. thick, larger than three thousandths by seven tenths. That's pronounced three and seven tenth thousandths or shop-shortened to three and seven tenths. As odd as that sounds to an outsider, any person in the trade would understand exactly. Say to an inspector or engineer, "The diameter is five tenths too small," and he or she would know that 0.0005 in. more must be taken out of the hole to be the right size (Fig. 2-2).

TRY IT

0.1259

ANSWER

One hundred twenty-five thousandths *and nine tenths*

TRADE TIP

First pronounce the thousandths; then add on the tenths.

Figure 2-2 This machining inspector needs math skills to read the drawing and then program this computer coordinate-measuring machine (CMM). Courtesy Contour Aerospace/Everett, WA

TRY IT

Practice pronouncing these with another student.

A. 0.0067 B. 1.5678 C. 0.9999
D. 0.0878 E. 0.0087

ANSWERS

A. Six thousandths and seven tenths or six and seven tenths thousandths (Either expression would be okay even though it isn't correct outside the machining field.)

B. One inch, five hundred sixty-seven and eight tenths thousandths

C. Nine hundred ninety-nine and nine tenths thousandths, or nine hundred ninety-nine and nine tenths

D. Eighty-seven thousandths and eight tenths

E. Eight and seven tenths thousandths

2.1.3 Getting the Most Accuracy Using Your Calculator

When the calculations are to be made into solid metal, there simply can be no answering less than 100 percent correct. In the real world, anything less results in scrap and lost profit! So before moving on to the review problems, here are a few suggestions on how to get the best results when using a calculator in applied math.

Rounding

Never round any number until the final result.
Then, *always round to the nearest tenth (0.0001 inch).*
Use the whole decimal number during calculations.
Keep all numbers and results on the calculator using the memory keys.
Round up if the trailing digits are 5 or greater. Round down if they are less than 5. Example: rounding to the nearest tenth (of a thousandth of an inch):

1.3466*52 in.* = 1.3467 (Rounded up)
1.3466*48 in.* = 1.3466 (Rounded down)

Take Advantage of "The Mystery Digits"

The display isn't the entire amount the calculator is using. In some calculations where decimals extend very far from the point, the processor will be using a number that extends two or three places beyond the display, depending on the calculator sophistication.

If the screen number is written on paper to be used later, the unseen decimals are lost. However, by using the calculator's memory to record intermediate results, the entire number is stored, including the unseen digits. Usually we do not need this exceptional accuracy, but it can make a difference when doing several multiplications of the number in a series. While the difference might be small, keep in mind we deal in small. Missing this hint might result in a loss of one or two tenths—just enough to cause a problem.

Calculator Rounding

Your calculator may have a decimal fix function (rounding). Use it to round results to the job tolerance of thousandths or tenths. But doesn't that diminish the accuracy? *No.* Unlike pencil and paper rounding, nothing is lost in the calculator. Only the display is rounded. The internal number continues to the full capacity of the processor.

Little Hints

Use Memory to Record Intermediate Results By all means, write them on paper, too, but *do not depend on written numbers;* they create a chance to introduce errors.

Use Fresh Data When given the choice between two numbers to solve a problem, always choose the number that is closest to the original information on the print. Do not use calculated results if they can be avoided. They may be rounded, transposed, or wrong. Next is a hint to avoid that.

Talk to Yourself During calculator entry avoid accidental transposition and "fat finger" errors by saying them aloud slowly as you touch the keys. While doing so, look at the display. No kidding, this works when writing numbers on paper, too. It's okay to talk to yourself in shop math!

Simplifying Fractions To convert a fraction into a decimal number divide the numerator (top) by the denominator (bottom); that's the rule. But modern calculators often feature a direct fraction key. It may be an *A*/*B* on the keypad. There may be several fractional keys involving *A*/*B* and *C* as variables. These keys allow dual inputs in a single problem; both decimal and fractional numbers can be used at the same time. If an older print is dimensioned with fractions, using this key can speed up and simplify the math. Find it and teach yourself to use it. It will be very helpful in the upcoming problems.

KEYPOINT

Use your calculator for rounding numbers with no loss of accuracy, for simplifying fractions, and for storing intermediate numbers carried out to the capability of the calculator.

2.1.4 Conversion Review: Metric and Imperial Units

Occasionally, it becomes necessary to convert between **imperial** (foot-inch) and metric **(SI)** units, especially when making products for the world market. As we enter the world competition, expect more work to be dimensioned in SI units. Here's a brief refresher on conversion. Most calculators feature direct conversion functions—read the manual or experiment with these examples:

Converting to Metric from Imperial Units

Multiply inches	by 25.4	To obtain millimeters

Examples:

How many millimeters are in 2.125 in.?

2.125 × 25.4 = 53.975 mm

Convert 0.0935 in. to millimeters

0.0935 × 25.4 = 2.3749 mm

Converting from Metric to Imperial Units

Multiply millimeters	by 0.03937	To obtain inches in thousandths

Examples:

How many thousandths are in 23 mm?

23 × 0.03937 = 0.9055 in.

Convert 245 mm to inches

245 × 0.03937 = 9.6457 in.

TRY IT

A. On a separate sheet of paper or on keys, using Fig. 2-3, convert the imperial dimensions to millimeters.

B. From Fig. 2-4, convert the metric print to imperial units.

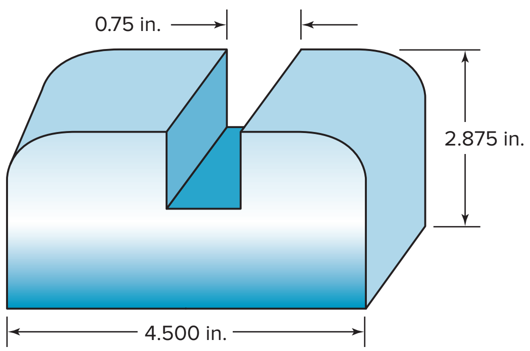


Figure 2-3 Convert these dimensions to metric units.

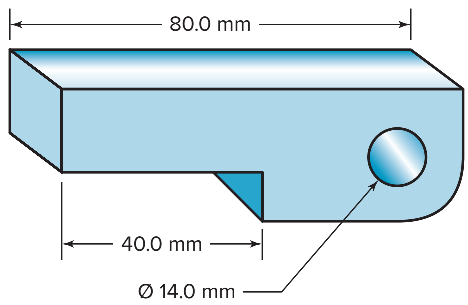


Figure 2-4 Convert this metric print to imperial (inch) units.

ANSWERS

A. Converting to metric units:
Width 4.500 in. = 114.3 mm
(4.5 × 25.4 = 114.3 mm)
Height 2.875 in. = 73.025 mm
Slot 0.75 in. = 19.05 mm

B. A metric block 80 × 40 × 14 mm is 3.1496 by 1.5748 by 0.5512 in.

Xcursion. Ever wonder how that calculator on your phone or in your pocket works? Scan here.

UNIT 2-1 REVIEW

Replay the Key Points

- Machinists pronounce decimals as though the thousandth of an inch was their base.
- Using a calculator to its fullest requires study of its various functions.

Respond

Move on to Unit 2-2 to solve the first set of self-evaluation problems.

Unit 2-2 Using Feature Tolerances

Introduction: The essence of machining a feature on a part (e.g., drilling a hole or tiring a diameter) requires achieving a quality target. The hole must be the right size and in the right location on the part. It might also have a specification for roundness or straightness—those targets are called the **nominal dimensions** for the feature.

But we cannot realistically achieve perfection, so a range of acceptability is added to the nominal in the form of a **tolerance**—the amount of allowable variation. The best quality is right at the specified size (nominal size), but the feature is okay within the range.

Look at Fig. 2-5 to see examples as we discuss several kinds of tolerances.

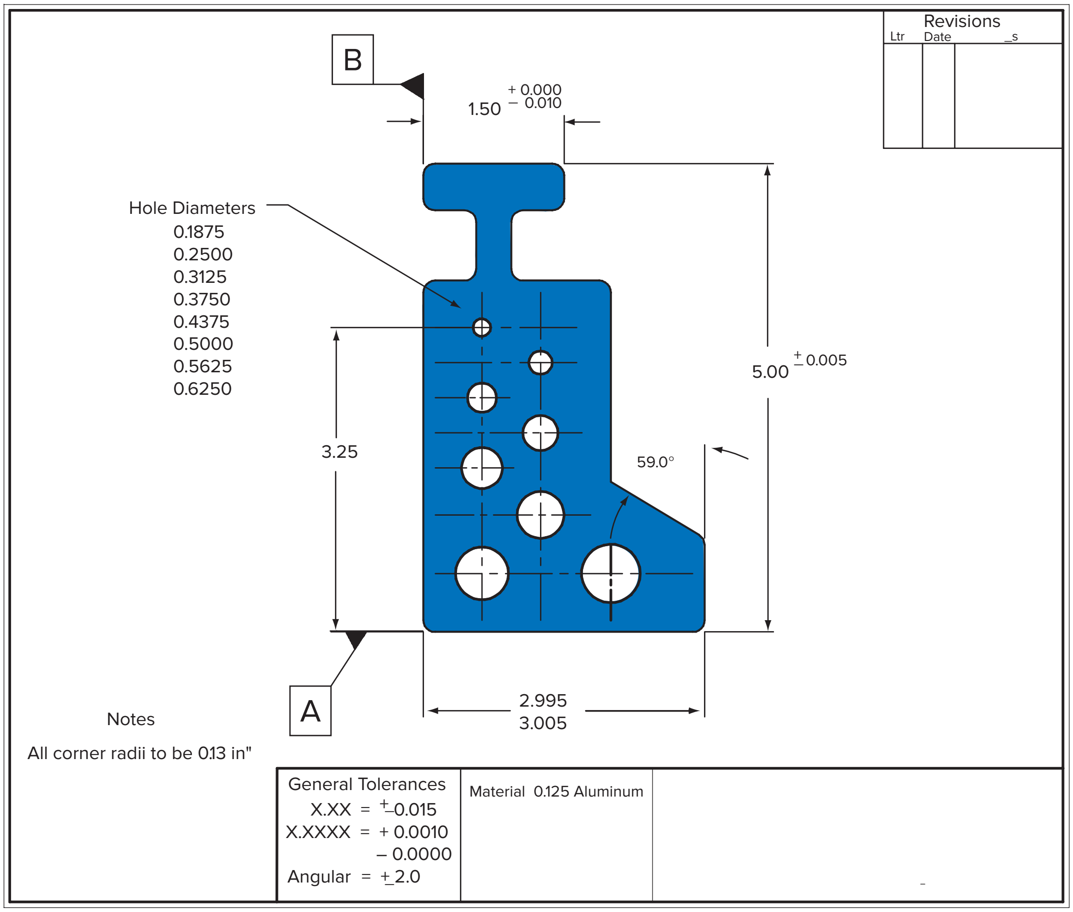


Figure 2-5 Different types of dimensioning and tolerancing.

TERMS TOOLBOX

Nominal dimensions The desired target value.

Tolerance The amount of acceptable variation from nominal.

Bilateral Tolerance that extends both plus and minus values from nominal only.

Unilateral Tolerance that extends one direction plus or minus from nominal.

Limits Tolerance expressed as a maximum and minimum value.

2.2.1 Bilateral Tolerances

Bilateral tolerances are easy to understand but not always easy to accomplish. That's how we earn our pay! For example, on the engineering drawing you read that a hole diameter specification is to be 0.6250 diameter; then, in the table on drawing, you see the tolerance for a four-place number is "±0.0010."

Question: So, what size range would be acceptable?
Answer: 1.624 in. on the low and 1.626 in. on the high.

Expressing it as a plus/minus range is called a **bilateral tolerance,** meaning its acceptable range extends both directions from nominal.

2.2.2 Unilateral Tolerance

Expressing the tolerance in one direction from nominal is a **unilateral tolerance.** Look at the 1.50-in. width dimension in Fig. 2-5.

$$01.50\,\frac{+.000}{-.010}$$

And now what is the range? Answer 1.500 to 1.490 in.

You cannot machine the width larger than 1.50 in., but ten thousandths smaller is okay.

2.2.3 Limits

Sometimes the designer will express the tolerance as **limits** of size; for example, the bottom width:

2.995 in.
2.305 in.

That means there is no specific quality target—any result within the limited range is okay.

Final point: No matter how it's expressed, your task will be to machine and measure the controlled feature well within the tolerance!

CHAPTER 2 REVIEW

Terms Toolbox! To review key terms, please go to **www.mhhe.com/fitzpatrick4e.**

Introduction Now, with a review of the previous problems, see how much improvement has been achieved. Remember, ask for help with unfamiliar terms or symbols.

Instructions

A. This is a self-test—not a warmup.
B. Do not look at each answer—be certain you are correct on all problems.
C. Correct your own work and conclude readiness for lab experiences.

QUESTIONS AND PROBLEMS

Write these decimals in words. (Units 2-1 and 2-2)

1. 0.809 in.
2. 0.056 in.
3. 2.345 in.
4. 6.09 in.
5. 0.12 in.
6. 0.0089 in.
7. 0.0324 in.
8. 3.0506 in.
9. 0.5427 in.
10. 5.3387 in.

Convert imperial numbers to metric. (Unit 2-1)

11. 4 in. = _______mm
12. 2.5 in. = _______mm
13. 4.75 in. = _______mm
14. 20.0 in. = _______mm

Convert metric numbers to imperial inches—to the nearest tenth of a thousandth.

15. 25 mm = _______in.

16. 120.5 mm = _______in.

17. 358 mm = _______in.

18. 225 mm = _______in.

19. 4.75 mm = _______in.

20. 2.5 mm = _______in.

CRITICAL THINKING

21. A print calls for one rectangular part made from sheet steel. It is to be machined to $3\frac{3}{4}$ by $5\frac{3}{8}$ in. when finished. (See Fig. 2-6.) Operation 30 requests 0.150 in. extra machining metal added to every edge of the rough sawed material. The saw kerf consumes 0.060 in. for each cut. How much material will be consumed from the sheet for the one rectangle? (Units 2-1 and 2-2)

22. A customer asks for 50 tool hooks. This job is made from $\frac{3}{8}$-in. round steel rod. Each hook requires a length of $4\frac{3}{8}$-in. material plus 0.06 lathe, parting tool, kerf where it is cut away from the bar. How much material in inches must you bring to your lathe to make all 50 parts—rounded to the nearest inch? Answer in feet and inches, rounded to the nearest inch. (Unit 2-2)

23. The print requires a custom bored hole of 0.875-in. diameter. You need to select a drill bit that is $\frac{1}{32}$ in. smaller than the finished bore size, for machining excess (metal left to machine after drilling). What size drill will be used to predrill this operation? (Unit 2-2)

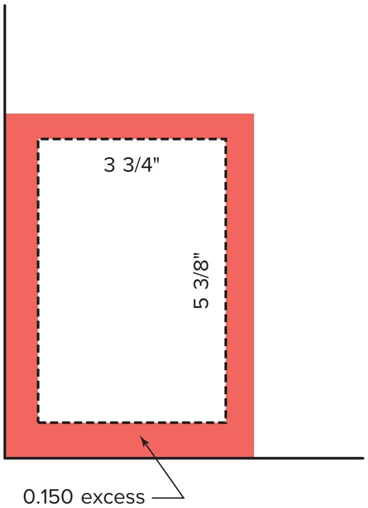


Figure 2-6 Problem 21.

24. Using the decimal chart in *Appendix I,* what is the next nearest whole-millimeter metric drill diameter that is *smaller* than the inch drill of Question 23?

CNC QUESTION

25. In writing a drill routine for a CNC mill, you need to complete the **S** command word to tell the controller to revolve the given spindle **S**peed. The numbers following the **S** prefix will tell the controller the RPM speed. Calculate the RPM; then fill in the command statement **S**_______.

For this hardened steel workpiece, the recommended surface speed is 80 ft per minute. The drill diameter is $\frac{7}{16}$ in. The formula to find the correct drill RPM for drilling a steel workpiece is

$$\text{RPM} = \frac{\text{surface speed} \times 12}{\pi(3.1416) \times \text{drill diameter}}$$

$$\text{RPM} = \frac{\text{surface speed} \times 12}{\pi \times \text{drill diameter}}$$

$$\pi = (3.1416)$$

(Units 2-1 and 2-2)

Review: Pi (π) is the ratio comparison of a circle's diameter compared to its circumference equal to 3.1415926 in. Any circle is just over three times bigger around than it is across.

CHAPTER 2 ANSWERS

Answers to Chapter Review Questions

Note that "of an inch" could be said where the parentheses appear but would probably not be added in real shop life.

1. Eight hundred nine thousandths (of an inch)
2. Fifty-six thousandths (of an inch)
3. Two inches, three hundred forty-five thousandths ( )
4. Six inches, ninety thousandths ( )
5. One hundred twenty thousandths ( )
6. Eight thousandths and nine tenths *or* eight and nine tenths thousandths ( )
7. Thirty-two and four tenths thousandths ( ) *or* thirty-two thousandths and four tenths
8. Three inches, fifty thousandths and six tenths *or* three inches, fifty and six tenths thousandths ( )
9. Five hundred forty-two and seven tenths
10. Five inches, three hundred thirty-eight and seven tenths
11. 101.6 mm
12. 63.5 mm
13. 120.65 mm
14. 508 mm
15. 0.9843 in.
16. 4.7441 in.
17. 14.0945 in.
18. 8.8583 in.
19. 0.1870 in.
20. 0.0984 in.
21. The finished rectangle will be 3.75 × 5.375 in. The larger rough rectangle as sawed will be 4.05 × 5.675 in. Adding 0.06 kerf to each edge sawed yields the final consumed rectangle taken from the sheet:

    4.11 × 5.735 in.

    (*Hint:* There were only two saw cuts to remove this product from the sheet!)
22. You need 221.75 rounded to 222 in. of steel rod. In feet and inches, 18 ft − 6 in.
23. The drill will be $\frac{27}{32}$ in.
24. A 21-mm drill is the next smaller whole-millimeter drill down from the $\frac{27}{32}$-in. drill.
25. The correct RPM is 698.4.

Chapter 3

Reading Technical Drawings

Units

INTRODUCTION

Technical drawings and their companion documents, work orders (WOs), are the means by which machinists receive instructions. These orders tie the industry together, linking management, customers, engineers, planners, programmers, and quality assurance people. These two very different documents work together to create a foolproof way to deliver the goods. That is, they're foolproof if all involved understand how to read them!

Drawings are the master engineering document. In pictures, numbers, symbols, and words, they show exactly how the parts are to be shaped and/or assembled, but they don't tell the machinist how to make them. The work order serves that purpose. The main body of a work order is a carefully planned sequence of operations. The work order includes step-by-step instructions on how to follow the drawing and produce the part. Learning to use WOs is so important that we'll explore them twice in later chapters. Chapter 3 is about reading the drawings, to equip machining students with just enough baseline information to get started with lab assignments.

ONLINE ELECTRONIC SOLID MODEL DOCUMENTS OR PAPER

Paperless Trend Today nearly all designs are created with computer software called CAD (computer-aided design) (Chapter 1, Chapter 24, Solid Modeling). That's the way most of the illustrations in this book were drawn.

Drawings printed on paper can be useful in the shop. They probably won't ever be completely eliminated. But more and more, machinists are receiving their drawings and work orders in digital form, at their CNC workstations.

Many CNC controls have evolved from single-purpose program managers to multitask computers. Machinists can access programs, drawings, and work orders right at their CNC stations. They can communicate with programmers and with other support people who bring cutters or lubricants, for example, or with other machinists in other locations. Using these stations, the machinist becomes a data manager and can input job tracking, information, quality assurance data, and program requests and can return suggested edits to the programmer and perform many other tasks—all from the CNC control. The shop foreman can instantly see the number of parts completed, the number that were not acceptable (hopefully, none), and generally do a much better job of managing the shop.

This paperless trend not only saves storing thousands of hard-copy drawings and the people required to manage them, but it also makes it possible to control and instantly distribute design updates to everyone working on the same job, worldwide. It also saves forests.

SHOPTALK

Technical drawings are also called several different names: prints, drawings, engineering drawings, and blueprints. But why "blue" when they are black and white? Read on.

Unit 3-1 Orthographic Projection

Introduction: In Unit 3-1, we'll look at the system used by the designer to lay out the various views you see on paper—**orthographic projection.** Projecting means showing something on a flat surface, a computer screen or paper, for example. The Latin root *ortho* means "90-degree relationships," and *graphic* refers to images. But an orthographic drawing is more than images; it's also about how they are arranged on the paper.

When assigned a job with a set of instructions, the machinist must be able to get to work as soon as possible. But it's critical that no metal is removed until the true nature of the part is fully understood. That means visualizing the part shown on the drawing.

TERMS TOOLBOX

Auxiliary view A view taken as though an extra sheet of glass were added to the box that shows details not seen from any other perspective.

Cutting plane (line) The thickest line on a drawing indicating where the part has been sliced open to reveal interior details.

Detail view A view that is magnified larger than the general drawing to show fine details not clearly seen otherwise.

First-angle projection The second-most popular method of projecting orthographic drawings—one that does not change the image but rearranges its location on the paper.

Fold lines Imaginary lines where a paper drawing could be folded to re-create a model of the glass box; fold lines simulate hinges between the glass surfaces.

Orthographic projection Views taken at various 90° perspectives.

Projection lines Lines that are not on the drawing but when added connect details in one view to the next; when drawn a projection line runs 90° to the fold lines.

Section view A view taken internally to show details not clearly seen from the outside of a part.

Third-angle projection The more common system of arranging the views in North America; the imaginary glass box in which the part is envisioned is the third of a possible four.

***Review the key terms in the Terms Toolbox Challenge!** Just scan the code in every Chapter Review, or go to www.mhhe.com/fitzpatrick4e.

3.1.1 Print-Reading Skills Needed

No matter in what form the drawing comes to you, on a computer screen or on paper, the skill of understanding and applying it to your work remains the same. Print reading divides into two categories:

1. *Visualization* is the ability to see the image and compile an idea of what the designer saw when creating the drawing. It is the ability to look at a flat, two-dimensional image on screen or paper and then create a three-dimensional (3-D) object in your mind. This skill is where we'll concentrate our efforts in Chapter 3.
2. *Interpretation* is the second and far more complex set of print-reading skills. It comprises what might be called the "legal" aspects of taking a design from drawing to reality. Interpreting a drawing requires an understanding of the rules, symbols, nomenclature, and procedures of manufacturing.

3.1.2 The Six Standard Orthographic Views

There are six possible standard views, but it's rare that more than three or four will be needed to convey the image for any one part (Fig. 3-1). They can be envisioned as projections of the part out to one of six possible sides of an imaginary glass box surrounding it: *top, front, bottom, rear, right,* and *left*.

The imaginary glass box provides a model of how each view relates to the overall drawing. It can be envisioned as the surfaces upon which the views were projected, from the object out to the glass—then folded out to become a drawing. Although drawings aren't actually made in this way, Fig. 3-2 illustrates the best way to begin learning visualization. Each view on the paper is as though the box had hinges and each surface was unfolded.

All views that show the height of the object might be called *elevation* views: front elevation, right-side elevation, back elevation, and so on. But they are usually just called front, right-side, rear, left-side (or left/right-end) views. The term *elevation* is more correctly used in architectural (building) drawings.

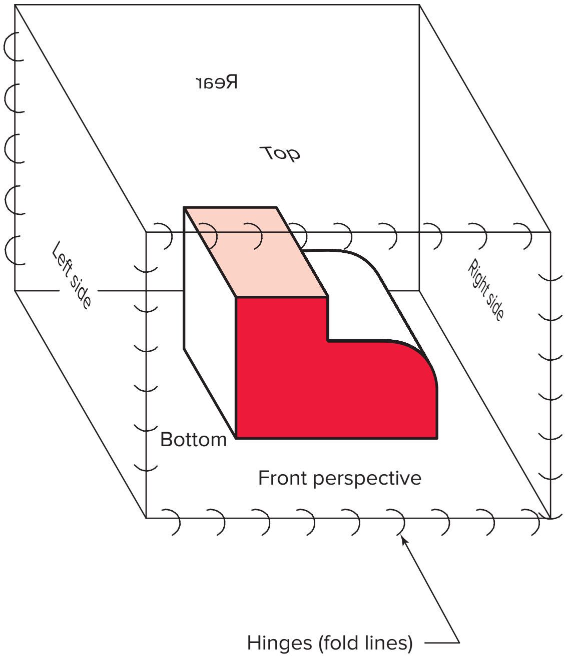


Figure 3-1 The *imaginary* glass box surrounding the object.

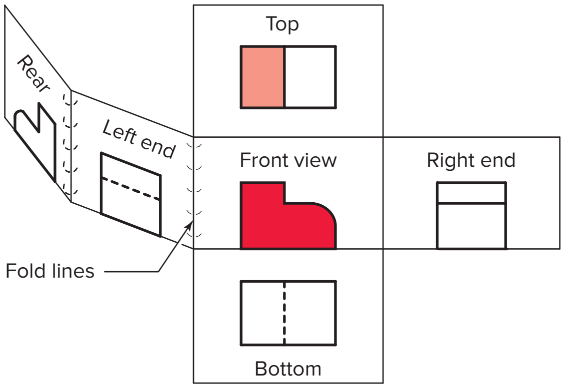


Figure 3-2 Each drawing view is rendered as though the viewer is directly facing the various surfaces of the glass box.

Third-Angle Projection

While there are other systems of projecting objects to flat surfaces, the most common in North America is **third-angle projection.** In this system, print readers envision each view as though they were standing outside the box and the view they see (top, front, and so on) is projected to the glass surface *between the object and viewer.* In other words, each view is as though you were walking around the box and looking in from each side.

The symbol used to notify the reader that the drawing was produced with third-angle projection is a cone as seen from the front and side views as if it were in the box (Fig. 3-3). Where there is a chance that there might be more than one method used, such as for an international customer, you will see this symbol in the drawing

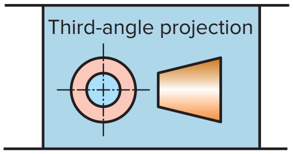


Figure 3-3 The symbol for a *third-angle* orthographic projection drawing is a cone from the top and the right side.

title area to indicate that the drawing is a *third-angle* projection. With third-angle projection, the top front edge of the box is considered the prime edge (or hinge) out of which all other views unfold.

KEYPOINT

Third-angle projected images are created as though the projection surface (glass) is between the viewer and the object. These are the drawings you will use in this book and probably in your lab training, too.

First-Angle Projection

The other projection method used works equally well. Here the views are arranged differently as though the image were projected out of the object to the far glass surface—the surface away from the viewer on the other

SHOPTALK

Why are drawings called *blueprints?* The answer is found back down the technical timeline, before drawings were files, when they were hand-drawn pencil copies on semitransparent paper called vellum (tracing paper). Copies of that precious master were made for the shop.

There were no photocopy machines then, either. Copies were made one at a time on chemically treated paper that turned dark blue with exposure to strong light. To make the duplicate, the vellum was laid over the treated paper, and a strong light was shown on the pair. The treated paper below turned blue if not shadowed by the pencil lines on the master above. The pencil shadows became white lines, but the exposed paper turned blue: truly a blue print. Those old drawings were hard to read if the design was very complex, plus they tended to fade over a long time. The process has passed, but the term lives beyond the technology. See Fig. 3-4.

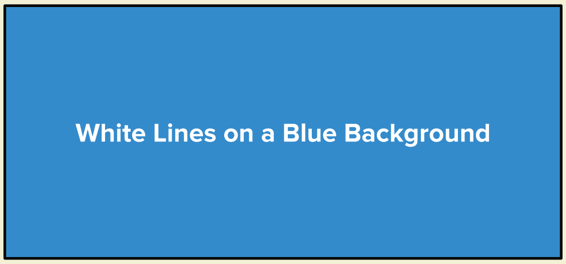


Figure 3-4 A page out of history, a blueprint.

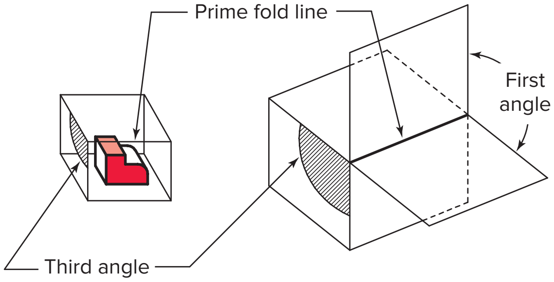


Figure 3-5 The third-angle projection box comes from the third quadrant of a possible four.

side of the box. It does not change the appearance of the six standard views, but it changes where they are placed on the drawing. Drawings produced with **first-angle projection** rearrange the image placement on the paper.

To see the difference in first- and third-angle drawings, we examine the four possible quadrants created by intersecting a pair of glass planes, as seen in Fig. 3-5. This is the universe of four boxes. Much of the industrialized world uses the third box; fewer use the first.

Xcursion. Confused about the difference between first- and third-angle projection? See how SolidWorks illustrates it. Scan here.

The Glass Box Universe

If two imaginary glass planes are intersected, they create four possible glass box areas. Their mutual intersection line becomes the prime edge or hinge to each. In third-angle drawings, the object is placed in the third possible box of the four. First-angle drawings are then taken from the first possible box. Due to common usage, from this point forward in this book we will study only third-angle drawings. We'll leave first-angle drawings for your formal print-reading course. Neither system is better. Once understood, they are used with equal ease.

KEYPOINT

The third-angle box uses the top front hinge as its prime or parent hinge. All other views radiate out from this front view and the prime fold line (studied next).

Fold and Projection Lines

To speed up visualization of the object, mentally place imaginary **fold lines** between each view. They represent where the hinges would have been between the glass surfaces if the box were real. As long as the views

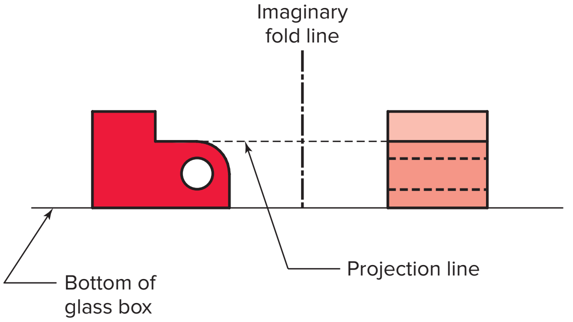


Figure 3-6 Details project to the same height above the bottom of the glass box in both views.

are correctly arranged on the paper, it is possible to cut, then fold the print along these lines to make a paper model of the box, complete with the projected views.

The designer used the concept of fold and **projection lines** when generating the image on paper or computer screen.

You can use them to visualize the object. For example, notice in Fig. 3-6, in both front and end views, the bottom of the object is touching the bottom of the box, and the top is the same height in adjoining elevation views. The bottom of the box is a projection line. Details are found directly across the fold line from each other. They project from view to view. Again in Fig. 3-6, to ensure that the step was the same height in both views, a temporary projection line was extended from the front view to the right side.

Ruler Check

To see how this works, check out the hole in Fig. 3-6 with a straightedge or ruler. Extend the dotted lines representing the hole, on the right, over to the front view.

TRADE TIP

Ruler Projection Use this projection line trick to test for the relationship between confusing lines or details from one view to the next.

3.1.3 Auxiliary, Section, and Detail Views

There are several other views that can be added to clarify details not shown well in any of the six standard perspectives. We will examine the three most common: **auxiliary views, section views, and detail views.**

Auxiliary Views

Sometimes, the six-sided glass box doesn't provide a view perspective that reveals the true size or shape of the object, or some detail on the object in the right perspective. For example, in Fig. 3-7, in every standard

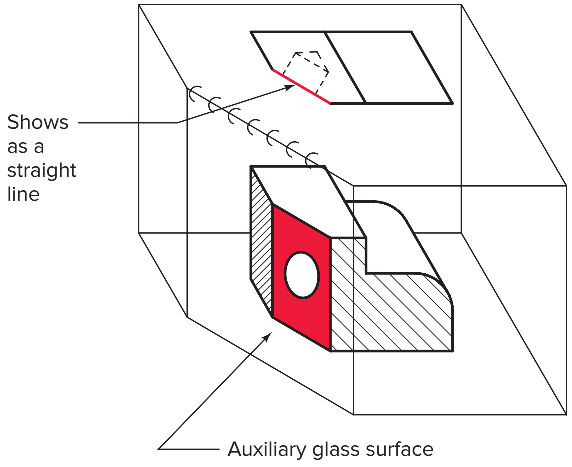


Figure 3-7 An extra (auxiliary) sheet of glass is added to show the hole in true size and shape.

view the hole in the angular surface appears as an ellipse or it is hidden from view. To show this hole in true perspective, an extra (*auxiliary*) sheet of glass is added to provide a straight-on view of the detail—in other words, to look directly into the hole where it appears as a circle. Notice that the hinge/fold line is on the top of the box where the angular surface is shown as a straight line. This is the only view from which the new auxiliary view can be hinged out as a true surface.

Removed or Rotated for Convenience Due to that auxiliary projection rule, we often find auxiliary views projecting or folding out to odd positions on a standard orthographic drawing, as seen in Fig. 3-8. To solve this problem, they are usually transferred to a better location on the drawing, and a note is *usually* provided next to the view to let the reader know this has been done—that the view is not found directly across the imaginary

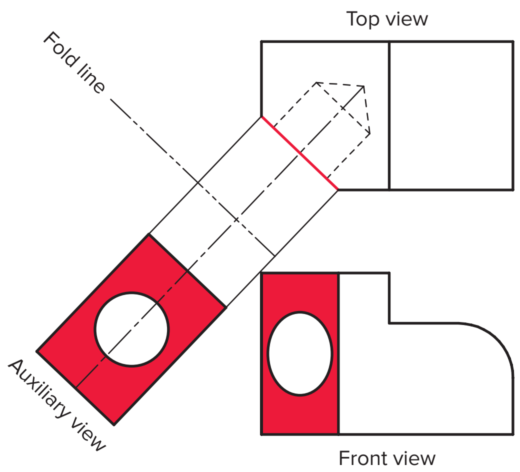


Figure 3-8 This auxiliary view is in its correct position, across the fold line.

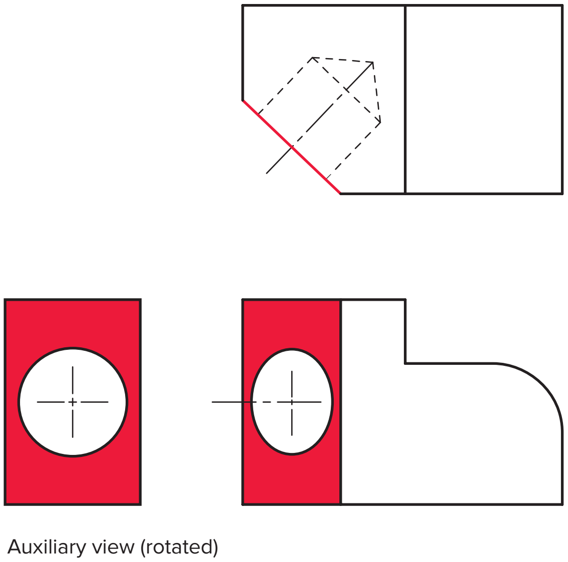


Figure 3-9 The auxiliary view has been moved to a better location on the paper but no longer projects back to the top view.

fold line but put elsewhere to make the drawing more compact. The view will be found in a more logical place on the paper but not in the place it would have been projected (Fig. 3-9).

KEYPOINT

When the auxiliary view is no longer in its correct ortho position, the projection line ruler trick will not work. Remember, auxiliary views are drawn to show some detail(s) of the object not shown clearly in the standard view perspective.

Section Views

Another secondary view arises when the designer needs to show some internal feature not shown clearly from the outside of the object. There are several types of section views, but they all share the concept that they are drawn as though material has been sliced away from the object and you are seeing the inside of the part. **The section view is depicted as it would appear if the material between the viewer and the remaining object had been removed.**

Here are two common section views, the *full section* and the *broken out section*. Each clarifies inside details of this machined-brass hose fitting (Fig. 3-10).

Two rules are used as guidelines for creating section views:

1. **Cutting Plane Rule**
   The theoretical surface along which the material has been sliced open is called the **cutting plane.**

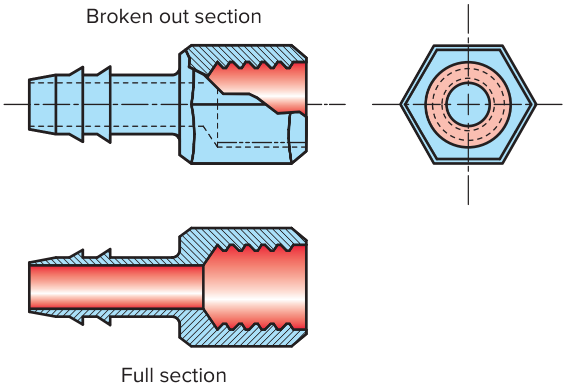


Figure 3-10 Two different kinds of section views show internal detail.

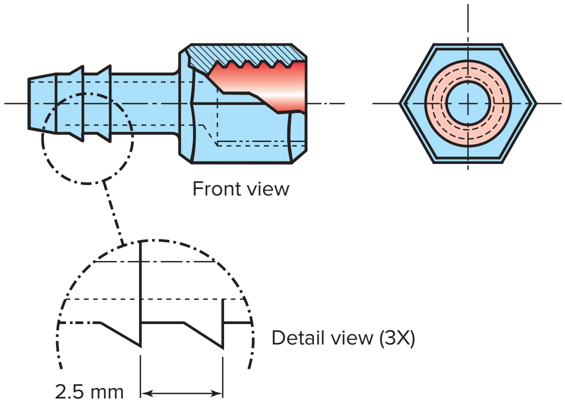


Figure 3-12 A typical detail view—three times the size of the actual drawing.

In Fig. 3-11, note that the extra heavy, dashed line with arrowheads at each end is the cutting plane line. It represents the edge of the slice. The section view created by the cutting plane will be seen as though the viewer were looking in the direction of the arrowheads. The material that will be removed in the section view is behind the arrowheads, between the viewer and the remaining object. If at all possible, the section view is placed in its correct orthographic position on the paper. But as with auxiliary views, it may be necessary to locate it elsewhere on the drawing (Fig. 3-11). The person making the drawing may or may not choose to draw the cutting plane line, as was the case in Fig. 3-10. Also, there may or may not be arrowheads, depending on the simplicity of the section view.

2. **Sectioning Rule**
After the section view is drawn, light lines will probably be added to clarify where the internal cut has been made. Section lines are not required but are added only when the designer feels they clarify a view or detail. Sectioning lines are also called *crosshatch* lines, as seen in Figs. 3-10 and 3-11.

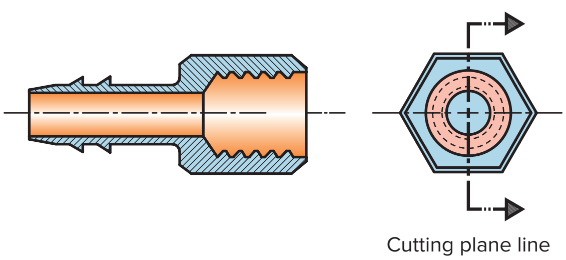


Figure 3-11 The cutting plane line shows where the slice has been taken. It's wider than all other lines on the drawing.

Detail Views

Detail views are magnifications of small features not seen clearly at the scale of the entire drawing. They might be labeled as to how much they have been scaled up (blown up), and a circle might be shown to indicate from where the view has been taken—again, these are options the person drawing may or may not use. For example, "3X" in Fig. 3-12 means the view is three times the normal drawing size.

UNIT 3-1 REVIEW

Replay the Key Points

- There are six standard orthographic views: front, top, right and left end, bottom, and rear.
- All the standard views are pictures at 90° to each other.
- The *front* view should depict the object best. Study it first when starting a new job. It is the parent view out of which all other views originate.
- Auxiliary, detail, and section views clarify a detail not clearly shown in the standard views.
- Section views show internal detail obscured by material. These views show the details as though the intervening material has been removed.

Respond

1. In your own words describe an orthographic projection.
2. To interpret a drawing means to collect all the views together in your head, then create a 3-D image in your mind. Is this statement true or false? If it is false, what will make it true?