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Structural Journeyman

Volume 2. Project Planning, Tools, Equipment and Safety

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IN THIS VOLUME, you will study construction drawings, materials, estimating standards and formulas used for project planning, tools, and equipment that you may use to perform your job.

Unit 1 addresses the different types of construction drawings and how to read those drawings. It also discusses how to sketch shop drawings. Unit 2 covers construction materials, fasteners, and different types of metals. In Unit 3, we talk about estimating standards and special precautionary measures for project planning. We also discuss calculations and material estimating formulas. Unit 4 provides information on the use and care of hand tools, portable power tools, and shop equipment. There will also be an overview of safety, ladders and mobile work platforms.

A glossary of abbreviations, acronyms, and terms used in this course is included at the end of this volume.

Code numbers on figures are for preparing agency identification only.

The foldouts discussed in unit 1 are printed and bound in a separate supplement. Refer to them as directed.

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This volume is valued at 15 hours and 5 points.

NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then do the unit review exercises.

Page

Student Notes

Unit 1. Drawings

THIS UNIT covers drawings—the different types and their uses. One of the most important drawings that you will need to understand is the blueprint. Within this unit we discuss the use and interpretation of lines, dimensions, symbols, specifications, and notes used in blueprints and other working drawings. You can use the knowledge gained in this unit every time you develop patterns or fabricate and install components. Now, let's take the first step and learn about drawings.

1–1. Construction Drawings

To plan any project, you must first be familiar with construction drawings and specifications. The construction of any structure or facility is described by a set of related drawings that gives the craftsmen a complete sequential graphic description of each phase of the construction process. In most cases, a set of drawings shows the location of the project, the boundaries, the contours, and the outstanding physical features of the construction site and its adjoining areas. Succeeding drawings give further graphic and printed instructions for each phase of construction. In this section, we discuss the types of drawings used in the construction industry.

201. Using construction drawings

Drawings are generally categorized according to their intended purposes. In this lesson, we discuss the types of drawings commonly used in military construction.

Master plan drawings

Master plan drawings are commonly used in the architectural and the construction fields. They show sufficient features to be used as guides in long-range area development. They usually contain the following list of features: section boundary lines, horizontal and vertical control data, acreage, locations and descriptions of existing and proposed structures, surfaced and unsurfaced roads and sidewalks, streams, rights-of-way, existing utilities, a north point indicator (arrow), contour lines, and profiles.

Presentation drawings

Presentation drawings present the proposed building or facility in an attractive setting in its natural surroundings at the proposed site. These often consist of perspective views complete with colors and shading. Presentation drawings are actually used to "sell" an idea or a design concept.

Shop drawings

Shop drawings are drawings, schedules, diagrams, and other related data that are used to illustrate a material, a product, or a system for some portion of the work prepared by a construction contractor, subcontractor, manufacturer, distributor, or supplier. As a structural journeyman, you may be required to draft shop drawings for minor shop and field projects.

Working drawings

A working drawing, also called project drawing, is any drawing that furnishes the information required for a construction crew to erect a structure; it is prepared from a freehand sketch or a design drawing. Complete information is presented in a set of working drawings that are complete enough for the user to require no further information. Project drawings include all of the drawings necessary for the different civil engineer (CE) specialties to complete the project. These are the drawings that show the size, quantity, location, and relationship of the building components. A complete set of project drawings consists of general drawings, detail drawings, and assembly drawings.

- *General drawings*—consist of "plans" (views from above) and elevations (side or front views) drawn on a relatively small defined scale, such as ⅛ inch = 1 foot.
- *Detail drawings*—show a particular item on a larger scale than that of the general drawing in which the item appears, or it may show an item that is too small to appear at all on a general drawing.
- *Assembly drawings*—are either an exterior or a sectional view of an object showing the details in the proper relationship to one another. Usually, assembly drawings are drawn to a smaller scale than are detail drawings. This procedure provides a check on the accuracy of the design of detail drawings and often discloses errors.

Drawing life-cycle

Construction drawings are reviewed and evaluated for design and technical accuracy to ensure the design is of good quality, consistency, and cost effectiveness. Special terms covered in the following paragraphs describe these procedures from the initial development of the project to the final phase of construction.

Preliminary drawings

Preliminary drawings are the initial plans of projects prepared by a designer or architect during the early stage of building development. These drawings are *not* intended to be used for construction, but they are used for exploring design concepts, material selection, preliminary cost estimates, and customer approval. They serve as a basis for the preparation of finished working drawings. Most of the design work incorporates the preliminary drawings at the 35 percent completion stage. At a minimum, these drawings contain site plans, architectural floor plans, elevations, building sections, preliminary finish schedule and furniture layouts, interior and exterior mechanical and electrical data, and civil and structural details.

Final drawings

Final drawings are 100 percent complete, signed by the contracting officer, and are used for bidding purposes. This set of plans becomes the official contract drawings once the contract is awarded. Final drawings are often revised to show changes made by a scope change or a change order with both the contractor's and the contracting officer's concurrence. At this stage of completion, no further functional input may be introduced into the final drawings because of time constraints. In general, final drawings, together with project specifications, cost estimates, and all of the calculations, comprise the final stages of design requirements.

Redlined drawings

Redlined drawings are the official contract drawings that you mark up during construction to show as-built conditions. They are marked in the color "red" to indicate either a minor design change or a field adjustment.

As-built drawings

As-built drawings are the original contract drawings that are changed to show the conditions from the redlined drawings. When the facilities are completed, the construction contractor or the military construction force is required to provide as-built drawings, indicating construction deviations from the contract drawings. All of the as-built marked-up prints must reflect the exact conditions on all features of the project as constructed.

Record drawings

The original contract drawings, corrected according to the marked prints, provide a permanent record of as-built conditions when the construction work on a project is completed.

Main divisions of project drawings

Generally, working or project drawings are divided into the following major divisions: civil, architectural, structural, mechanical, electrical, HVAC, and fire protection. Regardless of the division, working drawings serve the following functions:

- They provide a basis for making material, labor, and equipment estimates before construction begins.
- They give instructions for construction, showing the sizes and locations of the various parts.
- They provide a means of coordination between the different trades.
- They complement the specifications; one source of information is incomplete without the others.

Civil drawings

Civil working drawings encompass a variety of plans and information to include the following:

- Site preparation and site development.
- Fencing.
- Rigid and flexible pavements for roads and walkways.
- Environmental pollution control.
- Water supply units (e.g., pumps and wells).

Depending on the size of the construction project, the number of sheets in a set of civil drawings may vary from a bare minimum to several sheets of related drawings. Generally, on an average-size project, the first sheet has a location map, soil boring log, legends, and sometimes site plans and small civil detail drawings. Soil boring tests are conducted to determine the water table of the construction site and classify the existing soil. Civil drawings are often identified with the designating letter *C* in their title blocks.

Site plan

A site plan, foldout (FO 1) furnishes the essential data for laying out the proposed building lines. It is drawn from notes and sketches based upon a survey. It shows the contours, boundaries, roads, utilities, trees, structures, references, and other significant physical features on or near the construction site. Site plans are drawn to scale. In most instances, an engineer’s scale is used, rather than an architect’s scale.

Architectural drawings

Architectural drawings are identified with the designating letter *A* in their title blocks. A set of architectural drawings includes floor plans, building sections, exterior and interior elevations, millwork, door and window details and schedules, interior and exterior finish schedules, and special architectural treatments. For small, uncomplicated buildings, the architectural drawings might also include foundation and framing plans, which are generally part of the structural drawings.

Floor plan

The floor plan is the key drawing in a set of project drawings—the drawing at which all of the construction crew looks. Thus, the purpose of the floor plan is to show information about the location and type of construction, location of doors, windows, built-in fireplaces, stairs, rooms, and exterior and interior features. Ideally, drawings of floor plans should be drawn to ¼ inch = 1 foot scale for easy readability. Foldout (FO 2) represents a drawing of a first and second floor plan.

Elevations

Elevations show the finished interior and exterior appearance of the structure. Interior elevations (FO 3) are required for important features, such as built-in cabinets and shelves. Cabinet elevations show the cabinet lengths and heights, distance between base cabinets and wall cabinets, shelf arrangements, doors and direction of door swings, and materials used. Interior wall elevations show wall lengths, finished floor-to-ceiling heights, doors, windows, other openings, and the types of finish materials used.

Exterior elevations (FO 4) show the types of materials used on the exterior, the finished grade around the structure, the roof slope, the basement or foundation walls, footings, and all of the vertical dimensions. A typical elevation is drawn at the same scale as the floor plan, either ¼ inch = 1 foot or ⅛ inch = 1 foot.

Structural drawings

The structural drawings, usually identified with the designating letter *S* on the title block consist of all of the drawings that describe the structural members of the building and their relationship to each other. A set of structural drawings includes foundation plans and details, framing plans and details, wall sections, column and beam details, and other plans, sections, details, and schedules necessary to describe the structural components of a structure. The general notes in the structural drawings should also include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable stresses of all material used in the design.

Foundation plan

A foundation plan (FO 5) is a top view of the footings or foundation walls, showing their area and their location by distances between centerlines and by distances from reference lines or boundary lines. They also usually include a horizontal section view cut through the walls of the foundation showing beams, girders, piers or columns, and openings, along with dimensions and internal composition. Primarily, the building crew uses the foundation plan to construct the foundation of the proposed structure.

Framing plan

The framing plans show the size, the number, and the location of the structural members constituting the building framework. Separate framing plans are drawn for the floors, roofs and sometimes ceilings. Occasionally, a wall-framing plan may be drafted; however, wall-framing plans are generally viewed in the sectional views or detail drawings.

1. The *floor framing plan* must specify the sizes and spacing of joists, girders, and columns used to support the floor. Detail drawings must be added, if necessary, to show the methods of anchoring joists and girders to the columns and foundation walls or footings. The floor framing plan is basically an overhead (plan) view, showing the layout of the girders and joists. Joist symbols are drawn in the position they will occupy in the completed building. Double framing around openings and beneath bathroom fixtures is shown where used.

   Dimensions need not be given between joists. Such information is given along with the notes. For example, 2″ x 8″ joists @ 2 ft - 0 in OC indicates that the joists are to be spaced at intervals of 2 feet 0 inches on center (OC). Lengths may not be indicated in framing plans; the overall building dimensions and the dimensions for each bay or distances between columns or posts provide such data. Notes also identify floor openings, bridging, girts, or plates.
2. The *roof framing plan* shows the construction of the members used to span the building and support the roof. The size, the spacing, the roof slope, and all of the details are also shown in the plan. The roof framing plan is drawn in the same manner as the floor framing plan; rafters are shown in the same manner as joists on most plans. Roof framing plans in the construction world today are very technical and highly engineered (i.e., wind resistance, load-bearing capacity) for buildings; however, in a lot of “stick frame” construction for residential houses, they are not too complex.

Sections

As necessary, sections (FO 6) are used in each of the main divisions of construction drawings to show the types of construction required, the types of materials used, their locations, and the method of assembling the building parts. Although they may be used in each of the divisions, the most common sections are generally located in the architectural and structural divisions.

As a structural journeyman, probably the most important section drawings to you are the wall sections. These sections, commonly drawn at a scale of ¾ inch = 1 foot and normally located in the structural division, provide a wealth of information that is necessary to understand structural arrangement, construction methods, and material composition of the walls of the building.

Details

Details are large-scale drawings of the construction assemblies and installation that were not clearly shown in the sections. These enlarged drawings show you how the various parts of the structure are to be connected and placed. The construction of specific types of foundations, doors, windows, insulation, cornices, and so forth, is customarily shown in the detail drawings located within their appropriate main division of the construction drawings. Details are usually grouped together so that references may be made readily available.

The scale selected for details depends on how large it needs to be drawn to explain the necessary information clearly. Details are usually drawn at a larger scale than sections, generally ¾ inch, 1 ½ inch, or 3 inches per 1 foot. Details commonly used are readily available in the Architectural Graphics Standards (AGS).

Schedules

Schedules (FO 7) are tabular or graphic arrangements of extensive information or notes related to construction materials. Planners, estimators, contractors, and suppliers use schedules as a quick and easy way to share similar data, thus reducing construction errors and saving time. Schedules help keep the drawings clear of a lot of notes. The material information most commonly placed in schedules relates to doors, windows, room finishes, lintels, and other structural elements. Items in the schedules are keyed to the drawing with identification letters, numbers, and various symbols. For example, when using a door schedule, the key may label the doors with a letter or number placed within different geometric figures.

1. A *door schedule* may include the following: door number, quantity, mark or code number, type, size, material description, lintel, and remarks. An example of a tabular door schedule is shown in foldout 7. Doors are commonly marked with a number or numbers and letters. The floor plan shown in FO 2 lists the type door by using a number over a letter placed inside of a circle.
2. A *window schedule* (FO 7) often includes the following: mark, window type, size, required opening size, material type, lintel, and remarks. Windows are often marked with letters or letters with numbers. The floor plan shown in FO 2 lists the type window by using a letter placed inside of a hexagon.
3. A *material finish schedule* (FO 7) may include the following: room number, material finish for floors, walls, base, and remarks. Where several rooms in a row have an identical finish, a common practice is to use the ditto mark (″) or the initials do; however, errors are less likely to occur when each space in the schedule is lettered individually.

NOTE: Whenever possible, all of the schedules are placed on the same sheet as their respective drawings on the building.

Written specifications

Because many aspects of construction cannot be shown graphically, even the best-prepared construction drawings often inadequately show some portions of a project. For example, on a drawing, can anyone show the quality of workmanship required for the installation of doors and windows, or who is responsible for supplying the materials? These are things that can be conveyed only by hand-lettered notes. The standard procedure is to supplement construction drawings with detailed written instructions. These written instructions, called *specifications* or more commonly known as *specs,* define and limit materials and fabrication to the intent of the engineer or designer.

Usually, it is the design engineer's responsibility to prepare project specifications. As a structural journeyman, you will be required to read, interpret, and use these in your work as a crew leader or supervisor. You must be familiar with the various types of federal, military, and nongovernmental reference specifications used in preparing project specs. When assisting the engineer in preparing or using specifications, you also need to be familiar with the general format and terminology used.

Unified Facilities Guide Specifications

The Unified Facilities Guide Specifications (UFGS) are a joint effort of the U.S. Army Corps of Engineers (USACE), the Naval Facilities Engineering Command (NAVFAC), and the Air Force Civil Engineer Support Agency (AFCESA). UFGS are for use in specifying construction for the military services and are only published in electronic format. UFGS are designed to be used with special software.

UFGS that cover similar subjects and those that have been identified for later consolidation into a single specification section are identified with an alpha designation ("A" for USACE, "N" for NAVFAC, and "F" for AFCESA) following the section number. Users of UFGS must first consider a UFGS without an alpha designation if one is available and next a UFGS with an alpha designation of their agency, and lastly a UFGS with an alpha designation of another agency.

Technical society and trade association specifications

Technical society specifications must be referenced in project specifications when applicable. The organizations publishing these specifications include, but are not limited to, the American National Standards Institute (ANSI), the American Society for Testing and Materials (ASTM), the Underwriters Laboratories (UL), and the American Iron and Steel Institute (AISI). Trade association specifications contain requirements common to many companies within a given industry.

Manufacturer's specifications

Manufacturer's specifications contain the precise description for the manner and process for making, constructing, compounding, and using any items the manufacturer produces. They should not be referenced or copied verbatim in project specifications but may be used to aid in the preparation of them.

Project specifications

Written project specifications supplement construction drawings. Project specifications give detailed information regarding materials and work methods for a particular construction project. They cover various factors relating to the project, such as general conditions, scope of work, quality of materials, standards of workmanship, and protection of finished work.

NOTE: Whenever there is conflicting information between the drawings and project specs, the specifications take precedence over the drawings.

202. Reading construction drawings

Construction (i.e., working) drawings are useless if you don't know how to read them. In this lesson, we cover the items found on the drawings to give you a better understanding of what they represent.

Title block

The title block identifies each sheet in a set of drawings. Generally, the title block is located in the bottom right corner of the drawing, regardless of the size of the drawing (except for vertical title block). Each company that produces drawings may use a slightly different design; however, the same general information is usually found in each.

The information provided in the title block is very important information that you, the structural journeyman, must understand. In addition to the size of the drawing, other information provided in the title block is as follows:

- Architect's name, address and phone number.
- Project or client.
- Drawing title (i.e., ELEVATION).
- Date prepared.
- Size of drawing.
- Scale of drawing.
- Drawn by.
- Checked by (i.e., person that approves drawing for release).
- Architect or designer.
- Drawing number (e.g., this may be a specific job or file number).
- Sheet or drawing identification. Each sheet in a set of drawings is numbered. For example, if there are 12 sheets in a set, then each sheet is numbered 1 of 12, 2 of 12, etc. Commercial drawings may be further divided into major divisions such as *A* for architectural, *S* for structural, *M* for mechanical and *P* for plumbing.
- Revisions.

As we mentioned previously, there are many variations to title blocks. Depending on the preparing activity, all title blocks should contain the same information listed previously. If the information is not in the title block, it should be on the sheet itself. For example, some companies place the drawing title on the face of the sheet at the bottom and place the scale below the title or directly below the view.

Drawing revisions

A revision block contains a list of revisions made to a drawing. The revision block is usually located in the top right corner. The revision block may include a separate "PREPARED BY" column to indicate the organization that prepared the revision. Like title blocks, revision blocks may vary in format.

Scales

Scales must be shown prominently on each drawing, because as drawings are reduced in size, the reductions are often not to scaled proportions. For obvious reasons, construction plans (i.e., drawings) are drawn to scale so that all parts of building or project can appear on a set of plans. All parts must be in exact proportion to the building. There are three types of rules used—the architect's, engineer's, and metric scales. You can use these scales to check or find dimensions that have been omitted from the drawings. For example, if your drawing is scaled ¼″ (inch) equals 1′ (foot), then each ¼ inch on the drawing equals 1 foot of the actual building size.

Architect's scale

This is a triangular scale that is used to scale drawings that are drawn to the English measurement.

Engineer's scale

This is also a triangular scale that is used most often for dimensioning larger areas, such as site plans. The six choices on the scale are 1″ = 10′, 20′, 30′, 40′, 50′, and 60′.

Metric scale

Like the previous scales, this one is also triangular. It is used when construction plans are drawn with metric line measurements and is commonly used in overseas areas.

Lines

As with everything on a drawing, each item has a specific purpose—lines are no exception. Different types of lines on a drawing are used to identify different functions. The following is a brief overview of some of the most common lines:

Property line

The property line (fig. 1–1, 1) is a heavy solid line with one long dash followed by two short dashes or dots. As the name implies, it identifies the property boundaries.

Dimension line

The dimension line (fig. 1–1, 2) is a solid thin line with terminators at each end. The terminators can be arrows, as shown, or dots, slash marks, or accent marks. Dimension lines provide the horizontal or vertical distance between two points. If the dimension line is located outside the drawing, it touches extension lines.

Most floor plans show a series of dimension lines that appear around the exterior of the building. The outside dimension lines usually represent the total width and length of the building. The second row of dimension lines usually shows the interior partitions and any offsets and recesses of exterior walls. The third (i.e., inner) row of dimension lines usually shows the placement of doors, windows, and other structural features.

When reading dimension lines, you need to know where the measurements are coming from. The total measurements are usually taken from the outside edges of the structure. Dimensions between interior partitions may be taken from outside/inside edges (i.e., surfaces) or from center to center.

NOTE: Most windows locations on floor plans are found (i.e., measured) using their centerlines.

Extension line

Extension lines (fig. 1–1, 3) are thin lines that project at a right angle from walls or other objects. They are used in conjunction with dimension lines.

Short dimension line

Short dimension lines (fig. 1–1, 4) are used when there is not enough space to write the dimension between the arrows. They are often used inside angles or other geometric figures.

Hidden line

A hidden line (fig. 1–1, 5) is identified as a series of short dashes. It shows edges that would not be visible from the view shown on the drawing. On many foundation plans, the interior footings below the slab are shown on the plans as dashed lines.

Leader line

A leader line (fig. 1–1, 6) is a short line that is drawn at an angle to an object. It extends from a description, note, or measurement and extends to the object that is being described.

Cutting plane line

A cutting plane line (fig. 1–1, 7) is a solid line with short right angle lines with arrows at each end. There is usually a letter that appears in front of or next to one of the arrows. These lines are used to show where an object or wall is cut to reveal a cross section. This allows the architect to show features or information within that object. The arrows show the direction from which the object is viewed. The letters that appear next to the arrows refer to the section view or detail that provides the information.

Object line
An object line (fig. 1–1, 8) is used to identify the edges or outlines of an object such as walls, buildings, or sidewalks.

Breaker line
A breaker line (fig. 1–1, 9) is distinguished as a long line that is broken with zigzags. It is used when there is not enough space on the paper to continue the scaled drawing or it is not necessary to provide any additional information.

Centerline
A centerline (fig. 1–1, 10) is recognized as a series of alternating long and short dashes that extend at a right angle from parts of a structure. It is used to find the center of objects, such as walls, door and window openings, holes, and so forth. Dimension lines usually touch against the centerlines to provide the on center distance. Centerlines are sometimes referred to as CL.

Phantom line
Phantom lines (fig. 1–1, 11) look similar to hidden lines; however, they are used to identify an object that is not shown versus one that is just hidden from view. For example, looking at a floor plan, you may find phantom lines that show the edge of a roof overhang or an overhead balcony.

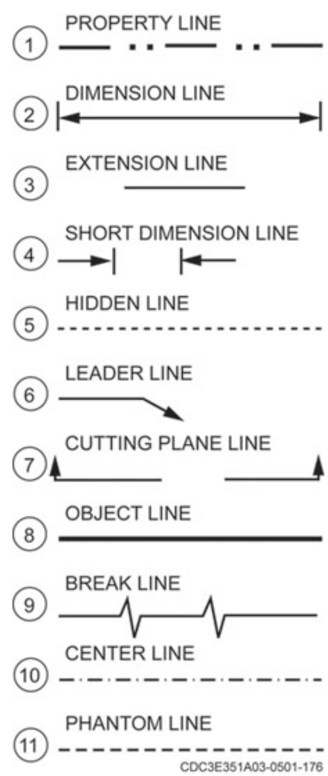


Figure 1–1. Types of lines.

Drawing symbols and abbreviations
Because of the small scale used in most drawings, standardized graphic symbols are used to present complete information concerning construction items and materials. These typical symbols are used so frequently in construction drawings that their meaning must be familiar not only to the preparer, but to the user as well. The main information sources for a particular symbol are the Military (Drawing) Standards (MIL-STD) and the American National Standards Institute (ANSI). Refer to these standards before you use other references.

Symbols

Symbols are used to identify various materials and structural parts. Topographic symbols are used to indicate the natural features found on the job site. The symbols on our drawings refer to notes and other drawings. The numbers placed inside of squares represent the notes placed along the right side of the drawing. The letters above the letter/number in a circle are a reference to detail drawings. Take a look at the second floor plan (FO 2). Just below the master bedroom's walk-in closet, there is a "C" placed above "A-21". The "C" tells us that we need to refer to detail "C" that can be found on drawing "A-21" (architectural drawing 21) An "S", such as "S-21" would refer to a structural drawing. Figure 1–2 shows some common symbols used for doors and windows.

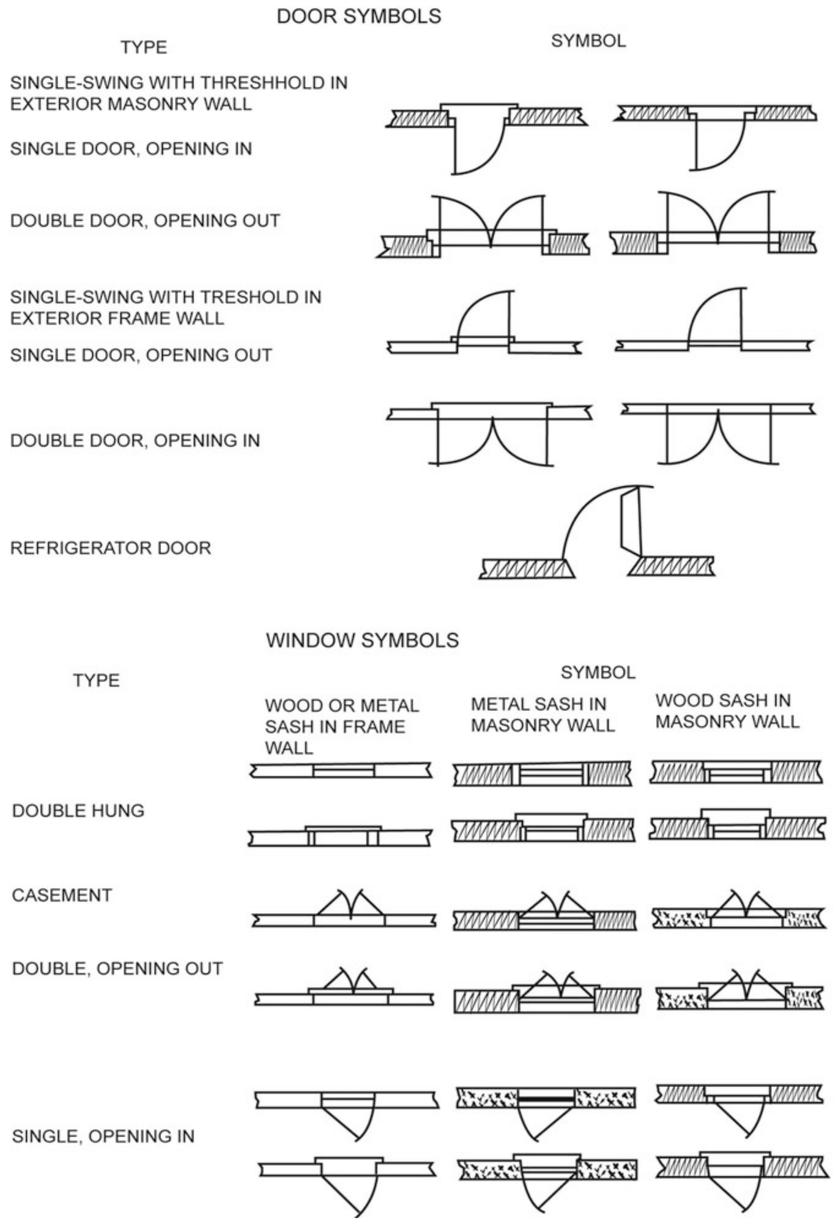


Figure 1–2. Door and window symbols.

Abbreviations

Because working drawings have limited space available, abbreviations are used to identify objects and materials. The following are some basic guidelines that apply to abbreviations:

- Written with one or more capitalized letter (i.e., BR for bedroom).
- Two or more words may be abbreviated by using the first letters of the words and placing them together (i.e., PSF for per square foot).
- Periods are only required at the end of an abbreviation if the abbreviation spells out a word (i.e., CLOS. for closet).
- Two or more abbreviated words may be separated with a space (i.e., FAM. RM. for family room).
- There is more than one standardized way to abbreviate some words (i.e., closet may be abbreviated as C, CL, or CLOS).
- The same abbreviation may be used for different items. It is important to take note where they are placed on the drawing to determine the correct meaning (i.e., R may be used for riser, ridge, radius, or range).

Drawing notes

Notes are brief, clear, and explicit statements regarding material use and finish and construction methods. Notes in a construction drawing are classified as specific and general.

Specific notes

Specific notes are used either to reflect dimensioning information on the drawing or to be explanatory. As a means of saving space, many of the terms used in these notes are often expressed as abbreviations. They are often accompanied with a leader line.

General notes

General notes (FO 8) refer to all of the notes on the drawing not accompanied by a leader line. General notes for a set of drawings that cover one particular type of work are placed on the first sheet of the set. General notes are usually placed a minimum of 3 inches below the revision block. General notes for architectural and structural drawings may include, when applicable, roof, floor, wind, seismic, and other loads, allowable soil pressure or pile-bearing capacity, and allowable unit stresses of all the construction materials used in the design. General notes for civil, mechanical, electrical, sanitary, plumbing, and similar drawings of a set may include, when applicable, references for vertical and horizontal control (including sounding) and basic specific design data. General notes may also refer to all of the notes grouped according to materials of construction in a tabular form (schedules).

Conclusion

The more you read prints, the more familiar you'll be with them. As you can tell, a set of drawings provides an abundance of information that must be used together to get the full picture of what you need to do. It's like piecing together a jigsaw puzzle. If you are ever in doubt as to what the plans call for, be sure to ask your supervisor for assistance. It's better to get clarification up front than to try and fix something down the road.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

201. Types of construction drawings

1. Match each construction drawing in column B with its characteristics in column A. Items in column B may be used once, more than once, or not at all.

Column A		Column B
____ (1)	Present the proposed building or facility in an attractive setting in its natural surroundings at the proposed site.	a. Master plan drawings.
____ (2)	The initial plans projects prepared by the designer or architect's and engineer's firm during the early planning or promotional stage of the building development.	b. Presentation drawings.
____ (3)	Drawings, schedules, diagrams, and other related data used to illustrate a material, a product, or a system for some portion of the work prepared by the construction contractor, subcontractor, manufacturer, distributor, or supplier.	c. Shop drawings.
____ (4)	Any drawing that furnishes the information the craftsmen requires to manufacture a machine part or a construction crew requires to erect a structure.	d. Working drawings.
____ (5)	Show sufficient features to be used as guides in long-range area development.	e. Preliminary drawings.
____ (6)	Drawings are 100 percent complete, signed by the contracting officer, and are used for bidding purposes.	f. Final drawings.
____ (7)	The original contract drawings, corrected according to the marked prints, provide a permanent record of as-built conditions when the construction work on a project is completed.	g. Redlined drawings.
____ (8)	The original contract drawings that are changed to show the conditions from the redlined drawings.	h. As-built drawings.
____ (9)	The official contract drawings that you will mark up during construction to show as-built conditions.	i. Record drawings.

2. Which plan furnishes the essential data for laying out the proposed building lines and shows the contours, boundaries, roads, utilities, trees, structures, references, and other significant physical features on or near the construction site?

3. Which plan is the key drawing in a set of drawings?

4. Match each structural drawing in column B with its characteristics in column A. Items in column B may be used once, more than once or not at all.

Column A		Column B
____(1)	Shows the size, the number, and the location of the structural members constituting the building framework.	a. Foundation plan.
____(2)	Large-scale drawings of the construction assemblies and installation that were not clearly shown.	b. Framing plan.
____(3)	Tabular or graphic arrangements of extensive information or notes related to construction materials.	c. Section.
____(4)	A top view of the footings or foundation walls.	d. Detail.
____(5)	Used in each main division, as necessary, to show the types of construction required, the types of materials used, their locations, and their assembling methods.	e. Schedule.

5. Match each specification in column B with its characteristics in column A. Items in column B may be used once, more than once or not at all.

Column A

____(1) Gives detailed information regarding materials and work methods for a particular construction project.

____(2) Contains requirements common to many companies within a given industry.

____(3) Published in electronic format.

____(4) Contains the precise description for the manner and process for making, constructing, compounding and using any items a manufacturer produces.

____(5) Used for specifying construction for the military services.

Column B

a. Unified Facilities Guide Specifications.

b. Technical Society and Trade Association Specifications.

c. Manufacturer's Specifications.

d. Project Specifications.

202. Reading construction drawings

1. What identifies each sheet in a set of drawings and where is it located?

2. What are the three types of rules used to draw construction drawings to scale?

3. Explain what the outside, second, and third (inner) rows of dimension lines represent.

4. How can you find window locations on a floor plan?

5. Match each line in column B with its characteristics in column A. Items in column B may be used once, more than once or not at all.

Column A	***Column B***
____ (1) Used to show where an object or wall is cut to reveal a cross section.	a. Property line.
____ (2) A long line that is broken with zigzags. It is used when there is not enough space on the paper to continue the scaled drawing	b. Dimension line.
____ (3) A heavy solid line with one long dash followed by two short dashes or dots.	c. Extension line.
____ (4) Used to find the center of objects, such as walls, door and window openings, holes, etc.	d. Short dimension line.
____ (5) A series of short dashes to show edges that would not be visible from the view on the drawing.	e. Hidden line.
____ (6) Used to identify the edges or outlines of an object such as walls, buildings or sidewalks.	f. Leader line.
____ (7) Used to identify an object that is not shown versus one that is just hidden from view.	g. Cutting plane line.
____ (8) A solid thin line with terminators at each end. It provides the horizontal or vertical distance between two points.	h. Object line.
____ (9) A short line that is drawn at an angle to an object. It extends from a description, note or measurement and will extend to the object that is being described.	i. Breaker line.
____ (10) Used when there is not enough space to write the dimension between the arrows.	j. Centerline.
_____ (11) Thin lines that project at a right angle from walls or other objects. They are used in conjunction with dimension lines.	k. Phantom line.

1–2. Shop Drawings

As a structural journeyman, there will probably come a time when you are tasked to develop a shop drawing (sketch) for a particular project. It could be something as simple as a small metal component or something more involved such as wall units and cabinet components. Whatever the case, you need to know how to develop accurate and readable sketches that can be read by other craftsmen, not just yourself. This section provides information on common drawing characteristics and dimensioning terms. You will learn more about developing sketches in CDC 3E351B, Volume 1, *Sheet Metal Layout and Forming*.

203. Sketching shop drawings

As you have already learned, drawings show your ideas concerning the fabrication, assembly, and installation of structural components. These drawings represent exactly what you, the drafter, want built. In this lesson, we cover two drawing types and views most common to shop drawings.

Shop drawing types

In figures 1–3 and 1–4, you can see the relationship of the two types of drawings we discuss: pictorial and orthographic projection drawings.

Pictorial drawings

A pictorial drawing (fig. 1–3, cube in the center) is given that name because it is similar to a picture. They are three-dimensional and can be compared to pictures of various objects in different views. You'll see them used in a limited extent on working drawings. However, an advantage is that they are used extensively in drawing shop sketches and are easy to interpret with little training. When using pictorial drawings, be careful to use the listed measurements. Don't go by the appearance of the item because its appearance may look distorted. Figure 1–4 shows a pictorial drawing of a house.

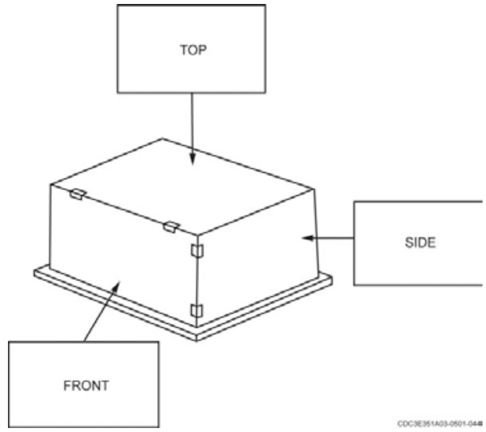


Figure 1–3. Pictorial and orthographic projection drawing.

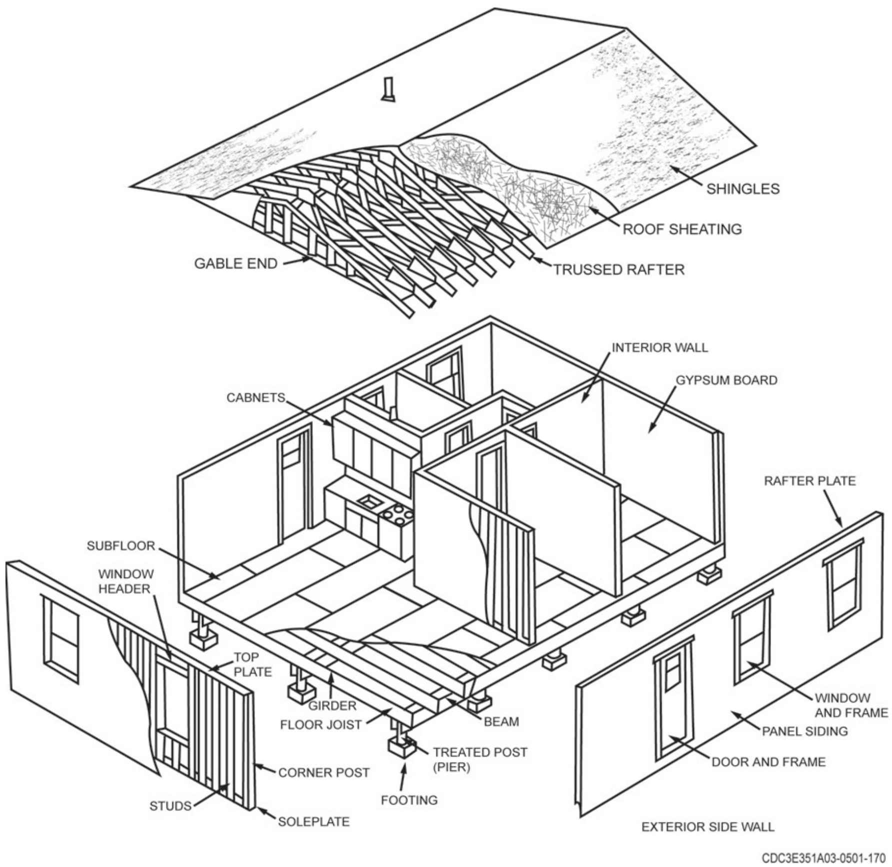


Figure 1–4. Pictorial drawing of a house.

Orthographic projection drawings

Orthographic projection is the method we use to create working drawings. The word, orthographic, means "straight line" and projection refers to the different parts of an object that are drawn on a flat surface. These drawings are two-dimensional, meaning that they only show one side or surface. That being the case, more than one orthographic drawing is needed to describe a single object.

Orthographic projection drawings have the advantage of showing all the features in their true shapes. The three rectangles marked "*top*," "*side*," and "*front*" (fig. 1–3) are called orthographic projections and show the true size and shape of each side of the object. Two or more views of orthographic projections are usually at right angles to each other and perpendicular to the plane of projection. Notice how the top, front, and side are projected so that each resembles a rectangular plane. In the pictorial view, it appears that the angles at the four corners are not equal; but in the projection view, you can see that all of the angles are equal.

In orthographic projection drawings, you can see three views of an object. This shows you the three main dimensions: length, width, and height. The orthographic projection showing the top is called the top or plan view. The orthographic projection showing the front is also called an elevation view. It shows the part as if you were standing directly in front of it. Note that you only see the front part. The orthographic projection of the end or side is also an elevation view. It shows the distance from the front to the back as if you were standing directly at the end of it. Note; you only see the end part. As you can see, in simple orthographic projections of regular shapes like this, the end view is not important because all dimensions are obtainable from the top and front views.

Curved surfaces don't always look curved in an orthographic projection because you are looking at the top, bottom, or side of an object 90° to the surface. In a pictorial drawing, you can see that the edges curve; but in an orthographic projection, you see the surface broadside, and it appears flat. The example shown in figure 1–5 is a plan and elevation view of the orthographic drawing of a cone. Although you know that the side of a cone curves, you cannot see the curvature in the elevation view of the drawing. However, from the accompanying plan view, you can see that the base of the elevation view is circular. It is a good idea to keep in mind that lines in orthographic projections are not curved, but may indicate a curved surface. It is up to you to determine the curvature from one of the other views.

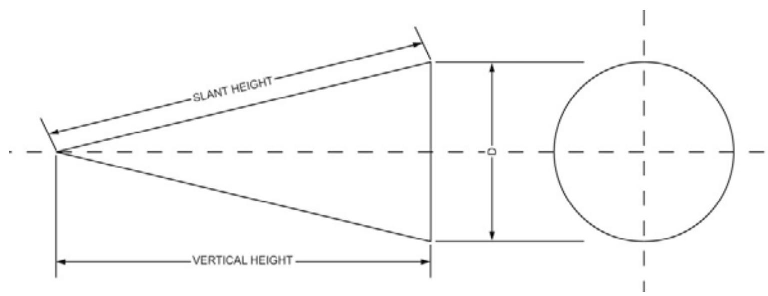


Figure 1–5. Orthographic projection of a cone.

Types of views

Drawings provide you or your coworkers with information to develop patterns and fabricate, assemble, and install the components represented. This includes such information as size and shape of the components, and how to install them. You'll find drawings divided into three general classes—detail drawings, assembly drawings, and installation drawings. In structural drawings, these classes combine into three views, such as plan view, elevation view, and detail view.

Plan views

We've already mentioned plan views and have used two figures to illustrate them. In the orthographic projections shown in figures 1–3 and 1–5, the plan views show the objects as you see them when you are standing directly over them and looking down. This also is true of an architectural drawing, where the plan view is an overhead view of the floor plan.

A plan view includes much of the information necessary for installation of components or assemblies in a building. It shows the dimensions necessary for locating duct components in relation to the building layout and it shows room dimensions that are helpful in the various layout and installation tasks. In the illustration, notice the information concerning the overall appearance of the installed duct system—the size and shape of the duct pieces, the room dimensions, the grille locations, the direction of airflow, and the location of return ducts under the floor. It shows the part you would see if you were standing directly over the object and looking down on it.

Elevation views

In figures 1–3 and 1–5, two simple elevation views are illustrated. Now in figure 1–6, you can see the elevation view of a furnace and air supply trunk. Notice that this side view contains information that may be shown in a plan view. From elevation views of this type, you also can determine vertical dimensions and distances needed for pattern layout, fabrication, and installation. In structural work, elevation views similar to this are often contained on the same working drawings as the plan views.

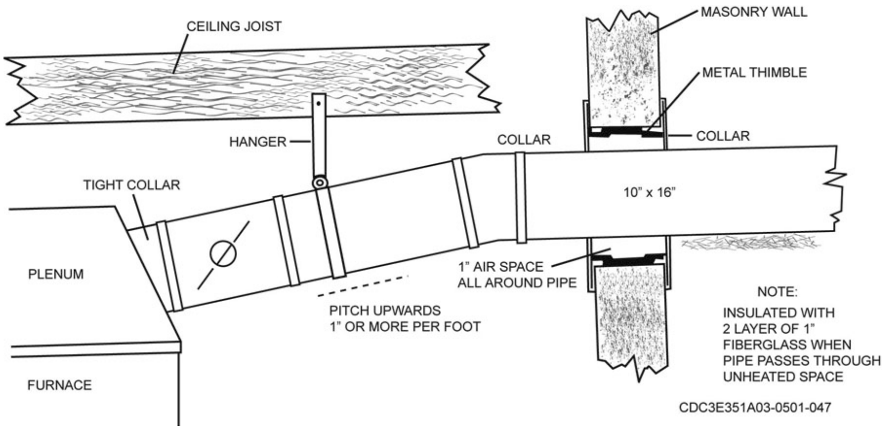


Figure 1–6. Elevation view.

Detail views

Detail views show small parts that you cannot see clearly in the plan and elevation views. For example, the detail view shown in figure 1–7 illustrates the use of a flexible connector and methods of making the connection. This connector prevents furnace noise from being transmitted through the duct system. You'll find detail views that include descriptions (e.g., size, specifications, shape, materials, and methods of fabrication) similar to these included with most plan and elevation views.

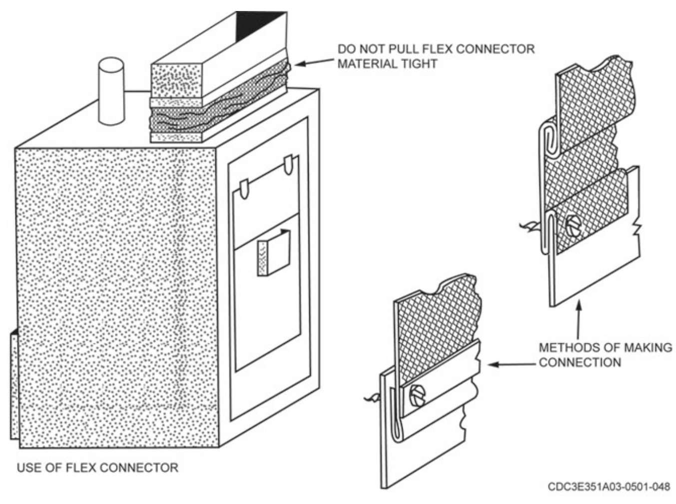


Figure 1–7. Detail view of a flexible connector.

Dimensioning terms

To accurately understand the dimensions of an object, it is necessary that you and the drafting person follow the same definition of length, width, thickness, height, and depth.

Length

Length normally refers to the greatest dimension of an object or the greatest dimension of any part of an object being described. For example, figure 1–8 shows a board with a cleat attached. It shows the board as being 24 inches in length and the cleat as being 18 inches in length. In both cases, the length is the greatest dimension of each object.

Width

Width usually refers to the dimension of an object from side to side, or in a direction at right angles to the length. In figure 1–8, the board is 18 inches wide and the cleat is 3 inches wide.

Thickness

Thickness usually refers to the smallest dimension of any part of an object being described. Thickness can apply either to the main part of the object or to some separate part attached to the object being described. It also can apply to a part projecting from an object; however, it does not apply to a groove cut in an object. Figure 1–8 shows you that the board is ¾-inch thick and that the cleat also is ¾-inch thick.

Height

Height indicates an object's dimension, or a part of it, that rises above either the surface of the object described or the one on which it stands. For example, if you place a block on a table so that its greatest dimension is upright (i.e., standing on end), you would refer to the longest dimension as height instead of length. In figure 1–8, the center block is 3 inches high.

Depth

Depth is a perpendicular measurement downward from the top surface or backward from the front. Note in figure 1–8, the drawing of a block with a groove in the top surface. You could say the groove is ½ inch below the top surface of the block, or simply ½-inch deep.

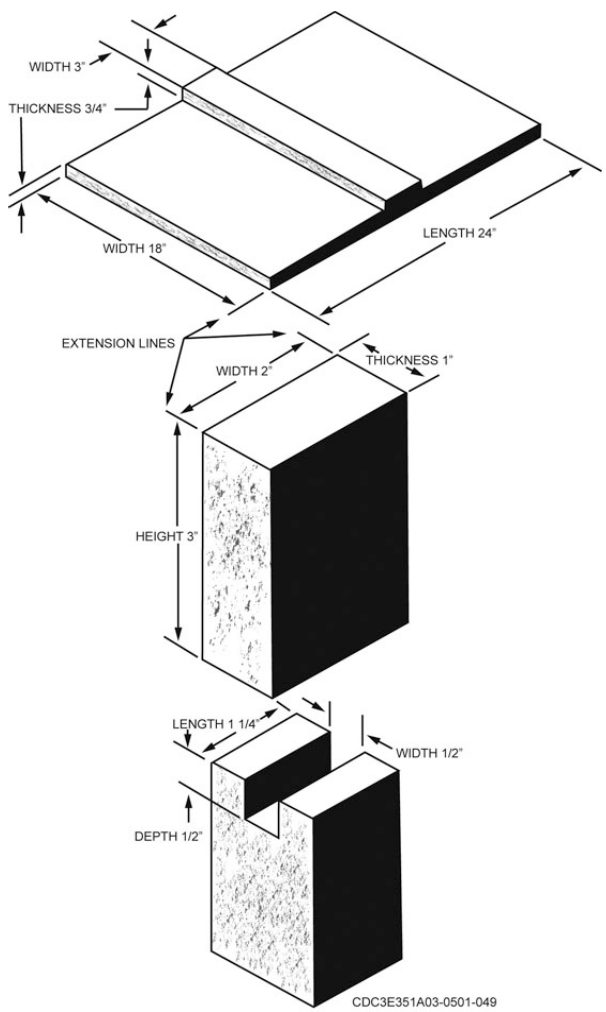


Figure 1–8. Dimensioning terms.

Use of dimensions

There is a standard procedure for placing dimensions on drawings. Learning this standard procedure enables you to read drawings quickly and accurately.

Rectangular duct dimensions are often written on working drawings. Notice the section of 10″ x 16″ duct in figure 1–6, meaning 10 inches high and 16 inches wide. When the dimensions are shown on the duct, the first number indicates the side of the duct facing the reader. If this same section of duct is shown on a plan view, it is marked 16″ x 10″.

Angles

You can see angle dimensions in figure 1–9. Notice how the dimension lines are used and how angle sizes are read from a horizontal position, regardless of the angle position. If the angle is extremely acute, as shown by the 15° angle, the dimension lines and the dimension may be placed outside the angle.

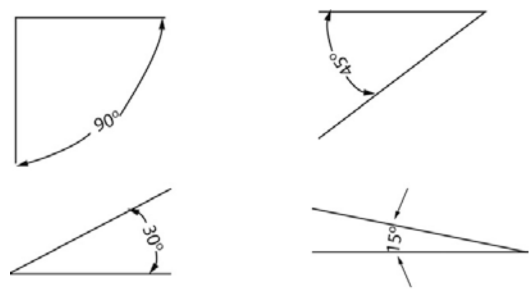


Figure 1–9. Dimensions of angles.

Circles

Figure 1–10 shows how dimensions are drawn for circles on working drawings. Centerlines should not be used as dimension lines; therefore, when you show diameters inside the circles, do it as shown in the upper left circle of the illustration. Notice the preferred way of showing the diameter by drawing parallel extension lines from the outer surface of the circle and indicating dimensions between these two lines. The circles shown in the center and lower right illustrate the way small circles are dimensioned.

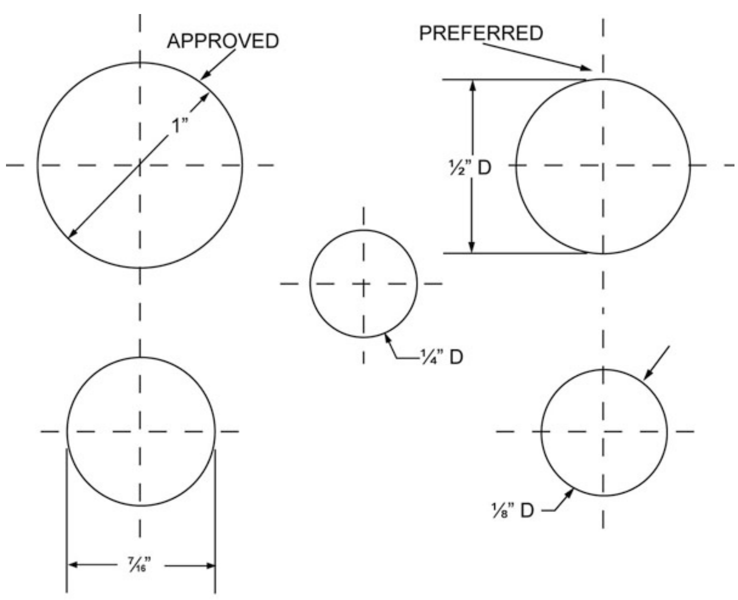


Figure 1–10. Dimensions of circles and holes.

Arcs

An arc is a curved object. Figure 1–11 shows how dimension lines are used to indicate the radii of arcs. Notice that an X is placed at the center point, with a dimension line going to the appropriate arc. In this illustration, the radius is shown for each arc, although in actual practice the drawing of a rectangular elbow has only the throat radius marked. The throat radius is the smaller of the two arcs. The larger arc is the heel radius.

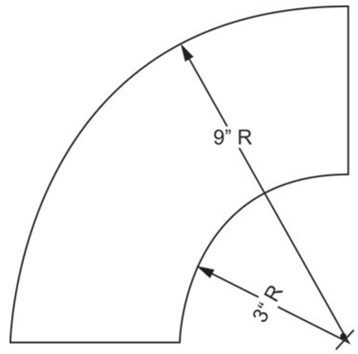


Figure 1–11. Dimensions of arcs.

Holes

Most drawings show the dimensions between holes from center to center rather than from outside edge to outside edge. Figure 1–12 shows a piece of metal with three equally spaced $^{9}/_{16}$-inch-diameter holes not on a centerline. Dimension and extension lines have been used to indicate various dimensions. All three holes have a note to show their diameter. These diameters could have been labeled separately, as shown in figure 1–10.

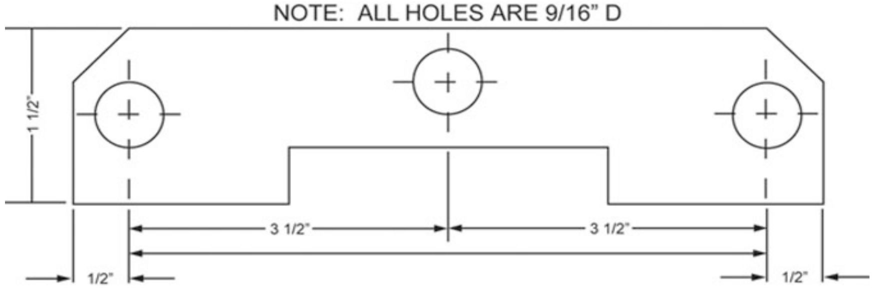


Figure 1–12. Dimensions for holes.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

203. Sketching shop drawings

1. What is the advantage of pictorial drawings?

2. Which drawing shows the true size and shape of all sides of an item?

3. What are the three main dimensions shown by orthographic projection drawings?

4. What view is an overhead view?

5. What view contains vertical dimensions?

6. List five terms that deal with the dimensions of an object.

7. What is the preferred method of indicating dimensions of a circle?

8. In using dimension lines on arcs, how do we locate the center point?

9. How do you indicate the dimension between two holes in an object?

Answers to Self-Test Questions

201

1.
   (1) b.
   (2) e.
   (3) c.
   (4) d.
   (5) a.
   (6) f.
   (7) i.
   (8) h.
   (9) g.

2. Site plan.

3. Floor plan.

4.
   (1) b.
   (2) d.
   (3) e.
   (4) a.
   (5) c.

5.
   (1) d.
   (2) b.
   (3) a.

(4) c.
(5) a.

202

1. Title block; bottom right hand corner of the drawing.
2. Architects scale, engineer's scale and metric scale.
3. The outside dimension lines usually represent the total width and length of the building. The second row of dimension lines usually shows the interior partitions and any offsets and recesses of exterior walls. The third (inner) row of dimension lines usually shows the placement of doors, windows and other structural features.
4. On centerline measurements.
5.
   (1) g.
   (2) i.
   (3) a.
   (4) j.
   (5) e.
   (6) h.
   (7) k.
   (8) b.
   (9) f.
   (10) d.
   (11) c.

203

1. They are good for drawing shop sketches and are easy to interpret with little training.
2. Orthographic projection.
3. Length, width, and height.
4. Plan.
5. Elevation.
6. (1) Length.
   (2) Width.
   (3) Thickness.
   (4) Height.
   (5) Depth.
7. By drawing parallel extension lines from the outer surface of the circle and indicating dimensions between these two lines.
8. By placing an X at the center point.
9. Usually indicated from center to center.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

1. (201) Before you erect a structure, obtain the required information needed from the
   a. master plans.
   b. shop drawings.
   c. working drawings.
   d. presentation drawings.

2. (201) To determine the size, the number, and the location of structural members constituting the building framework, which plan should you review?
   a. Site.
   b. Floor.
   c. Framing.
   d. Foundation.

3. (201) Which project drawing would you reference to see construction assemblies and installations on a large-scale drawing that were *not* clearly shown in other drawings?
   a. Details.
   b. Sections.
   c. Elevation.
   d. Schedules.

4. (201) To specify construction for the military services, which specification would you use?
   a. Project.
   b. Manufacturer.
   c. Technical Society and Trade Association.
   d. Uniformed Facilities Guide Specifications (UFGS).

5. (202) You identify each sheet in a set of construction drawings by referring to the
   a. revision block in the top left corner.
   b. revision block in the top right corner.
   c. title block in the bottom left corner.
   d. title block in the bottom right corner.

6. (202) Where on a construction drawing would you refer to determine the total width and length of a building?
   a. Outer dimension lines on a floor plan.
   b. Inner dimension lines on a floor plan.
   c. Outer dimension lines on a detail drawing.
   d. Inner dimension lines on a detail drawing.

7. (202) To determine window locations on a construction drawing you should refer to the
   a. window schedule.
   b. exterior elevations.
   c. centerline measurements on the floor plans.
   d. second row dimension lines on the floor plans.

8. (202) When reading a slab foundation plan, you can determine if there are any interior footings below the slab because they are shown as
   a. object lines.
   b. hidden lines.
   c. dimension lines.
   d. cutting plane lines.

9. (203) When sketching working drawings, which view would you use to show an object as if you are standing directly over it and looking down on it?
   a. Plan.
   b. Detail.
   c. Elevation.
   d. Projection.

10. (203) When sketching working drawings, you may write an angle dimension outside of the angle when the angle is extremely
    a. acute.
    b. obtuse.
    c. inverted.
    d. extended.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Materials

OF ALL THE CONSTRUCTION materials, wood products are probably used most often and are perhaps the most important. However, as a structural journeyman, you not only need to know about wood products, you also need to know about the different types of metals, fasteners, and other products of the construction industry. In this unit, we cover these types of materials.

2–1. Construction Materials

We use wooden building materials, such as lumber and wood panels, for many building tasks that include repairing or modifying existing buildings or constructing a new building. On many large construction projects, the project drawings usually include a wood classification sheet. On small projects, many times it is the craftsman that decides on what materials to use.

204. Identifying lumber and timber

Lumber and timber are both wood products that come from trees. We often speak or write the terms “lumber,” and “timber” in ways to suggest that their meanings are alike or nearly so. In the structural field, however, the terms have distinct, separate meanings. Lumber is wood that has been cut, seasoned, and dressed for construction work. Timber is lumber that is 5 inches or more in both thickness and width. In this lesson, we look at standards for grading, identification, and basic use.

Lumber sizes

Standard lumber sizes have been established in the United States for uniformity in planning structures and in ordering materials. Lumber is identified by nominal sizes. (The nominal size is the rough-cut size.) For construction work, the rough-cut lumber is smoothed and squared in a process called dressing. This is why a 2- × 4-inch stud is actually only 1½ × 3½ inches.

Seasoning lumber

Seasoning lumber is a process that removes moisture from wood, reduces its weight, increases its strength, improves its decay resistance, and controls further evaporation. The seasoning process tends to stabilize the wood’s moisture content so that shrinkage, checking, and warping are minimized to produce lumber that is uniform in size. Seasoning is usually done in a kiln at the lumber mill where the lumber was first cut to size. A kiln is a large oven that uses heat that is supplied by a gas- or an oil-fired furnace to dry the lumber quickly. One method to season lumber is air-drying in a shed or stacking in the open until dry; however, it is seldom used and rather slow. We consider lumber dry enough for most uses when its moisture content is reduced to about 12 to 15 percent. To assure the right percentage is achieved, the mill checks it with a moisture meter.

Defects and blemishes

A defect in lumber is any flaw that affects the strength, durability, or function. A blemish is a flaw that mars only the appearance. A blemish can also be classified as a defect if it affects the function of the lumber, for example, a tight knot that mars the appearance of lumber intended for fine cabinetwork. Generally, high-grade lumber has very few knots or blemishes. Low-grade lumber may have knotholes and many loose knots. The lowest grades usually have splits, checks, and some warping. The lumber grade for a construction job is usually stated in the blueprint specifications. The following chart identifies common wood defects and blemishes that are found in lumber.

Wood Defects and Blemishes in Lumber	
Common Name	**Description**
Blue stain	Caused by mold. It may look bad but it has little or no effect on strength.
Check and split	Separation along the lengthwise grain, caused by too rapid or non-uniform seasoning (drying).
Decay	Deterioration caused by various fungi. Early stages are hard to identify. Advanced stages show wood that is soft, spongy, and that crumbles easily.
Hole	Caused by handling equipment, insects, or worms. It lowers the lumber's grade.
Knot	Branch section that may appear on a surface in crosswise or lengthwise section. A cross-sectional knot may be loose or tight. A lengthwise knot we call a spike knot. Knots generally reduce strength.
Pitch pocket	Solid or liquid pitch enclosed in the wood.
Shake	Separation along the lengthwise grain that exists before the tree is cut. A heart shake moves outward from the center of the tree and is caused by decay at the center of the trunk. A windshake follows the circular lines of the annual rings; its cause is not definitely known.
Wane	Flaw in an edge or corner of a board or timber. Caused by the appearance of bark or a lack of wood in that section.
Warp	Twist or curve caused by shrinkage that develops in a once flat or straight board.

Lumber classification

Lumber association classifications include the following types of classification.

Lumber	Classification
Rough lumber	Cut to the nominal size (sawed, edged, and trimmed).
Dressed lumber	Planed on one or more sides to attain smoothness and uniformity.
Matched lumber	Dressed with each piece having a tongue cut on one edge and a groove on the other edge.
Worked lumber	Dressed, ship-lapped, or patterned.
Ship-lapped lumber	Dressed and rabbeted on both edges.
Patterned lumber	Dressed and cut into a pattern or molded form.

A basic way to begin grading lumber is to classify it as "softwood" or "hardwood." At times, this classification can be confusing since some softwood lumber is harder than some hardwood lumber. Generally, however, hardwoods are denser and harder than softwoods. In addition, we can further classify lumber by the name of the tree from which it comes.

Softwood lumber types

There are different softwood lumber types that have certain characteristics that make them suited for certain uses. The following table shows a few of these characteristics.

Softwood	Characteristics	Common uses
Southern yellow pine	Color: Yellowish brown. Grain: Close and coarse. Decay resistance: Medium. Strength: High. Hardness: Soft to hard.	As lumber for heavy exterior construction such as posts. In solid lumber form, it is hard to work with. Also used as plywood for framing.

Softwood	Characteristics	Common uses
Western white pine	Color: Brownish white. Grain: Close and medium. Decay resistance: Low. Strength: Low. Hardness: Soft to medium.	As window sashes, cabinets, cornices, and other interior trim. It is usually knot free and easy to work with. It takes paint easily for a smooth finish.
Sugar pine	Color: Creamy white. Grain: Close and fine. Decay resistance: Low. Strength: Low. Hardness: Soft.	The same as western white pine, plus it is available in wide, knot free boards for pattern making. It takes paint easily for a very smooth finish.
Ponderosa pine	Color: White with a brown grain. Grain: Close and coarse. Decay resistance: Low. Strength: Medium. Hardness: Medium.	As interior trim and for general purpose work. It has a distinctive pine smell. It usually has knots that, if painted, must be sealed and primed first.
Spruce	Color: Cream to tan. Grain: Close and medium. Decay resistance: Low. Strength: Medium. Hardness: Medium.	As siding and subflooring and other general-purpose work. It has a distinctive spruce smell.
Fir	Color: Yellow to orange brown. Grain: Close and coarse. Decay resistance: Medium. Strength: High. Hardness: Medium to hard.	An excellent and widely used building material. It is used as structural lumber, interior trim, and as plywood.
Redwood	Color: Reddish brown. Grain: Close and medium. Decay resistance: Very high. Strength: Low. Hardness: Soft.	As general-purpose lumber where decay resistance is a major factor. It is also used as wall paneling.
Red cedar	Color: Dark reddish brown. Grain: Close and medium. Decay resistance: Very high. Strength: Low. Hardness: Soft.	To make top quality storage chests and as a closet liner because it is moth proof and has a pleasant cedar smell. It can also be used where decay resistance is a major factor.
White cedar	Color: Cream with reddish to tan grain lines. Grain: Close and medium. Decay resistance: Very high. Strength: Low. Hardness: Soft.	As roof shingles, siding, structural timber, and utility poles. It can also be used where decay resistance is a major factor.

Softwood grading

The American Lumber Standards Committee governs the basic principles for grading softwood lumber. In turn, various lumber producer associations use it to develop and publish grading rules for lumber produced in their region. These associations place a grade stamp on their lumber to show that strict quality controls were followed. The grade stamp also shows the association trademark, mill number, and if the lumber was seasoned before planning. These quality controls cover strength, stiffness, and appearance. Knowing the softwood grading system can help you make the best choice for your project. For example, don't use a no. 1 grade when a no. 3 grade meets all requirements. We begin our softwood grading with two lumber subdivisions that are explained in the following table below.

Select Lumber	
Grade	***Description***
A	Practically defect and blemish free. Recommended for clear coating.
B	Contains a few minor blemishes. Recommended for clear coating.
C	Contains more numerous and significant blemishes than grade B. Can easily and thoroughly be concealed with paint.
D	Contains more numerous and more significant blemishes than grade C. Can still present a satisfactory appearance when painted.
Common Lumber	
Grade	***Description***
No. 1	Sound, tight-knotted stock containing only a few minor defects. Must be suitable for use as watertight lumber.
No. 2	Limited defects but no knotholes or other serious defects. Must be suitable for use as grain-tight lumber.
No. 3	Contains a few defects that are larger and coarser than those in No. 2 common; for example, occasional knotholes.
No. 4	Contains serious defects like knotholes, checks, shakes, and decay.
No. 5	Capable only of holding together under ordinary handling.

Softwood classifications

There are many ways to classify softwood lumber. These classification sizes refer to the nominal size; let's look at some of them.

Board classifications

We consider lumber less than 2 inches thick and 2 inches or more in width to be a board. Most commercially available boards have a nominal 1-inch thickness; we refer to them to as "one bys." For example, lumber that is 1 inch thick × 4 inches wide we call a "1 by 4."

Dimension classifications

Lumber that is 2 to 4 inches thick we consider to be dimension lumber. It is classified for light framing, studs, structural light framing, structural joists and planks. A common term for these boards is "2 by" and "4 by." The table following shows the grades in order of strength and appearance along with common uses.

Dimension Lumber		
Classification	***Grade***	***Use***
Light framing (2 to 4 inches wide)	Construction Standard Utility	Where strength is not a primary concern. Use for partition walls, cripples, blocking, and other light duty work.
Studs (2 inches and wider)	Stud	Where strength and stiffness is a concern. Use as vertical framing members such as load bearing walls.
Structural light framing (2 to 4 inches wide)	No. 1 No. 2 No. 3	Where high bending strength is needed. Use as trusses, as forms for concrete pier walls, or other work subject to a bending force.

Dimension Lumber		
Classification	***Grade***	***Use***
Structural joists and planks (5 inches wide and wider)	No. 1 No. 2 No. 3	Where the greatest strength is needed. Use as joists, rafters, and general framing.

Timber classifications

We consider lumber that is 5 inches or more in thickness to be timber. This type of lumber is classified as beams, stringers, posts, and timbers. The table below shows the grades in order of timber strength and appearance.

Timber	
Classification	***Grade***
Beams and stringers (Width is 2 inches or greater than the thickness).	No. 1 No. 2 No. 3
Posts and timbers (5 by 5 inches or larger). (Width must not be 2 inches greater than the thickness).	No. 1 No. 2 No. 3

Hardwood grades

The National Hardwood Lumber Association establishes hardwood lumber grades. See the table below for some of these grades.

Hardwood	
Grade	***Description***
Firsts and seconds	Best hardwood grade. Each piece must be at least 6 inches wide by 8 feet long.
Select	Next best grade after first and seconds. Each piece must be at least 4 inches wide by 6 feet long.
No. 1	Each piece can be a different width and length.

Air Force structural craftsmen occasionally use hardwood lumber and plywood with a hardwood veneer for finish work. For many jobs, the hardwood is stained and clear coated. The following table identifies some hardwood species, the characteristics, and its uses.

Hardwood species	Characteristics	Common uses
Birch	Color: Light brown. Grain: Close and fine. Decay resistance: Low. Strength: High. Hardness: Hard.	Furniture making and as a plywood veneer.
Cherry	Color: Light reddish brown. Grain: Close and fine. Decay resistance: Medium. Strength: High. Hardness: Medium.	Furniture making, as plywood veneer, as wall paneling, and as excellent quality molding.

Hardwood species	Characteristics	Common uses
Lauan	Color: Light reddish brown. Grain: Open and medium. Decay: Resistance, low. Strength: Low. Hardness: Soft.	Plywood veneer and as wall paneling. (Common on hollow core doors).
Mahogany	Color: Russet brown. Grain: Open and fine. Decay resistance: High. Strength: Medium. Hardness: Medium.	Furniture making, as a plywood veneer, and for wall paneling.
Maple	Color: Light tan. Grain: Close and medium. Decay resistance: Low. Strength: High. Hardness: Hard.	Plywood veneer and as flooring.
Oak	Color: Light tan. Grain: Open and course. Decay resistance: Medium. Strength: High. Hardness: Hard.	Plywood veneer, as flooring, and as excellent quality molding.
Poplar	Color: Greenish yellow. Grain: Close and fine. Decay resistance: Low. Strength: Medium low. Hardness: Medium soft.	Furniture making, as a veneer core, and as good quality molding.
Walnut	Color: Dark brown. Grain: Open and fine. Decay resistance: High. Strength: High. Hardness: Medium.	Furniture making, as a veneer, and as superior quality molding.

205. Identifying engineered lumber products and wood panels b

Engineered lumber products and wood panels are two types of construction products that are being used quite extensively in the construction industry. There are various types available that are used for all types of construction projects. Familiarization with each type will aid you when it comes time for you to decide the best materials to order for certain projects.

Engineered lumber products

Engineered lumber products are factory made using various techniques to glue wood together. They are used in place of traditional lumber on many structural jobs.

Glue laminated beams

Glue laminated beams are usually made from 2- × 4-inch or 2- × 6-inch-softwood lumber that is glued together under pressure through a process called lamination. The lamination process can be used to make a beam up to 30 inches wide. The lamination process greatly increases the lumber's load-carrying capacity and rigidity. In addition, the beams can be made to add architectural beauty to a building. They are usually delivered prefinished in many shapes and sizes such as straight lines, tapers, curves, or arches. They are often used in large open space areas such as meeting halls and churches.

Laminated-veneer lumber

Laminated-veneer lumber looks very much like plywood. It is made from glue and veneer panels. The difference is that plywood has the plies stacked with the grain at 90° to the previous layer. In laminated-veneer lumber, the plies are stacked with the grain parallel to provide greater strength to carry heavy loads for such components as beams, headers and trusses. Laminated-veneer lumber is cut to various sizes, such as 1½ inch or 1¾ inch thick with depths from 5½ to 18 inches.

Wood I-beams

Wood I-beam flanges (i.e., the horizontal components) are made from laminated veneer lumber and the chord (i.e., the vertical component) is made from plywood or oriented strand board that is $^{3}/_{8}$ or $^{7}/_{16}$ inch thick. The web is glued to each flange groove. A wood I-beam is used as a rafter, a ceiling joist, or as a floor joist. They are available in lengths up to 60 feet and depths from 9½ up to 32 inches.

Open-web trusses

Open web trusses are made from solid 2- × 4-inch lumber. On long spans, steel webs are used instead of wood. Advantages of the open web are easy installation of pipes, drains, wiring, and other components without cutting the truss. An open web truss is often used in place of floor joists.

Parallel-strand lumber

Parallel-strand lumber is made from laying out 8-foot-long wood veneer strands and gluing them under pressure to form blocks up to 66 feet long. They are then cut and used as posts and beams. Pressure treatment is available for outside use, such as decks or porches.

Laminated-strand lumber

Laminated strand lumber is made from laying out 12-inch-long wood veneer strands with polyurethane glue to form lumber. It is sold in two thicknesses: 1¼ and 3½ inches. It is also used for door and window headers and for floor end joists.

Wood panels

Wood panels are man-made products made from wood and glue. They are available in different sizes for various repairs and construction needs. A standard panel size is 4 × 8 feet that you can cut into any shape. We are primarily concerned with plywood, but we also give a brief look at oriented strand board (OSB) and particleboard. Let's look at some of them.

Plywood

Plywood is made with wood plies (thin layers) that are stacked and glued with the grain direction turned at a 90 degree angle to each other (fig. 2–1). Then, pressure is applied to form a strong and split resistant sheet. The sheet can range in thickness from ⅛ to more than 1 inch. A standard sheet is 4 feet wide by 8 feet long. Manufacturers always use an odd number of plies such as 3, 5, and 7 to make plywood. The odd number creates an even ply amount on each side of the center ply (core). It also keeps the grain in the same direction on the outer plies (face and back). The face veneer often identifies a plywood sheet.

Basic classification

We can classify plywood as hardwood/softwood or as interior/exterior. The hardwood/softwood describes the face and back veneer. The interior/exterior describes where the plywood is to be used and is a very popular way to identify plywood. Exterior plywood plies are bonded with waterproof glues; while some is pressure treated for very wet conditions. You can select the type that matches your exterior requirements, such as siding, forms for concrete, and moisture exposure. Interior plywood can be bonded with one of two glue types: waterproof or non-waterproof. The non-waterproof type is used for cabinets and other inside construction. The waterproof type is used for the same purpose, but it can temporarily withstand wet conditions. All plywood types can be worked quickly and easily with common carpentry tools. They can also be sanded, painted, or texture coated.

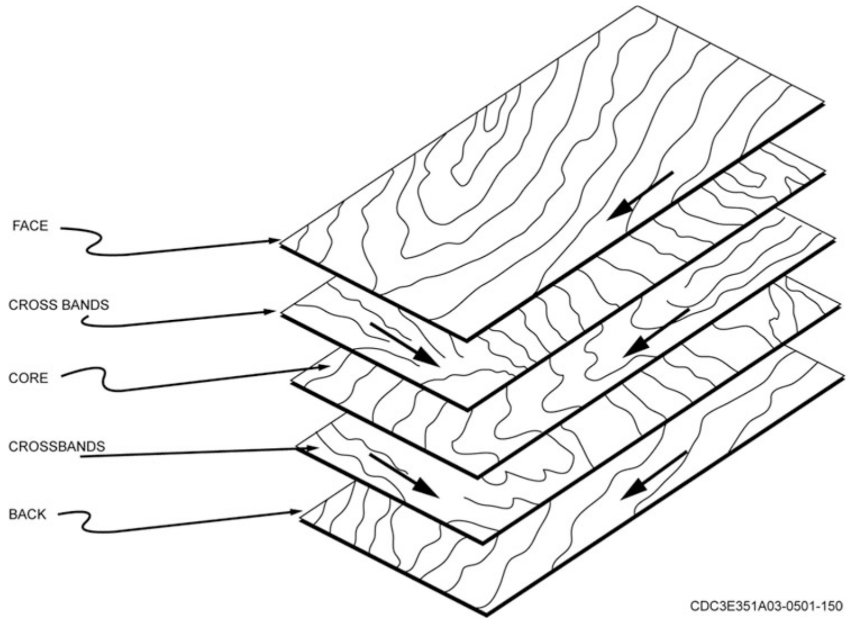


Figure 2–1. Plywood layers.

Softwood plywood grades

All plywood panels are quality graded based on the US Product Standard (PS) 1–95, *Construction and Industrial Plywood*, which includes species type, strength, glue type, and appearance. There are other standards that are stricter; associations such as the *American Plywood Association* places a grade-trademark stamp on its plywood that shows the compliance standard along with other information. An easy way to identify plywood is by letter grade (i.e., appearance). See the table below for the different plywood veneer grades and descriptions.

Plywood Veneer	
Grade	***Description***
A	Smooth and paintable. Up to 18 neatly made repairs permissible. Also used for natural finish in less demanding applications.
B	Solid surface veneer. Circular repair plugs and tight knots up to 1 inch permitted. Minor splits are also permitted.
C Plugged	Improved C veneer with splits limited to ⅛ inch wide. Knotholes and open defects are limited to ¼ by ½ inch.
D	Permits knots and knotholes to 2½ -inches in width and ½ inch larger under certain specified limits. Limited splits are permitted.

Double letter grades

Double letter grades identify the plywood panels' appearance and typical use. For example, a panel graded as "A-C" has an "A"-grade veneer on the face and a "C"-grade veneer on the back and can be used for work where only one side needs to have a good appearance. The grading is based on defects, such as knotholes, pitch pockets, splits, discoloration, and patches in the face. The following table lists some exterior and interior uses for construction grade plywood.

Exterior Grades for Softwood Plywood				
Grade	***Face***	***Back***	***Inner Plies***	***Uses***
A-A	A	A	C	Outdoors where appearance of both sides is important.
A-B	A	B	C	Alternate for "A-A" where appearance of one side is less important.

Exterior Grades for Softwood Plywood				
Grade	***Face***	***Back***	***Inner Plies***	***Uses***
A-C	A	C	C	Siding, soffits, fences. Face is finish grade.
B-C	B	C	C	For utility uses, such as farm buildings, some kinds of fences, etc.
C-C (Plugged)	C (Plugged)	C	C	Excellent base for tile and linoleum, backing for wall coverings.
C-C	C	C	C	Unsanded, for backing and rough construction exposed to weather.
B-B Concrete Forms	B	B	C	Concrete forms. Reuse until wood literally wears out.
Interior Grades for Softwood Plywood				
Grade	***Face***	***Back***	***Inner Plies***	***Uses***
A-A	A	A	D	Cabinet doors, built-ins, furniture where both sides will show.
A-B	A	B	D	Alternate of “A-A.” Face is finish grade; back is solid and smooth.
A-D	A	D	D	Finish grade face for paneling, built-ins, backing.
B-D	B	D	D	Utility grade. One paintable side. For backing, cabinet sides, etc.

There are five separate groups we use to grade softwood plywood. These groups are based on stiffness and strength. Group 1 includes the stiffest and strongest; group 5 includes the weakest woods. **NOTE:** No softwood species are rated in group 5.

Plywood Strength and Stiffness Grades				
Group 1	***Group 2***	***Group 3***	***Group 4***	***Group 5***
• **Fir:** Douglas Fir (Depends on region) • **Southern Pine:** Longleaf, Short leaf, Slash	• **Fir:** Douglas Fir (Depends on region) • **Fir:** Balsam, California • **Pine:** Ponderosa, Red, Virginia, Western, White • **Cedar:** Port Orford • **Spruce:** Red, Sitka, Sweetgum, Tamarack	• **Cedar:** Alaska • **Fir:** Sub-alpine • **Pine:** Jack, Lodgepole, Ponderosa, Spruce • **Spruce:** Engelman, White • **Redwood**	• **Cedar:** Incense, Western, Red • **Pine:** Eastern, White, Sugar	

Performance rated panels

The performance rated panels are designed for a specific purpose such as sheathing, flooring, and siding. An association grade stamp on the panel identifies the panel’s use, spacing, thickness, exposure rating, and its product compliance number.

Exposure ratings

The grade/trademark stamp lists the weather or moisture exposure rating as Exterior, Exposure 1, and Exposure 2. We can use plywood sheets stamped “Exterior” for continual exposure. Panels marked “Exposure 1” are for temporary exposure. We use them when construction delays cause them to be exposed for long periods before they are protected. Panels marked “Exposure 2” are also for temporary exposure. We use them when construction delays cause a moderate delay before they are protected.

Hardwood plywood grades

Hardwood plywood panels are primarily used for door skins, cabinets, and wall paneling. The Hardwood Plywood Institute uses a grading system with the following grades:

Hardwood Plywood	
Grade	***Description***
A	The best grade. Good quality. Used for the best quality work.
No. 1	Sound quality. Used for average and above average work.
No. 2	Utility quality. Used for general-purpose work.
No. 3	The lowest grade. Used as back face so that it does not show when installed.

These grades describe the face of the veneer; for example, an “A–2” grade would have a good quality face with a utility back. Other symbols that are used for both hardwood and softwood plywood are “G1S” (good, one side) and “G2S” (good, both sides).

Oriented strand board

OSB is made from wood strands (narrow strips). These strands are coated with resins and waterproof glue, stacked at 90 degree to each other, and then compressed and heated to form a uniformed sized board (sheet). OSB offers the same strength and stability that plywood does. OSB is available in different sizes and thickness for use as subflooring, roof sheathing, or as exterior wall sheathing.

Waferboard

Waferboard is made from wood chips (wafers). These wafers are much wider than the strands used to make OSB. These wafers are coated with a phenolic resin (a waterproof adhesive). Then the wafers are compressed and heated to form uniformed sized boards (sheets). Waferboard does not have the same strength and stability that OSB does, but it is available in different sizes and thickness for use as interior wall sheathing or as interior wall paneling.

Particleboard

Particleboard is made from wood particles that include flakes, chips, and shavings. These particles are arranged with the large ones in the center and the smaller ones closer to the surface. This arrangement gives it strength with a smooth level surface. The smooth surface makes it popular for laminates and veneers. It is available in different sizes and thicknesses and is used to make countertops, cabinets, drawers, shelving, sliding doors, room dividers, and built-ins.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

204. Identifying lumber and timber

1. What is the dressed size of 2- × 4-inch (2 by 4) lumber?

2. Match the common name of a wood defect and/or blemish in column B with its description in column A. The wood defects in column B are only used once.

Column A	*Column B*
____ (1) Separation along the lengthwise grain, caused by too rapid or non-uniform seasoning.	a. Bark pocket.
____ (2) Caused by handling equipment, insects, or worms. It lowers the lumber's grade.	b. Knot.
____ (3) Deterioration caused by various fungi.	c. Hole.
____ (4) Branch section that may appear on the wood surface in a crosswise or lengthwise location.	d. Pitch pocket.
____ (5) Solid or liquid pitch enclosed in the wood.	e. Shake.
____ (6) Caused by mold. With little or no effect on wood strength.	f. Check and split.
____ (7) Separation along the lengthwise grain that exists before the tree is cut. A heart shake moves outward from the center of the tree and is caused by decay at the center of the trunk.	g. Wane.
____ (8) Flaw appearing in an edge or corner of a board or timber. The presence of bark or lack of wood in that part causes it.	h. Decay.
____ (9) Twist or curve caused by shrinkage that develops in a once flat or straight board.	i. Warp.
	j. Blue stain.

3. Generally, what is the difference between hardwoods and softwoods?

4. What do the three quality controls cover for grading softwood lumber?

5. What number represents the best quality grade of softwood lumber?

6. What thickness lumber is considered timber??

205. Identifying engineered lumber products and wood panels

1. From what size softwood lumber do manufacturers usually make glue-laminated beams?

2. What is the difference between laminated veneer lumber and plywood?

3. What is an advantage of using open web trusses?

4. How is plywood constructed, and why is it a good design feature?

5. What do manufacturers use to bond the plies together in exterior plywood?

6. What do we use to identify plywood appearance quality?

7. What are the three plywood exposure ratings?

8. For what are hardwood plywood panels primarily used?

2–2. Fasteners

This section discusses some of the most common types of fasteners available that you can use on various types of projects—from woodworking to metal working. It's important for you to know which fasteners work best in differing situations to which you may be exposed.

206. Identifying fasteners

We use fasteners to attach material either to itself or to other materials. Some common fasteners include nails, staples, screws, bolts, anchors, drift pins, rivets and adhesives. In this lesson, we look at their basic identification and use.

Nails

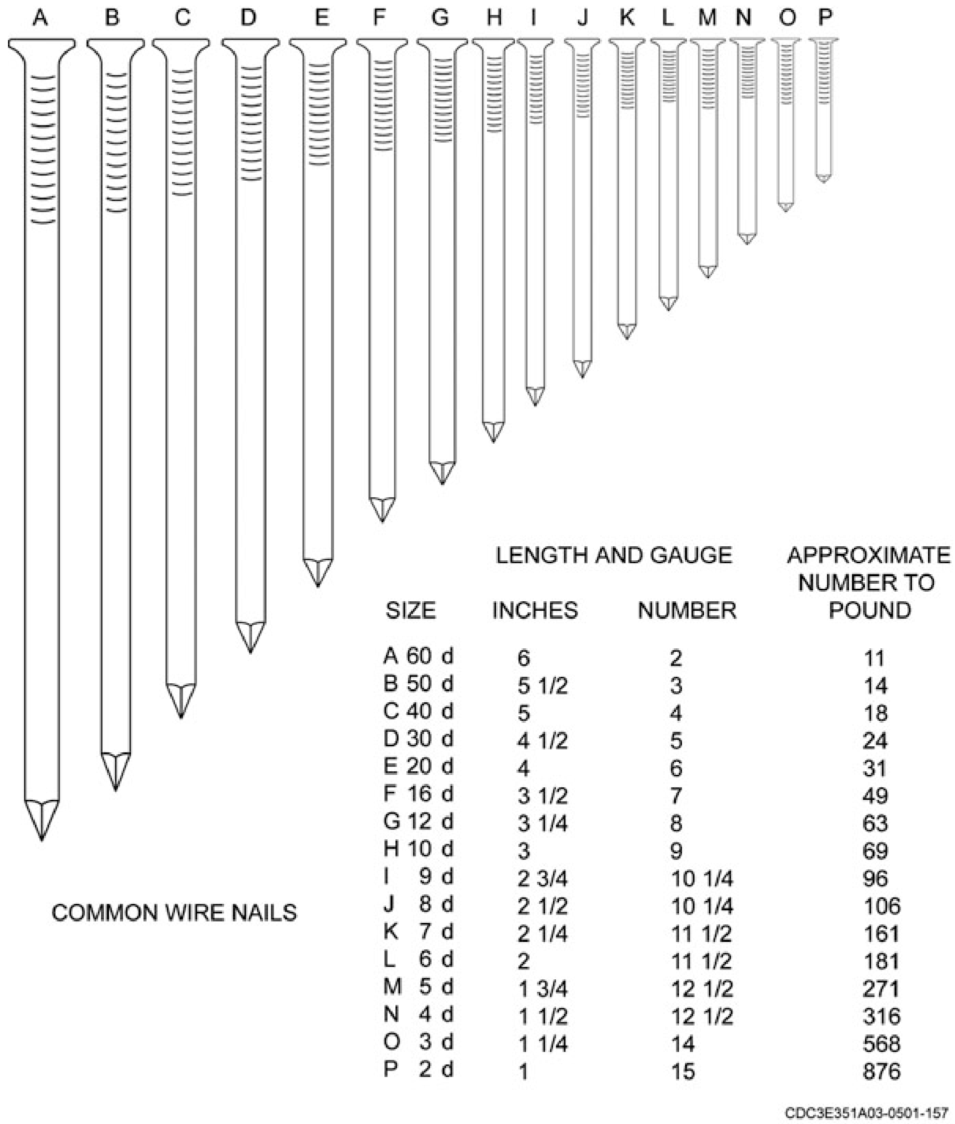
We generally consider nails the cheapest and easiest fasteners to install. They are available in many types and sizes. The table below shows the basic types:

Nails		
Type	***Description***	***Uses***
Common	Made from heavy gauge wire with a medium sized head.	Rough framing.

Nails		
Type	***Description***	***Uses***
Box	Similar to common nails, but they are thinner in gauge.	Toenailing and where common nails tend to split the wood.
Casing	Made from wire with a cone-shaped head. They are slightly larger in gauge when compared to finishing nails.	To attach door and window casings and other finished wood trim.
Finishing	Made from light gauge wire with a small head.	To attach wood trim and other wood items. Often used with a nail set to drive the head below the wood surface where you can then cover it with filler.
Brad	Similar to finishing nails, but they are thinner in gauge and length.	To attach thin wood trim. Often used with a nail set to drive the head below the wood surface where you can then cover it with filler.
Roofing	Short, heavy gauges with wide round heads.	Primarily used for roofing material, but also used to fasten softboard wall sheathing. The wide, thin head helps to hold material more securely than narrower heads.
Duplex	Similar to a common nail, but it has two heads. The lower head fastens into the wood. The upper head allows for easy nail removal.	To construct temporary structures that you must take apart, such as scaffolding and forms for concrete.

We measure most nail sizes in a unit known as a penny. We abbreviate penny with the lowercase letter “d.” Penny indicates nail length (fig. 2–2). A 6d (6-penny) nail is 2 inches long. A 10d (10-penny) nail is 3 inches long. These measurements apply to common, box, casing, and finish nails only. Some nails do not use the penny system, such as brads. We identify them by their actual length and gauge number. There are a few general rules to follow when using nails, which are listed in the following list.

- Select the best nail for the job.
- Drive nails at an angle slightly toward each other to improve their holding power.
- Nails driven with the grain do not hold as well as nails driven across the grain.
- A few nails properly spaced hold better than a bunch of nails driven close together.
- Bend over protruding nails that go all the way through the wood to prevent material damage and injury to people.



SIZE	LENGTH AND GAUGE INCHES	NUMBER	APPROXIMATE NUMBER TO POUND
A 60 d	6	2	11
B 50 d	5 1/2	3	14
C 40 d	5	4	18
D 30 d	4 1/2	5	24
E 20 d	4	6	31
F 16 d	3 1/2	7	49
G 12 d	3 1/4	8	63
H 10 d	3	9	69
I 9 d	2 3/4	10 1/4	96
J 8 d	2 1/2	10 1/4	106
K 7 d	2 1/4	11 1/2	161
L 6 d	2	11 1/2	181
M 5 d	1 3/4	12 1/2	271
N 4 d	1 1/2	12 1/2	316
O 3 d	1 1/4	14	568
P 2 d	1	15	876

Figure 2–2. Common nails.

Specialty nails

Specialty nails are classified as nails with special coatings, designs, or material composition. Figure 2–3 shows some examples of specialty nails. These specialties help the nail in some way. For example, zinc adds corrosion resistance and cement or resin provides greater holding strength. We often use resin coated nails to make utility storage boxes.

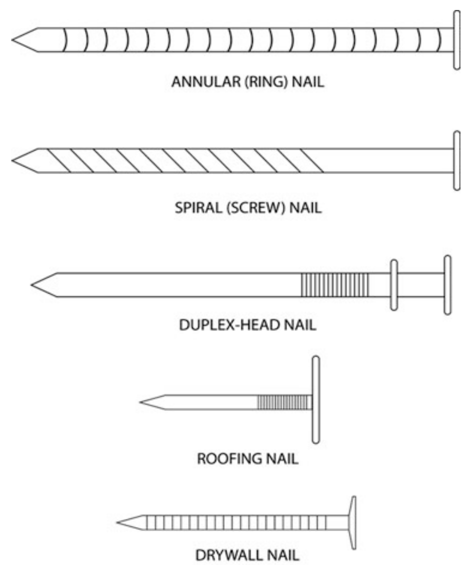


Figure 2-3. Specialty nails.

Some nails have designs, such as spirals or annular rings. These designs improve holding strength and are made for particular uses such as paneling, plywood flooring, or gypsum board. Other nails that are considered specialty nails include roofing and duplex nails. Nails are made from various materials, such as iron, steel, copper, bronze, aluminum, and stainless steel for strength or corrosion resistance. For example, we often use copper nails on copper flashing to prevent corrosion. Some specialty nails are arranged in rolls or clips for easy loading into a power nailer for fast nailing.

Staples

Staples are classified as heavy-duty, medium-duty and light-duty; we can drive them in pneumatically, electrically, or by spring lever action (fig. 2–4). We use the heavy-duty staples to fasten plywood sheeting and subflooring. They are packaged in clips to be used with a heavy-duty staple gun. We can use medium-duty and some light-duty staples to attach molding and other interior trim. Other light-duty staples use a hand-operated spring/lever action gun or staple hammer to attach material such as plastic vapor barriers or to attach resin paper to an exterior stud wall.

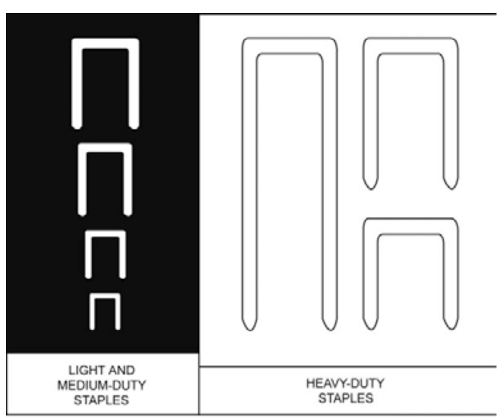


Figure 2–4. Staples.

Wood screws

Some factors to consider before using screws over nails include the material to be fastened, the job's holding power needs, finished appearance, and the total number of fasteners needed. Some advantages that wood screws have over nails are that they provide more holding power, are neater in appearance, and can be withdrawn without damaging the material. A disadvantage is that they cost more and take more time to install.

The common wood screw is usually made of unhardened steel, stainless steel, aluminum, or brass. The steel may be plated with zinc, cadmium, or chrome. We call the pointed end of a screw the gimlet. The threaded part starts at the gimlet and ends at the shank. The shank extends from the threads to the head.

The screw's head shape and screwdriver slot also varies. Figure 2–5 shows some wood screws along with lag and sheet metal screws. The most used head shapes are flathead, oval head, and roundhead. The most used screwdriver slots are common (slotted) or Phillips. We often use the slot shape to identify screws; for example, we refer to screws as flathead Phillips or as oval head common.

It is sometimes necessary that we drill starter holes into the wood before we install screws. These holes must have a smaller diameter than the screw threads and a depth of one-half or two-thirds the thread length. These starter holes reduce wood splits and the time and effort needed to drive the screws. Properly set flathead and oval-head screws are countersunk to permit us to cover them with wood filler. Some screws, such as the round-head screw, are not countersunk. For these screws, you drive them so that the head is firmly flush with the wood surface.

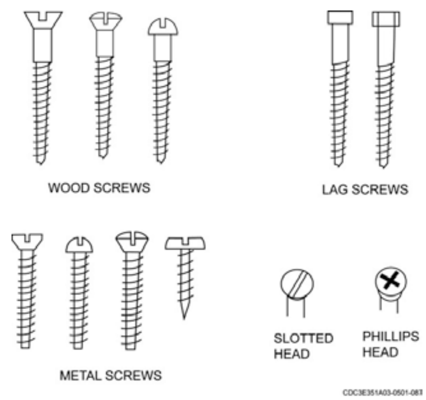


Figure 2–5. Screws.

Sheet metal screws

Sheet metal screws are often used in locations that make riveting difficult or to fasten sheet metal parts that may later be disassembled. If the hole is drilled or punched to the right size, sheet metal screws are easily installed since they form their own threads in the metal during installation. If the hole is too small, the sheet metal screw may break. The three types of sheet metal screws shown in figure 2–6 are type A, type Z, and self-tapping. Notice that type A and type Z have several different head styles; reading from left to right on the figure, they are roundhead, pan head, stove head, countersunk flathead, and countersunk oval head.

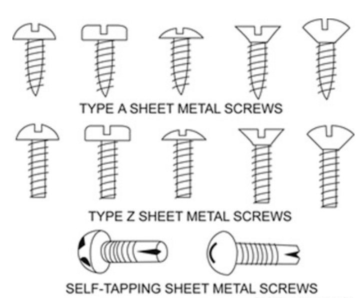


Figure 2–6. Sheet metal screws.

Type A sheet metal screws have a sharp point and resemble a wood screw except that the threads are coarser and extend to the head of the screw. They're recommended for joining and fastening light gauges of sheet metal. *Type Z* sheet metal screws have blunt points and the same threads as type A; they're recommended for joining and fastening light- or heavy-gauge metal. *Self-tapping* sheet metal screws are recommended for heavier gauge sheet metal, since they form threads while being screwed into the proper size hole. This sheet metal screw is also available with a hex head for use with socket wrenches. *Self-drilling* sheet metal screws (fig. 2–7) are designed with a tip that can drill through light-gauge sheet metal and light structural building materials. They normally have a hexagonal head and can be driven with portable electric drills. Self-drilling sheet metal screws work well in light-gauge materials, but they tend to break when driven into heavier materials. Also note that the self-drilling tip on these is not made of high-speed steel like a twist drill and is good for drilling only one hole.

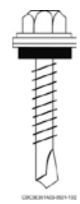


Figure 2–7. Self-drilling screw.

Machine screws

"Machine screw" is the general term we use to designate small screws that may be used in tapped holes or with nuts. Most machine screws have fine threads and are made of steel or brass; they may be plated to prevent corrosion. A variety of diameters, lengths, and head shapes are manufactured, some of which are shown in figure 2–8. When you order or draw machine screws from supply, you need the kind of head, diameter, threads, length, and finish to determine the stock number. For example: screw, machine, round head $^{8}/_{32}$ by 1″, cadmium plated.

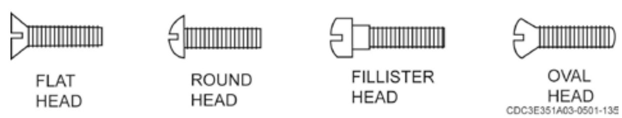


Figure 2–8. Machine screws.

Lag screw or bolt

We also call a lag screw a *lag bolt* (fig. 2–5). We use it when we need great holding power and cannot use a bolt and nut. Examples include securing sole plates and joining heavy timber. A lag screw is similar to a wood screw, but it is larger and has a hex or square head that you turn with a wrench instead of a screwdriver. A lag screw is longer and much heavier than the common wood screw and has coarser threads that extend from a cone, or gimlet point, to slightly more than half the screw length with some having threads all the way up to the screw head. Lag screws range in size from ¼ to 1 inch thick and from 1 to 12 inches long.

To install a lag screw, drill a starter hole smaller than the screw diameter and about one-half to two-thirds the thread length. We suggest you use a washer with the lag screw to keep the head from digging into the wood. Another suggestion is to wax the threads to allow it to screw in more easily and prevent the head from snapping off while you are tightening the screw.

Bolts

In construction, we use bolts when great strength is required or when the work under construction must be frequently disassembled. We usually use bolts with nuts for fastening strength and with flat washers to protect the material surface and spread the fastening pressure. Base your bolt choice on the bolt's intended use. Because there are many varieties (fig. 2–9), choosing the best one can be difficult. Some factors to consider are the basic bolt type (e.g., carriage bolt or machine bolt), length, diameter, thread type, head shape, corrosion resistance, and strength.

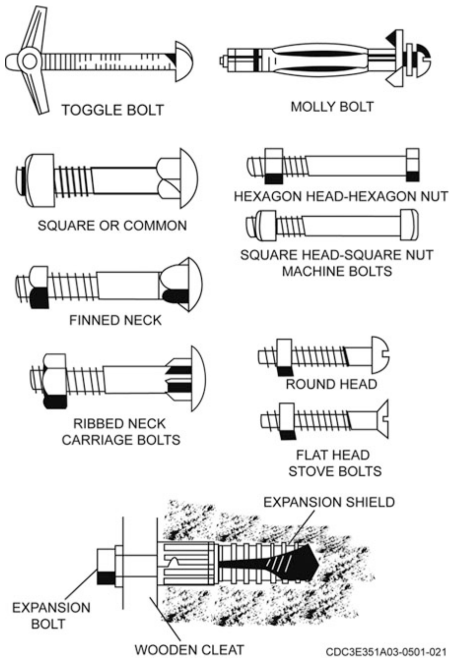


Figure 2–9. Bolts.

Carriage bolts

All carriage bolts have round heads with one of the following neck types: square, finned, or ribbed. The neck is located at the top of the shank and just under the round head. The shank is threaded for use with a nut. Some shanks are threaded from the tip to the neck but most are only threaded part way up. Carriage bolts are available from ¼ to 1 inch in diameter and from ¾ to 20 inches long. To install a carriage bolt, accomplish the following five steps:

1. Drill a hole that is close to the shank diameter. The goal is to have a tight fit.
2. Insert the carriage bolt into the hole.
3. Strike the head with a hammer to seat the neck flush in the hole. (This prevents the bolt from turning when you tighten it.)
4. Place a flat washer and nut on the tip end.
5. Use a wrench to tighten the nut until the head starts to embed into the wood.

Carriage bolts are chiefly for wood-to-wood application, but we can also use them for wood-to-metal applications. If you use them for wood-to-metal application, fit the head to the wood item.

Machine bolts

Machine bolts are made with cut national fine and national coarse threads. These threads extend from a length that is twice the diameter of the bolt plus ¼ inch (for bolts less than 6 inches in length) to twice the diameter of the bolt plus ½ inch (for bolts over 6 inches in length). The head may be square, hexagonal, rounded, or flat countersunk. The nut usually matches the head shape. Base your machine bolt selection on head style, length, diameter, number of threads per inch, and thread coarseness. Bore the hole through which the bolt is to pass to the same diameter as the bolt. The goal is to have as close a fit as possible without damaging the threads. Machine bolts are precision made in diameters from ¼ to 3 inches and in various lengths.

Stove bolts

Stove bolts (fig. 2–10) are similar to machine bolts but are not as precisely made. They have either a flat or round slotted head and are usually threaded from the tip to the head. We generally use stove bolts with square nuts to fasten metal-to-metal, wood-to-wood, or wood-to-metal. If the bolts are flat headed, countersink them. If they are round headed, draw them flush to the surface.

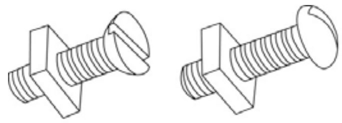


Figure 2–10. Stove bolts.

Anchors

We use anchors to fasten items to floors, walls, and ceilings. We use some on solid walls and some on hollow walls. There are many types available for different anchoring needs from light duty to heavy duty. Although some anchors do not require a predrilled hole, all of the types that we cover do, let's look at them.

Light-duty anchors

There are many light-duty anchors available for anchoring bathroom fixtures, smoke detectors, junction boxes, picture frames, and bulletin boards onto a masonry surface. We only cover a few. One type we call a *hammer drive anchor*. Anchors consist of a body with an expander pin. To use them, insert the body into the hole. Next, hit the pin with a hammer to expand the body tightly in the hole. These anchors are available with an aluminum body and aluminum pin, zinc alloy body and a steel pin, and a nylon body and steel pin. Both types are designed for anchoring the item permanently.

Another type is the *plastic anchor or plastic insert*. It uses a plastic body with a wood or sheet metal screw as the expander pin. A similar type is the *lead anchor or lead insert*. Since removing the screw un-anchors the item, this type is a good choice for items that may need to be removed at some time.

Medium-duty anchors

There are many medium-duty anchors available for hanging pipe and ductwork, securing doors or window frames, and securing cabinets to masonry surfaces. One type is the *double expansion anchor*. It uses a bolt and an expanding steel sleeve that is threaded. To use it, place the sleeve so that it is flush or slightly below the masonry surface. Next, position the object to be fastened, insert the bolt and tighten it. As it tightens, the two opposing wedges pull toward each other to expand the full length of the anchor body. After the initial bolting down, the object can be unbolted, removed, or refastened.

Another type that is gaining in popularity is the *concrete screw*. These use cutting threads to secure themselves into the masonry without the need for an expansion shield. They are available in $^3/_{16}$ and ¼ inch diameters with a length up to 6 inches. We recommend that the embedded depth be from 1 to $1^3/_4$ inches.

Heavy duty anchors

There are many heavy-duty anchors available for anchoring machinery, handrails, and storage racks to a masonry surface. One type we call the *wedge anchor*. We use it when we need high resistance to pullout. To use it, make sure the hole is the same size as the anchor body. With the object to be anchored in place, put the anchor in the hole with at least six threads showing above the object surface. Next, place the flat washer and nut onto the anchor shank and tighten with a wrench.

Another type is the *drop in anchor*. It uses a cone-shaped, internal expander plug (anchor body) and a machine screw or bolt. The drilled hole must be at least equal to the anchor length. To use it place the anchor body in the hole and use the setting tool (supplied with the anchors) to drive and expand the body. Next, position the object to be secured and use a flat washer and a machine screw or bolt to fasten it in place.

Anchors for hollow walls

There are many anchors that you can use to anchor an item to a hollow wall. One type is *a toggle bolt* (fig. 2–9). It has a round head with slotted screwdriver slot and a threaded shank. Use it with a spring-action, wing-head nut that folds back as it is pushed through a prepared hole in a hollow wall. The wing head then springs open inside the wall cavity. You can also use the toggle with a tumble type nut. This nut can pivot from a parallel position with the bolt to a "T" position. Both types grip into the inside wall surface as you tighten the bolt. Toggle bolt sizes range from 1/8 to 3/8 inch in diameter and 2 to 6 inches in length.

Another type of hollow wall anchor is the *molly screw (bolt)* shown in figure 2–9. It uses a screw and a threaded body. To use it, tap the body into the gypsum board so that the prongs bite into material to keep it from turning as you drive in the anchor screw. As you tighten the screw, the shield expands. Various molly screws are available in ⅛- to 1¾-inch lengths.

Drift pins

Drift pins are long, heavy, threadless bolts we use to hold heavy pieces of timber together. They have heads that vary in diameter from ½ to 1 inch and in length from 18 to 26 inches. The term "drift pin" is almost universally used in practice. However, for supply purposes, the correct designation is *drift bolt*.

To use the drift pin, you drill a hole slightly smaller than the diameter of the pin in the timber. Drive the pin into the hole, where it is held in place by the compression action.

Rivets

Rivets vary in the kind of metal from which they're made, type of head, diameter, and length. Figure 2–11 illustrates some of the various shapes of rivet heads you may encounter. The rivet most often used in the sheet metal shop is the tinner's rivet, but you may also use Monel, aluminum, and blind rivets of various shapes and styles.

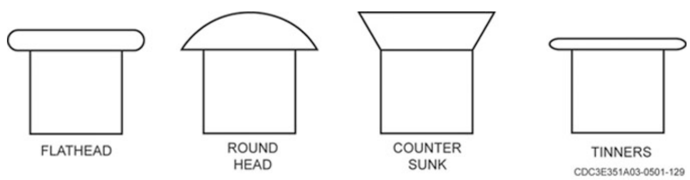


Figure 2–11. Rivet heads

Tinner's rivets

Tinner's rivets are made of mild (soft) steel, are easily formed with a hand-riveting set, and are usually tinned. The tinner's rivet in figure 2–11 is available in various diameters and lengths, and its head is thinner than most other rivets. The rivet sizes are identified according to the weight per thousand. Tinner's rivets are available in various sizes—from 1–12 pounds. Common sizes used are shown in the table below.

Size of rivet	Diameter of shank	Length	Gauge of sheets being joined
1lb	0.109"	3/16"	26
2lb	0.148"	9/32"	24
2 ½ lb	0.1607"	5/16"	22
3lb	0.165"	21/64"	20
4lb	0.176"	11/32"	16

Monel rivets

Monel rivets, like other rivets, vary in diameter, length, and head shape. These rivets are harder to drive than tinner's rivets because of the hardness of the metal. In sheet metal work, you use Monel rivets in manufacturing or repairing parts and components such as stainless steel trays, pans, hoods, and serving equipment in dining facilities.

Aluminum rivets

There are many types and shapes of aluminum rivets, but the aluminum sheets you're likely to rivet are generally soft aluminum and require soft aluminum rivets. Two general-purpose aluminum rivets, identified as the 1100-F and 3003, are recommended for use on nonstructural parts fabricated from soft aluminum. The 1100-F and 3003 are available with flat countersunk, round, or universal heads. The main advantage of these rivets in the sheet metal shop is that they can be used without further treatment and are easily driven with a handset.

Blind rivet

Blind rivets are very popular and have made their way into industry as approved fasteners. The word "blind" refers to the fact that access with a bucking bar to the back of the material being riveted is not necessary. Imagine trying to buck rivets on the inside of a pipe handrail that was embedded in a concrete step. Figure 2–12 shows some blind rivets that are set with a special tool called a rivet gun (fig. 2–13).

There are several types and varieties of rivet styles available as listed in figure 2–12. There are also several different sizes and lengths. Some rivets with large-diameter heads are used in fastening materials other than metal, such as wood, leather, plastic, or fabric. Using a washer on the backside of soft material lets you rivet two or more pieces of soft material together.

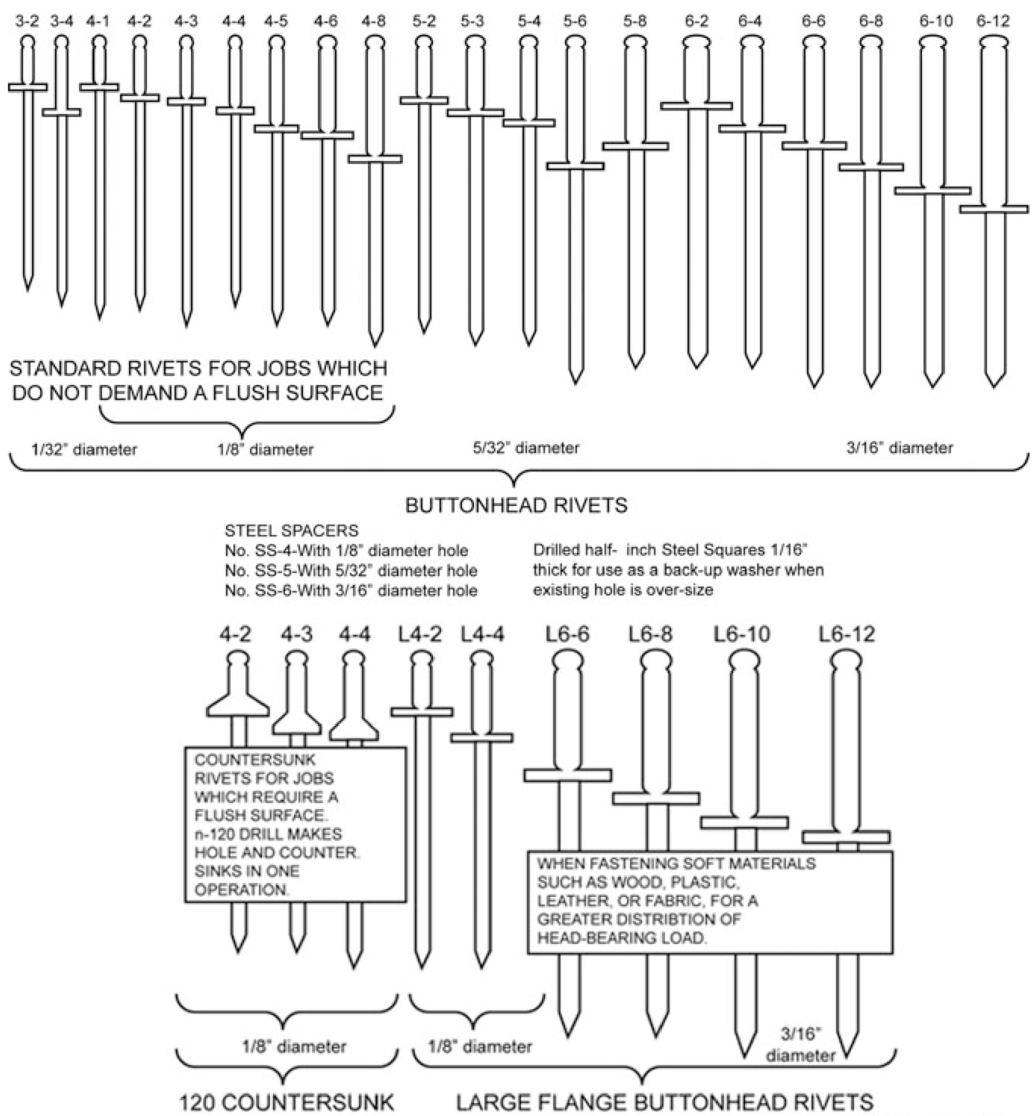


Figure 2–12. Blind rivets.

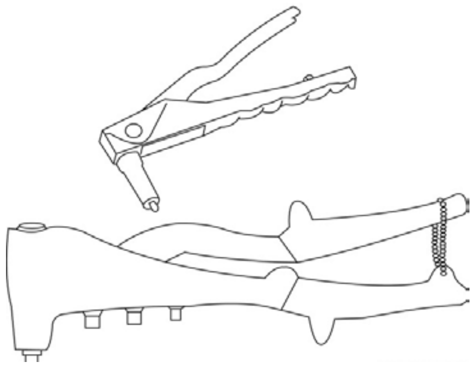


Figure 2–13. Rivet gun.

Adhesives

Adhesives bond materials together. The ingredients used to make them vary and so does their application method, bonding characteristics, and drying time. Basic adhesive types include glues and mastics.

SAFETY NOTE: Some adhesives are highly flammable; use them *only* in a well-ventilated work area. Others are highly irritating to the skin and eyes. It is very important to protect yourself by always following the manufacturer's instructions and keeping current on all material safety data sheets (MSDS) for hazardous material.

Glues

The primary function of glue is to hold wood joints together. Glue is usually sold under a brand name. Some wood glue is sold as a powder to which water must be added; others are liquid and ready to use. Glues use a resin base that has specific bonding characteristics. A brief description is listed in the following table of a few glue types.

Glue type	Description
Polyvinyl resin (white glue)	A fast-drying white liquid that comes in ready-to-use plastic squeeze bottles. Good for bonding wood together. It is not waterproof. Do *not* use it on work that is subjected to constant moisture or high humidity.
Urea resin	Plastic-based glue that is sold in a powder form. It is mixed with water when the glue is needed. It makes an excellent bond for wood and has fair water resistance.
Phenolic resin	Highly resistant to temperature extremes and water. It is often used for bonding the veneer layers of exterior grade plywood.
Resorcinol resin	Excellent water and temperature resistance. It makes a very strong bond. It is often used for bonding the wood layers of laminated timbers.
Contact cement	Bonds plastic laminates to wood surfaces. It has a neoprene rubber base. Because contact cement bonds very rapidly, it is useful for joining parts that cannot be clamped together.

Mastics

Mastics are widely used throughout the construction industry. The asphalt, rubber, or resin base of mastics gives them a thicker consistency. Mastics are sold in cans, tubes, or canisters that fit into various types of caulking guns. There are various kinds of mastics, such as construction adhesive, panel adhesive, and troweled mastics. These are just a few of the many types available.

You can use these adhesives to bond materials directly to masonry or concrete walls. If furring strips are required on a wavy concrete wall, you can apply the strips with mastic rather than with the more difficult procedure of driving in concrete nails. You can fasten insulation materials to masonry and concrete walls with mastic adhesives. You can also use mastics to bond drywall (gypsum board) directly to wall studs and to bond gypsum board to furring strips or directly to concrete or masonry walls. Because you don't use nails, there are no nail indentations to fill.

By using mastic adhesives, you can apply paneling with very few or no nails at all. Wall panels can be bonded to studs, furring strips, or directly against concrete or masonry walls. You can use mastic adhesives with nails or staples to fasten plywood panels to floor joists. The mastic adhesive helps eliminate squeaks, bounce, and nail popping. It also increases the floor's stiffness and strength. As you can see, there are numerous ways in which you can use mastics.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

206. Identifying fasteners

1. What type of nail do you use for toenailing when common nails tend to split the wood?

2. What type of nail do you use for temporary construction or when the construction project must be torn down?

3. What advantage do cement coated nails have over non-coated nails?

4. What type of screw has blunt points and is recommended for joining and fastening light- or heavy-gauge metal?

5. How is a lag screw different than a common screw?

6. What type of bolt has a round head with either a squared, finned, or ribbed neck?

7. What medium-duty anchor allows you to unbolt, remove, or refasten a previously anchored down object?

8. List two types of hollow wall anchors.

9. What type of rivet is commonly used for manufacturing or repairing parts and components such as stainless steel trays, pans, hoods, and serving equipment in dining facilities?

10. What is a very important safety procedure to always follow for adhesives?

2–3. Metal

This section covers the different types of metals that you may be exposed to as a structural journeyman. It's important for you to know what types are available and their inherent properties, so you don't choose the wrong type for a project.

207. Identifying metal

In this lesson, we discuss some of the most common types of metal. We do not attempt to list them all. The metals that we work with are divided into two general classifications: ferrous and nonferrous. Ferrous metals are made mainly of iron and iron alloys. Nonferrous metals are made mainly of some element or elements other than iron. Nonferrous metals or alloys sometimes contain a small amount of iron as an alloying element or as an impurity.

Ferrous metals

Ferrous metals include all forms of iron and steel alloys. A few examples include wrought iron, cast iron, carbon steels, alloy steels, and tool steels. Ferrous metals are alloys with iron bases. They have a small percentage of carbon and other elements added to achieve desirable properties. Normally, ferrous metals are magnetic and nonferrous metals are nonmagnetic.

Iron

You rarely see pure iron outside of a laboratory. Reducing iron ore to pig iron through the use of a blast furnace produces iron. Adding or deleting carbon and alloys to pig iron creates many types of iron and steel. The following paragraphs discuss some of the different types of iron and steel that can be made from iron ore.

Pig iron

Pig iron is composed of about 93 percent iron, from 3 to 5 percent carbon, and various amounts of other elements. Pig iron is relatively weak and brittle; therefore, it has a limited use. Most of the pig iron produced is refined to produce steel; however, some cast-iron pipe and some fittings and valves are manufactured from pig iron.

Wrought iron

Wrought iron is made from pig iron with some slag mixed in during the manufacturing process. It's almost pure iron. With the presence of slag, it is able to resist corrosion and oxidation. The chemical analyses of wrought iron and mild steel are just about the same. The difference comes from the properties controlled during the manufacturing process. Wrought iron can be gas and is welded, machined, plated, and easily formed; however, it has a low hardness and a low-fatigue strength.

Cast iron STQ2

Any iron containing more than 2 percent carbon alloy is considered a cast iron. Cast iron has a high-compressive strength and good wear resistance; however, it lacks ductility, malleability, and impact strength. When it's alloyed with nickel, chromium, molybdenum, silicon, or vanadium, its toughness, tensile strength, and hardness improves. You can produce a malleable (capable of being shaped or formed by hammering or pressure) cast iron through a prolonged annealing process.

Steel

Steel is one of the most important metals we use in our trade. It is manufactured from pig iron by decreasing the amount of carbon and other impurities and adding specific amounts of alloying elements.

Do not confuse steel with the two general classes of iron—cast iron (greater than 2 percent carbon) and pure iron (less than 0.15 percent carbon). When steel is manufactured, controlled amounts of alloying elements are added during the molten stage to produce the desired composition.

Carbon steel

This is a term applied to a broad range of steel and may be classified into four groups.

- Low-carbon steel . . .   . .. 0.05 to 0.30 percent carbon.
- Medium-carbon steel . .. .. 0.30 to 0.45 percent carbon.
- High-carbon steel . . . . 0.45 to 0.75 percent carbon.
- Very high-carbon steel . . . 0.75 to 1.70 percent carbon.

Low-carbon steel

Steel in this classification is tough and ductile; easily machined, formed, and welded. It does not respond to any form of heat-treating, except case hardening.

Medium-carbon steel

These steels are strong and hard but cannot be welded or worked as easily as the low-carbon steels. They are used for crane hooks, axles, shafts, setscrews, and the like.

High-carbon steel/very high-carbon steel

Steel in these classes respond well to heat treatment and can be welded. Welders must use special electrodes along with preheating and stress-relieving procedures to prevent cracks in the weld areas. These steels are used for dies, cutting tools, mill tools, railroad car wheels, chisels, knives, and like items.

Low-alloy, high-strength, tempered structural steel

This is a special low-carbon steel, containing specific small amounts of alloying elements, that is quenched and tempered to get a yield strength of greater than 50,000 psi and tensile strengths of 70,000 to 120,000 psi. Structural members made from these high-strength steels may have smaller cross-sectional areas than common structural steels and still have equal or greater strength. Additionally, these steels are normally more corrosion and abrasion resistant.

NOTE: This type of steel is much tougher than low-carbon steels. Shearing machines for this type of steel must have twice the capacity of that required for low-carbon steels.

Stainless steel

The American Iron and Steel Institute (AISI) classifies this type of steel into two general series—the 200–300 series and 400 series. Each series includes several types of steel with different characteristics.

The 200–300 series of stainless steel is known as *austenitic*. This type of steel is very tough and ductile in the as-welded condition; therefore, it is ideal for welding and requires no annealing under normal atmospheric conditions. The most well known types of steel in this series are the 302 and 304. They are commonly called 18–8 because they are composed of 18 percent chromium and 8 percent nickel. The chromium nickel steels are the most widely used and are normally nonmagnetic.

The 400 series of steel is subdivided according to its crystalline structure into two general groups. One group is known as *ferritic chromium* and the other group as *martensitic chromium*.

You can obtain 18–8 stainless steel in sheet sizes up to 48 inches wide and 12 feet long, depending on gauge thickness. For instance, 8 to 18 gauge is available in widths of 24, 36, or 48 inches, and in lengths up to 12 feet. The following is a list of surface finishes that are available:

- Hot Rolled Annealed and Pickled (No 1).
- Full Finish Bright Cold Rolled (No. 2B).
- Full Finish Dull Cold Rolled (No. 2D).
- Intermediate Polish (No. 3).

- Standard Polish (No. 4).
- Standard Polish Tampico Brushed (No. 6).
- Highly Polished (No. 7).

Alloy steels

Steels that get their properties mainly from some alloying element other than carbon are called *alloys* or *alloy steels*. They always have trace amounts of other elements, such as nickel, chromium, vanadium, and tungsten. To produce the desired characteristics, one or more of these elements are usually added to the steel during the manufacturing process. Better physical properties are achieved with these steels than are possible with hot-rolled carbon steels. There is a wide use for these steels, such as in structures where high strength is important. Other uses include bridge members, railroad cars, dump bodies, dozer blades, and crane booms.

Nickel steels

Nickel steels have increased strength and toughness. When more than 5 percent nickel is added, its corrosion and scale resistance is also increased. You see it commonly used in the manufacture of aircraft parts, such as propellers and airframe support members.

Chromium steels

Chromium steels have improved hardening ability, wear resistance, and strength. Some of these steels are used in antifriction bearings due to their high resistance to wear. Chromium steels are also highly resistant to corrosion and scale.

Chrome vanadium steel

Chrome vanadium steels produce the maximum amount of strength with the least amount of weight. They are commonly used for crankshafts, gears, axles, and other items where high strength is required. They are also used in the manufacture of high-quality hand tools, such as wrenches and sockets.

Tungsten steel

Tungsten is a special alloy that has the property of *red hardness*. This is the ability to continue to cut after it becomes red-hot. Due to the high cost incurred producing tungsten, its use is largely limited to the manufacture of drills, lathe tools, milling cutters, and similar cutting tools.

Molybdenum

This alloying agent is often used in combination with chromium and nickel to add toughness. It can also be used in place of tungsten to make cheaper grades of high-speed steel.

Nonferrous metals

Nonferrous metals contain either no iron or only insignificant amounts used as an alloy. Some of the more common nonferrous metals that you may use are copper, brass, bronze, copper-nickel alloys, lead, zinc, tin, aluminum, and Monel.

NOTE: All of these metals are nonmagnetic, except Monel; when boiled, it becomes nonmagnetic.

Copper

This metal and its alloys have many desirable properties. Among the commercial metals, it is one of the most popular. Copper is ductile, malleable, hard, tough, strong, wear resistant, machinable, weldable, and corrosion resistant. It also has high-tensile strength, fatigue strength, and thermal and electrical conductivity. Copper is one of the easier metals to work with but you must be careful because it easily becomes work-hardened; however, *annealing* restores it to a softened condition. This is heating it to a cherry red and then letting it cool. Annealing and softening are the only heat-treating procedures that apply to copper. Riveting, silver brazing, bronze brazing, soft soldering, gas welding, or electrical arc welding are used to join seams in copper. Copper is frequently used to give protective coating to sheets and rods and to make ball floats, containers, and soldering coppers.

Its thickness is referred to as weight in ounces per square foot. In the table below, you can see the gauge and decimal equivalents, ounces per square foot, and sizes of various copper sheets. Some of the common sizes used in metal shops are included in the following table.

Nearest Gauge	Decimal Thickness	Ounces Per Sq. Ft	Sheet Weight in Pounds, Size, and Thickness				
			14″x48″	24″x48″	30″x60″	36″x72″	48″x72″
31	.0107	8	2.33	4	6.25	9	12
29	.0134	10	2.91	5	7.81	11.25	15
26	.0188	14	4.08	7	10.93	15.75	21
24	.0215	16	4.66	8	12.50	18	24
22	.0269	20	5.83	10	15.62	22.50	30
18	.0538	40	11.66	20	31.25	45	60
16	.0645	48	14	24	37.50	54	72

As previously mentioned, copper resists corrosion and is used where long life of the metal is required. It’s often added to other metals to increase their corrosion resistance. Copper holds heat well; you’ve probably noticed that the soldering coppers (i.e., irons) in the shop are made of copper. Because copper is expensive, consider the job carefully before you use it.

True brass

This is an alloy of copper and zinc. Additional elements, such as aluminum, lead, tin, iron, manganese, or phosphorus, are added to give the alloy specific properties. Brass sheets and strips are available in several grades: soft, ¼ hard, ½ hard, full hard, and spring grades. The process of cold rolling creates hardness. All grades of brass can be softened by annealing at a temperature of 550°F to 600°F then allowing it to cool by itself without quenching. Overheating can destroy the zinc in the alloy.

Bronze

Bronze is a combination of 84 percent copper and 16 percent tin. Many complex bronze alloys, containing such elements as zinc, lead, iron, aluminum, silicon, and phosphorus, are now available. Today, the name bronze is applied to any copper-based alloy that looks like bronze. In many cases, there is no real distinction between the composition of bronze and that of brass.

Copper-nickel alloys

The addition of nickel makes these alloys strong, tough, and resistant to wear and corrosion. Saltwater piping systems use copper-nickel alloys because of their high corrosion resistance. Small storage tanks and hot-water reservoirs are constructed of a copper-nickel alloy that is available in sheet form. Use metal arc welding or brazing to join copper-nickel alloys.

Lead

Lead is a heavy metal that weighs about 710 pounds per cubic foot. In spite of its weight, lead is soft and malleable and is available in pig and sheet form. In sheet form, it is rolled upon a rod so the user can unroll it and cut off the desired amount. The surface of lead is grayish in color; however, after scratching or scraping it, you can see that the actual metal color is white. Because it is soft, we use lead as backing material when punching holes with a hollow punch or when forming (hammering) shapes. Sheet lead is also used to line sinks or protect bench tops where a large amount of acid is used. Lead-lined pipes are used in systems that carry corrosive chemicals. Frequently, lead is used in alloyed form to increase its low-tensile strength. Alloyed with tin, lead produces a soft solder. When added to metal alloys, lead improves their machinability.

CAUTION: When working with lead, you must take proper precautions because the dust, fumes, or vapors from it are highly poisonous.

Zinc

You often see zinc used on iron or steel in the form of a protective coating called galvanizing. When iron is dipped in melted zinc and allowed to cool, the zinc forms crystals that make a spotted appearance on the surface. Zinc is also used in soldering fluxes, die-castings, and as an alloy in making brass and bronze.

Tin

Tin has many important uses as an alloy. It can be alloyed with lead to produce softer solders and with copper to produce bronze. Tin-based alloys have a high resistance to corrosion, low-fatigue strength, and a compressive strength that accommodates light or medium loads. Tin, like lead, has a good resistance to corrosion and has the added advantage of not being poisonous; however, when subjected to extremely low temperatures, it has a tendency to decompose.

Aluminum

This metal is easy to work with and has a good appearance. Aluminum is light in weight and has a high strength per unit weight. A disadvantage is that the tensile strength is only one third of that of iron and one fifth of that of annealed mild steel.

Aluminum alloys usually contain at least 90 percent aluminum. The addition of silicon, magnesium, copper, nickel, or manganese can raise the strength of the alloy to that of mild steel. Aluminum, in its pure state, is soft and has a strong affinity for gases. The use of alloying elements is used to overcome these disadvantages; however, the alloys, unlike the pure aluminum, corrode unless given a protective coating. Coat threaded parts made of aluminum alloy with an antiseize compound to prevent sticking caused by corrosion.

Your shop probably stocks a few sheets of aluminum in the 1100 or 3003 types, which are usually 30, 36, or 48 inches wide, 8 or 10 feet long, and in various thicknesses. The thickness of aluminum sheets is measured in decimals rather than gauge. Here are some examples of the comparison of gauge and decimal equivalents: 16 gauge is 0.050, 20 gauge is 0.031, 24 gauge is 0.020, and 26 gauge is 0.015. These are a few of the common thickness that you will use.

Monel STQ9

Monel is an alloy in which nickel is the major element. Monel is harder and stronger than either nickel or copper and has high ductility. It resembles stainless steel in appearance and has many of its qualities. The strength, combined with a high resistance to corrosion, makes Monel an acceptable substitute for steel in systems where corrosion resistance is the primary concern. Nuts, bolts, screws, and various fittings are made of Monel. This alloy can be worked cold and can be forged and welded. If worked in the temperature range between 1200°F and 1600°F, it becomes “hot short” or brittle.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

207. Identifying metal

1. What is the difference between ferrous and nonferrous metals?

2. Cast iron contains what percent of carbon alloy?

3. Describe the four groups of carbon steel.

4. What are alloy steels?

5. What type of alloy has the property of red hardness?

6. Match each metal classification in column B with the type metal in column A. Items in column B may be used once, more than once, or not at all.

Column A	***Column B***
____ (1) Aluminum.	a. Ferrous.
____ (2) Brass.	b. Nonferrous.
____ (3) Bronze.	
____ (4) Carbon steel.	
____ (5) Copper.	
____ (6) Iron.	
____ (7) Lead.	
____ (8) Monel.	
____ (9) Steel.	
____ (10) Tin.	
____ (11) Zinc.	

7. How do we refer to the thickness of copper sheets?

8. List some common uses for lead.

9. What type of metal resembles stainless steel and has many of the same properties?

Answers to Self-Test Questions

204

1. 1½ × 3½ inches.
2. (1) f.
   (2) c.
   (3) h.
   (4) b.
   (5) d.

   (6) j.
   (7) e.
   (8) g.
   (9) i.
3. Hardwoods are generally denser and harder than softwoods.
4. Strength, stiffness, and appearance.
5. No. 1.
6. 5 inches thick.

205

1. 2 × 4 or 2 × 6 inches.
2. It's in the stacking of the plies. In plywood, the plies are stacked with the grain at 90° to the previous layer. In laminated-veneer lumber, the plies are stacked with the grain parallel.
3. It allows easy installation of pipes, drains, wiring, and other components without cutting the truss.
4. By stacking and gluing wood plies (thin layers) with the grain direction turned at a 90° angle to each other. Then, pressure is applied. It forms a strong and split resistant sheet.
5. Waterproof glue.
6. The letters A, B, C, and D separately or in combination.
7. Exterior, Exposure 1, and Exposure 2.
8. Door skins, cabinets, and wall paneling.

206

1. Box nail.
2. Duplex nail.
3. They have greater holding strength.
4. Type Z sheet metal screws.
5. A lag screw is longer and much heavier than the common wood screw and has coarser threads that extend from a cone, or gimlet point, to slightly more than half the screw length.
6. Carriage bolt.
7. The double expansion anchor.
8. Toggle bolt and molly screw.
9. Monel.
10. To protect yourself by always following the manufacturer's instructions and keeping current on all material safety data sheets (MSDS) for hazardous material.

207

1. Ferrous metals are made mainly of iron and iron alloys. Nonferrous metals are made mainly of some element or elements other than iron.
2. 2 percent.
3. Low-carbon steel (0.05 to 0.30 percent carbon), medium-carbon steel (0.30 to 0.45 percent carbon), high-carbon steel (0.45 to 0.75 percent carbon) and very high-carbon steel (0.75 to 1.70 percent carbon).
4. Steels that get their properties mainly from some alloying element other than carbon.
5. Tungsten.
6. (1) b.
   (2) b.
   (3) b.
   (4) a.
   (5) b.
   (6) a.

(7) b.

(8) b.

(9) a.

(10) b.

(11) b.

7. By its weight in ounces per square foot.
8. Backing material when punching holes with a hollow punch or when forming (hammering) shapes; line sinks or to protect bench tops where a large amount of acid is used; line pipes that are used in systems that carry corrosive chemicals.
9. Monel.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

11. (204) To determine if wood is defected with advanced stages of decay, you should inspect it to see if it is
a. stained blue.
b. infested with insects or worms.
c. soft, spongy and easily crumbles.
d. separated along the lengthwise grain.

12. (204) When select grade lumber contains a few minor blemishes and is recommended for clear coatings, how is it graded?
a. Grade A.
b. Grade B.
c. Grade C.
d. Grade D.

13. (204) How is a common lumber grade identified when the lumber contains serious defects, such as knotholes, checks, shakes, and decay?
a. Number 2.
b. Number 3.
c. Number 4.
d. Number 5.

14. (204) For us to identify lumber as timber, it *must* be
a. 4 inches thick or less.
b. 5 inches thick or less.
c. 4 inches thick or more.
d. 5 inches thick or more.

15. (205) Which engineered lumber product is made from stacked laminated plies with the grain running parallel to provide strength to carry heavy loads?
a. Wood I-beams.
b. Glue laminated beams.
c. Parallel-strand lumber.
d. Laminated veneer lumber.

16. (205) How is a plywood veneer panel identified that is smooth and paintable with up to 18 neatly made repairs?
a. Grade A.
b. Grade B.
c. Grade C.
d. Grade D.

17. (205) Which plywood panels can be used when continual exposure to the elements is required?
a. Exterior only.
b. Exposure 1 only.
c. Exterior and Exposure 2.
d. Exposure 1 and Exposure 2.

18. (206) Which sheet metal screw has a sharp point that resembles a wood screw and is recommended for joining and fastening light gauges of sheet metal?
a. Type A and self-tapping sheet metal screws.
b. Type A only.
c. Type Z and self-tapping sheet metal screws.
d. Type Z only.

19. (206) Which type of anchor uses a spring-action, wing-head nut that folds back as it is pushed through a hole in a hollow wall?
a. Toggle bolt.
b. Molly screw.
c. Plastic anchor.
d. Double expansion anchor.

20. (206) Which type of rivet would you use when manufacturing or repairing parts and components such as stainless steel trays, pans, hoods, and serving equipment in dining facilities?
a. Aluminum.
b. Flathead.
c. Tinners.
d. Monel.

21. (207) When manufacturers use carbon steels for dies, cutting tools, mill tools, chisels or knives, which type of carbon steel do they need?
a. Low-carbon or medium-carbon steel.
b. Low-carbon steel only.
c. High-carbon or very high-carbon steel.
d. High-carbon steel only.

22. (207) When ordering aluminum sheets, which unit of measurement do you use to identify the sheet thickness?
a. Gage.
b. Decimals.
c. Pounds per sheet.
d. Ounces per square foot.

Please read the unit menu for unit 3 and continue ➔

Unit 3. Project Planning and Estimating

NOW THAT YOU'RE FAMILIAR with the different types of drawings and materials, we are now going to discuss how to use estimating standards and mathematical formulas. Within this unit we discuss estimating standards, shop math, and some of the estimating formulas that you will use to make accurate material estimates. When performing your job be sure to take your time estimating materials to ensure you plan your projects accurately.

3–1. Project Planning

This section covers how to use estimating standards and special precautionary measures. There is more than one type of estimating standard on the market; however, the material presented here focuses on the Engineered Performance Standards (EPS).

208. Using estimating standards

EPS is one of many sources of facilities maintenance and repair standards. It was developed by the Department of Defense (DOD) and is considered the main source of facilities maintenance and repair standards used by DOD personnel.

History of Engineered Performance Standards

In the early 1950s, the DOD became concerned about managing real property maintenance activities. All the services faced the growing problem of maintaining facilities that were being used far beyond their designed life expectancy. To realize the fullest and most efficient utilization of available resources, industrial engineering procedures and techniques were applied and maintenance management systems developed. Engineers developed EPS using proven industrial engineering techniques and years of experience and expertise that have gone into these standards.

Definition

EPS is the average time necessary for a qualified worker, working at a normal pace, under capable supervision and experiencing normal delays, to perform a defined amount of work, of a specified quality, while following acceptable trade methods.

EPS data is a tool used by planner/estimators to develop consistent, uniform, and accurate facilities maintenance and repair estimates. Any trained planner and estimator who has a good working knowledge of the trade should be able to develop good labor estimates using these standards.

Engineered Performance Standards measurement

Engineered Performance Standards are designed specifically for facilities maintenance-type work through the observation of maintenance workers at work. The work is measured through the use of proven industrial engineering techniques, such as Methods-Time Measurement (MTM), work sampling, and time studies. They are designed to relate a given amount of work to the labor hours needed to accomplish the work.

Simply stated, EPS estimates are based on the labor hours needed to do a specified amount of work under normal conditions. When EPS is properly applied under those normal conditions, the craft time should be valid at any work site in any geographical location.

Engineered Performance Standards tasks

EPS tasks are divided into craft area standards, preventive maintenance/recurring maintenance (PM/RM) standards, and service standards. The EPS handbooks are numbered and the craft areas are identified by two or three letter designators. The table below provides a list of the handbooks and associated craft designators.

You can navigate through the EPS easily as long as you know what you are looking for. Let's walk through the different pages to give you a better understanding of how to use the EPS. Imagine that your supervisor just gave you a work order package to install a sheetrock ceiling. You'll need to accurately estimate the labor hours required to ensure adequate resources are available. Your first step in using EPS is to determine the correct handbook to reference. The EPS is divided into different handbooks by craft. In this scenario, you reference Handbook 02, Carpentry, since your project is dealing with carpentry type work.

Handbook Number	Craft	Craft Designator
01	General	
02	Carpentry	CT
03	Electric, Electronic	GT
04	HVAC	VT
05	Janitorial	JT
	Machine Shop, Machine Repairs	
06	Machine Shop	MT
	Machine Repair	NT
07	Masonry	DT
08	Moving, Rigging	BT
09	Paint	PT
10	Pipe fitting, Plumbing	QT
	Roads, Grounds, Pest Control & Refuse Collection	
	Roads	WT
11	Grounds	RT
	Pest Control	QAT
	Refuse Collection	ST
	Sheet metal, Structural Iron & Welding	
12	Sheet metal	LAT
	Structural Iron & Welding	EAT
13	Trackage	DAT
14	Wharf building	ZT
15	Preventive Maintenance/Recurring Maintenance Service	P/RM

Handbook table of contents

Each craft handbook has a table of contents. The table below shows a sample of the table of contents found in the carpentry handbook. At the top of the page you can see that you are in Book 02, Carpentry. The handbooks are further broken down into numerous chapters that represent the different divisions of craft tasks. This particular handbook ranges in increments of 10 beginning at 010 and ending with 600**.** The description column of each chapter identifies the content contained in the chapter.

Going back to the previously assigned work order that you were given, you would need to reference Chapter 050, Ceilings, Sheetrock (Install) in the table below.

TABLE OF CONTENTS BOOK 02

CHAPTER		**DESCRIPTION**
010	CARPET:	Tiles and Roll (Remove, Install, Replace, Cut)
020	CEILINGS/TRIM:	Fiberboard (Remove, Install, Replace, Repair)
030	CEILINGS:	Acoustical tiles (Remove, Install, Replace, Repair)
040	CEILINGS:	Suspended (Install, Replace)
050	CEILINGS:	Sheetrock (Install)
060	DOORS/HARDWARE:	Standard door (Remove, Install, Replace)

Navigating through the chapters

As we previously mentioned, you need to go to chapter 050. As with the handbook's table of contents page, you can easily find the book and chapter numbers at the top of each page in the chapter, as shown in the table below. A short chapter description is taken from the handbook table of contents: Ceilings: Sheetrock (Install). Below this is general information about the task time standards in the chapter and notes related to task performance.

Task Time Standards STQ4

The Task Time Standards (TTS) listing shows all of the task time standards contained in the chapter. This is a relatively small chapter; other chapters throughout the various handbooks are much larger. The left column identifies EPS TTS reference numbers for each task description. This is to help you find the EPS Task Time Standards – Descriptions and Unit Hours.

Once again, based on your work order, you can choose whether the ceiling is to be installed using scaffolding or ladders. For this example, let's choose scaffolding, CT 713 that is listed below.

BOOK NUMBER 02 CHAPTER NUMBER 050 PAGE 11
CEILINGS : Sheetrock (Install)

: :
: CEILINGS: Sheetrock, Install :
: Note: 4'x8' sheetrock, 16"–24" o.c., double nailed, :
: multi-person, rolling scaffold or ladders :
: :

TASK TIME STANDARDS LISTING

CT 713	CEILING: (Install) 4'X8' sheets, 1/2"–3/4", 16"–24"o.c., double nailed, SCAFFOLD, multi-person
CT 714	CEILING: (Install) 4'x8' sheets, 1/2"–3/4", 16"–24"o.c. double nailed, LADDERS USED, multi-person

EPS Task Time Standards – Descriptions and Unit Hours

The number of entries in the TTS determines how difficult it is to find the EPS TTS – Descriptions and Unit Hours shown below. Using the reference number identified on the TTS (CT 713), we can scroll through the pages. The EPS TTS – Descriptions and Unit Hours provides a detailed description of the specific amount of work contained in the task time standard. Below that description, the standard hours are displayed to show the amount of craft time required to perform the specific amount of work contained in the task time standard. We can see below in the following table that it takes 0.00959 hours to install one square feet of ceiling. You simply take this number and multiply it by the total square feet of sheetrock for the project.

BOOK NUMBER 02 CHAPTER NUMBER 050 PAGE 11 CEILINGS : Sheetrock (Install)	
EPS TASK TIME STANDARDS - DESCRIPTIONS AND UNIT HOURS	
CT 713	Install sheetrock on ceiling, 8’–10’ high, exposed ceiling joists, 16”–24” o.c., double nailed, 1/2”–3/4” sheetrock, average number of obstacles and electrical boxes, using ROLLING SCAFFOLD. Includes time for multi-person crew. (per sq ft) 000.00959 hours per sq.ft. of sheetrock to install on ceiling
CT 714	Install sheetrock on ceiling, 8’–10’ high, exposed ceiling joists, 16”–24” o.c., double nailed, 1/2”–3/4” sheetrock, average number of obstacles and electrical boxes, using LADDERS. Includes time for multi-person crew. (per sq ft) 000.00807 hours per sq.ft. of sheetrock to install on ceiling

Task Time Standards Development Backup

We show a Task Time Standards Development Backup page from the carpentry handbook below. Each page of standards development backup data contains a step-by-step list of the task time standards by reference number (CT 713) contained in the chapters of the handbook. Next to the reference number is a list of the steps required in the following table.

TASK TIME STANDARDS DEVELOPMENT BACKUP PAGE 111	
CT 713	1 MOVE ROLLING SCAFFOLD INTO POSITION FOR INSTALLATION, SECURE AT FLOOR, CLIMB UP & DOWN 2 MEASURE LOCATION AND CUT SHEETROCK TO FIT (INCLUDES CUTOUTS FOR BOXES AND OBSTRUCTIONS) 3 INSTALL SHEETROCK ON CEILING; DOUBLED NAILED 4 CARRY SHEETROCK MATERIAL TO INSTALLATION LOCATION AND LIFT INTO POSITION TO SCAFFOLD AND CEILING 5 CLEAN UP DEBRIS AND DISPOSE IN CONTAINER IN WORK AREA 6 CLEAN UP UNUSED PIECES OF SHEETROCK IN WORK AREA

NOTE: When you use the EPS as the primary standard source for developing facility maintenance and repair estimates, all other sources of standards and estimating information categories are considered *Non-EPS*.

Universal data

Universal data is EPS task time that is applicable to all crafts. You can locate it in the Handbook 01, General. It includes additional time for painting, ladders, scaffolds, material handling, heavy equipment travel time, work location travel time and safety time.

Paint

Traffic striping jobs are generally performed using a paint-striping machine. This machine requires daily cleaning at the end of each workday. Task time standard PWP–27 provides 1.1 hours of cleaning time that must be calculated into craft time for every job day.

Ladder time

At times a ladder is needed to perform the task, but the task time standard does not include ladder use in the task operations. Before you add ladder time, review the operations in a task time standard ladder time is not included in the task itself. In this way, you can avoid adding additional ladder time when it is not needed.

Scaffolding time

When scaffolding is required, this task provides time to assemble *or* disassemble, move, raise and lower scaffolding. Time is provided as time per scaffold section up to and including five sections high. As we just mentioned, be sure to review the task time standard to ensure that the time is not already included. In the example we used scaffold time which was already calculated.

Additional material handling

Standards have been developed in EPS for moving materials, equipment, or debris between storage areas and work sites, moving loads in one direction and unloading in the other. Do not confuse additional material handling standards with material handling operations that are part of the task time standard. Material handling within a task time standard is time provided for moving materials in conjunction with the craftwork being performed.

Heavy equipment travel

Heavy and large track equipment normally travels at speeds slower than normal. Heavy equipment travel (HET) allows workers riding in or waiting for the vehicle sufficient time for the vehicle to get to the job site.

Additional work location

Maintenance and repair work may require workers to work at different locations while on a job. The additional work location standard provides additional time to travel from the first work site to other locations.

Watchstanding/safety time

Standby or safety time is provided for jobs requiring a safety person or standby person in support of the worker performing the task. Calculate standby or safety time thusly:

CRAFT TIME divided by NUMBER OF WORKERS = STANDBY SAFETY TIME

General data factors

When you have identified task time standards and universal data, general data allowances are factored into the estimate to allow the workers sufficient time for job preparation, hazardous work, craft allowances, travel, and partial day influence associated with the particular type of work being performed. You apply general data by multiplying the total craft time for a job by an EPS General Data Factor.

209. Using special precautionary measures

Special precautionary measures are extra steps that you need to take in order to ensure that you take all possible safety hazards into consideration. This is important because you need to be sure that you are aware of the unknown anytime you plan a project. Using the six-step operational risk management process helps you to identify hazards and implement appropriate controls to minimize or eliminate any risks. The two forms that we cover in this lesson are the AF Form 103, Base Civil Engineering

Work Clearance Request, and AF Form 592, USAF Welding, Cutting, and Brazing Permit.

AF Form 103, Base Civil Engineering Work Clearance Request

You must ensure you use the AF Form 103 for any work (contract or in-house) that may disrupt aircraft or vehicular traffic flow, base utility services, fire and intrusion alarm protection systems, or routine installation activities. Use this form to coordinate the required work with key base activities and minimize customer inconvenience. Also use it to identify potentially hazardous work conditions in an attempt to prevent mishaps. You process the work clearance just prior to starting the work. If you encounter any delays or the project (i.e., job) conditions change, you must ensure you reprocess the work clearance.

NOTE: Disturbance of earth deeper than 100 millimeters (4 inches) requires processing a “digging permit” (AF Form 103). If you ignore this requirement and damages are incurred, all costs for repairs will be charged to the responsible party.

The requester fills in information on the location and type of work. The CE clearance reviewers complete block 8. The CE clearance reviewer’s section include blocks for electrical, steam, water, POL, and sewer distribution, environmental, pavements/grounds, fire protection, zone and other (as specified). Blocks 9–15 are reserved for security forces, safety, communications, base operations, cable, commercial utilities, and “other” clearance reviewers. If any reviewer must describe specific precautionary measures (i.e., excavation method, equipment type, etc.) to take before or during work accomplishment, they use Block 18 on the reverse side of the form. After the clearance review is completed, the operations flight chief or the engineering flight chief or their designated authority marks the request as either approved or disapproved.

NOTE: We can not overemphasize the importance of having the worksite reviewed. Imagine what could happen if you were driving in a grounding rod or digging a hole and you hit a high-voltage power line.

AF Form 592, USAF Welding, Cutting and Brazing Permit

Anytime you are welding equipment or have open flames away from your shop approved welding area, you must have an issued AF Form 592 with you. Only certain personnel are authorized to issue these permits. The authorized personnel must accomplish the following:

- Inspect the work area before allowing any welding, cutting or brazing activities to begin.
- Ensure a copy of the signed AF Form 592 is readily available in the immediate area of welding, cutting, and brazing operations.

Like the AF Form 103, the AF Form 592 is designed to identify special precautions that must be taken when using welding/cutting equipment in an attempt to prevent mishaps. The following are some key features identified on the AF Form 592:

- Work location (open/closed area).
- Work description (type welding, etc.).
- If a fire watch is required.
- If an after operation inspection is required.
- Special precautions noted by the fire inspector.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

208. Using estimating standards

1. What is the definition of Engineered Performance Standards?

2. How are the EPS handbooks organized?

3. Where are the EPS book and chapter numbers located?

4. What does the EPS TTS listing show?

5. What is universal data?

6. For what are general data allowances used?

209. Using special precautionary measures

1. When do we use the AF Form 103?

2. When is the AF Form 103 processed?

3. Who fills in information on the location and type of work on the AF Form 103?

4. After the clearance review is completed on the AF Form 103, who approves or disapproves the request?

5. When must you ensure that you have an AF Form 592, USAF Welding, Cutting, and Brazing Permit, with you?

6. What is the AF Form 592 designed to accomplish?

3–2. Working with Numbers

Almost every job that you work on as a structural journeyman involves mathematics. Mathematics provides the basic fundamentals for you to measure items, layout work, and estimate materials. It is very important that you understand and can apply the principles that we cover.

The mathematics discussed in this section includes fractions and decimals, the metric system, and equations and formulas related to structural work. Mathematics is frequently used in developing layouts and patterns for sheet metal repair, fabrications, and installations.

If you are not very familiar with the functions of basic math, geometry, or the metric system, this section will help you to perform most of the problems related to structural work. If you already have a good background in these functions, the text and review exercises will serve to refresh your memory.

Most measuring tools that you use on the job are divided into fractions of an inch. To use these tools successfully, you must quickly add, subtract, multiply, divide, and convert these fractions, decimals, and metrics to other units of measurement. First, let's define the term "fraction."

210. Calculating fractions

A fraction is a portion of something such as an inch, foot, pie, or just about anything. A fraction has two numbers that are separated by a diagonal line. The top (first) number we call the numerator; it is usually placed about halfway above the diagonal line. The bottom (second) number we call the denominator; it is usually placed halfway below the diagonal line. See the following example.

$$\text{Numerator}/\text{Denominator} \quad {}^{1}/_{4} \quad {}^{3}/_{8}$$

There are two classifications of fractions that we cover, proper and improper.

Proper fractions

Let's consider the proper fraction first. Most of the fractions that you'll be using are proper fractions. An example is 3/16. Notice that the numerator (3) is smaller than the denominator (16). This is the rule that classifies a fraction as being a proper fraction.

Improper fractions

Now, let's consider the improper fractions. If you saw an improper fraction such as ${}^{9}/_{8}$, it may look strange because the numerator (9) is larger than the denominator (8). This is the rule that classifies a fraction as being an improper fraction. It is customary to change improper fractions to mixed numbers by dividing the numerator by the denominator and expressing the quotient (result) as a whole number, followed by a fraction in which the remainder is the numerator, and the denominator is the same as before. In this case ${}^{9}/_{8} = {}^{8}/_{8}$ plus ${}^{1}/_{8}$ or $1\text{–}{}^{1}/_{8}$ let's take a look at the following table.

Type	Description	Example
Proper	Numerator is smaller than the denominator.	${}^{1}/_{4}$
Improper	Numerator is larger than the denominator.	${}^{9}/_{8}$

Example:

${}^{9}/_{8} = 1{}^{1}/_{8}$, since 8 is contained in 9 one time with a remainder of 1.

Reducing a fraction to lowest terms

When the numerator and denominator contain a common factor, we reduce the fraction by this common factor. That is, we divide the numerator and the denominator by the common factor. This process we call reducing a fraction to its lowest terms. If we multiply or divide both the numerator and denominator by the same number, the value of the fraction is not changed.

Example:

The fraction ${}^{6}/_{8}$ we can reduce by dividing both the 6 and 8 by 2 (6 divided by 2 equals 3, and 8 divided by 2 equals 4). The answer is ${}^{3}/_{4}$, which has the same value as the original ${}^{6}/_{8}$.

Adding fractions

You must first find the common denominator to add mixed numbers. The common denominator is a denominator that is divisible by all of the denominators involved. To change fractions to common denominator fractions, you find the smallest number that all denominators divide into evenly.

Example:

To Add	*Change To*
13 $^{1}/_{16}$	13 $^{2}/_{32}$
16 $^{5}/_{32}$	16 $^{5}/_{32}$
5 $^{7}/_{8}$	5 $^{28}/_{32}$

Why did we use 32 as a common denominator? The number 32 is appropriate because 16, 32, and 8 all divide into 32 evenly. Now, what happens to the numerators 1, 5, and 7? In the case of $^{1}/_{16}$, 16 goes into 32 twice, and 2 × 1 = 2; so $^{1}/_{16}$ equals $^{2}/_{32}$. Now look at $^{5}/_{32}$: 32 goes into 32 one time, and 1 times 5 equals 5; so it stays $^{5}/_{32}$. Finally the $^{7}/_{8}$, 32 divided by 8 equals 4, and 4 × 7 = 28; so $^{7}/_{8}$ equals $^{28}/_{32}$. Now, add them together. Remember, when adding common denominator fractions, you add the numerators only. In the example we have 2, 5, and 28 that add up to 35 or $^{35}/_{32}$, which equals 1 $^{3}/_{32}$. Now, add the whole numbers in the example (13, 16, and 5) and get 34. Then add 1 $^{3}/_{32}$ to 34 and get 35 $^{3}/_{32}$.

Example of reducing denominators to lowest terms and adding:

$$120\,{}^{3}\!/_{4} = 120\,{}^{6}\!/_{8}$$
$$52\,{}^{3}\!/_{8} = 52\,{}^{3}\!/_{8}$$
$$+\,23\,{}^{1}\!/_{2} = 23\,{}^{4}\!/_{8}$$
$$195\,{}^{13}\!/_{8}\ or\ 195 + 1\,{}^{5}\!/_{8}$$

So,

$$195 + 1\,{}^{5}\!/_{8} = 196\,{}^{5}\!/_{8}$$

Subtracting mixed numbers

When the fraction in the top number (minuend) is greater than the fraction in the lower number (subtrahend), subtract the whole part from the whole part and the fraction from the fraction.

Examples:

$$\begin{array}{r} 22\,{}^{3}\!/_{8} \\ -\,12\,{}^{1}\!/_{8} \\ \hline 10\,{}^{2}\!/_{8}\ or\ 10\,{}^{1}\!/_{4} \end{array} \qquad \begin{array}{r} 22\,{}^{3}\!/_{4} = 22\,{}^{3}\!/_{4} \\ -\,12\,{}^{1}\!/_{2} = 12\,{}^{2}\!/_{4} \\ \hline 10\,{}^{1}\!/_{4} \end{array}$$

If the upper fraction is smaller than the lower fraction, first borrow one whole unit from the top whole number and convert it into the fractional equivalent of a whole number. As an example: 1 = 4/4 or 1 = 3/3. Add this and the fraction you already have then proceed with the subtraction.

Example:

To subtract 15 ¾ from 29 ¼

$$\begin{array}{r} 29\,{}^{1}\!/_{4} = 28 + {}^{4}\!/_{4} + {}^{1}\!/_{4} = 28\,{}^{5}\!/_{4} \\ -15\,{}^{3}\!/_{4} \\ \hline 13\,{}^{2}\!/_{4}\ or\ 13\,{}^{1}\!/_{2} \end{array}$$

Multiplying fractions

Perhaps the simplest operation with fractions is multiplication ($^{1}/_{4} \times {}^{3}/_{4} = {}^{3}/_{16}$, and $2 \times {}^{3}/_{4} = {}^{6}/_{4}$). We can change the improper fraction $^{6}/_{4}$ to the mixed number 1 $^{2}/_{4}$, which we can then reduce to 1 $^{1}/_{2}$. When you multiply mixed numbers, first change each to an improper fraction and proceed. To do this conversion, multiply the whole number by the denominator and then add the numerator to your product; use this number as the new numerator for the original denominator. See the following example for clarification.

Example:

To change 2 $^{3}/_{4}$ to an improper fraction, multiply 2 x 4 and get 8; then add 8 and 3 to get 11. Putting this 11 over the original denominator 4, you now have 11/4.

$$^{8}\!/_{4} + {}^{3}\!/_{4} = {}^{11}\!/_{4}$$

The following example shows how you apply this conversion:

Example:

$$1\,{}^{1}\!/_{4} \times 3\,{}^{1}\!/_{2} = {}^{5}\!/_{4} \times {}^{7}\!/_{2} = {}^{35}\!/_{8} = 4\,{}^{3}\!/_{8}$$

and

$$1\,{}^{3}\!/_{16} \times 2\,{}^{1}\!/_{2} = {}^{19}\!/_{16} \times {}^{5}\!/_{2} = {}^{95}\!/_{32} = 2\,{}^{31}\!/_{32}$$

Frequently, you can simplify the multiplication of fractions by dividing numerators and denominators by common factors (canceling where possible) before proceeding with the indicated multiplication. For instance, you can multiply $^{4}/_{8}$ by $^{10}/_{16}$ in the following way.

Example:

$$\frac{\overset{1}{\cancel{4}}}{\underset{4}{\cancel{8}}} \times \frac{\overset{5}{\cancel{10}}}{\underset{4}{\cancel{16}}} = {}^{5}\!/_{16}$$

In the preceding example, you divided (commonly called canceling) before you performed the indicated multiplication. You divide the numerator 4 and the denominator 16 by the common factor 4. The numerator 10 and the denominator 8 you divided by the common factor 2. Then, with the numerators 1 and 5, and the denominators 4 and 4, you easily arrived at the answer $^{5}/_{16}$.

Dividing fractions

Division is like multiplication, with one change. You invert the divisor (second fraction). With the divisor inverted, multiply the dividend (first fraction) by the inverted divisor, as shown below. In division, after you invert the divisor, follow the principles of multiplication. *Example:*

$$\frac{3}{4} \div \frac{1}{4} = \frac{3}{4} \times \frac{4}{1} = \frac{12}{4} = 3$$

or

1

$$\frac{3}{4} \div \frac{1}{4} = \frac{3}{\cancel{4}} \times \frac{\cancel{4}}{1} = \frac{3}{1} = 3$$

1

211. Calculating decimals

When solving mathematical problems, you often find it easier to convert a fraction to a decimal before solving the problem. Also, measurements are often expressed in decimal form on a blueprint or drawing. Therefore, it is essential that you are able to perform math functions with decimal numbers.

A decimal is a number used to represent tenths, hundredths, thousandths, and so forth, of a unit that measures just about anything (i.e., weight, length, size, etc.) The decimal is written so that it has only a numerator which contains a decimal point; the denominator is implied based on the position of the decimal point. The decimal point is written at the left of the number expressing the numerator.

Whole Number	Written	Read	Fraction
Point 1	0.1	One tenth	1/10
Point 01	0.01	One hundredth	1/100
Point 001	0.001	One thousandth	1/1000

For example, 0.5 is a decimal and is read “point 5,” or five tenths. Its value is the same as the fraction 5/10. The table above shows the relationship between the whole number, how it is written, how it is read, and how it is written as a fraction.

A mixed decimal number, such as 1.25, is read one and twenty-five hundredths, or simply one point twenty-five.

Examples of some decimals you will be using are:

- A No. 39 twist drill. It is 0.099 inch in diameter; you read the decimal 0.099 as “ninety-nine thousandths.”
- A 24-gauge sheet metal. It is 0.025 inch thick; you read the decimal 0.025 as “twenty-five thousandths.”

Changing fractions to decimals

To change a common fraction to its decimal equivalent, you divide the numerator by the denominator.

For example, to change the fraction 7/8 to a decimal, you would divide 7 by 8.

$$\begin{array}{r} .875 \\ 8\overline{)7.000} \\ \underline{64} \\ 060 \\ 0\underline{56} \\ 0040 \\ 00\underline{40} \\ 0 \end{array}$$

So, $\frac{7}{8} = 0.875$

Changing decimals to fractions

When you change a decimal to its common fraction equivalent, write the decimal (omitting the decimal point) as the numerator over the implied denominator, and reduce to lowest terms.

Example:

$$.875 = \frac{875}{1000} = \frac{35}{40} = \frac{7}{8}$$

Using decimal equivalent charts

The following chart is a decimal equivalent chart that you can use to convert fractions to decimals and decimals to fractions without using the mathematical procedures we discussed. The chart contains the decimal equivalents of all fractional values from $^{1}/_{64}$ to 1 inch. In shop work, you can save time by using a decimal equivalent chart. However, sometimes you encounter fractions that are not on the chart. When this happens, use a calculator or compute the answer manually.

Example:

Use the following charts and determine the decimal equivalent of $^{1}/_{64}$, $^{5}/_{32}$, $^{6}/_{16}$, and $^{7}/_{8}$.

Decimal Equivalents									
Fractions	16th	32d	64th	Decimal	Fractions	16th	32d	64th	Decimal
			1	.015625				33	.515625
		1	2	.03125			17	34	.53125
			3	.046875				35	.546875
	1	2	4	.0625		9	18	36	.5625
			5	.078125				37	.578125
		3	6	.09375			19	38	.59375
			7	.109375				39	.609375
$^{1}/_{8}$	2	4	8	.125	$^{5}/_{8}$	10	20	40	.625
			9	.140625				41	.640625
		5	10	.15625			21	42	.65625
			11	.171875				43	.671875
	3	6	12	.1875		11	22	44	.6875
			13	.203125				45	.703125
		7	14	.21875			23	46	.71875
			15	.234375				47	.734375
$^{1}/_{4}$	4	8	16	.250	$^{3}/_{4}$	12	24	48	.750
			17	.265625				49	.765625
		9	18	.28125			25	50	.78125
			19	.296875				51	.796875
	5	10	20	.3125		13	26	52	.8125
			21	.328125				53	.818225
		11	22	.34375			27	54	.84375
			23	.359375				55	.859375
$^{3}/_{8}$	6	12	24	.375	$^{7}/_{8}$	14	28	56	.875
			25	.390625				57	.890625
		13	26	.40625			29	58	.90625
			27	.421875				59	.921875
	7	14	28	.4375		15	30	60	.9375

Decimal Equivalents									
Fractions	16th	32d	64th	Decimal	Fractions	16th	32d	64th	Decimal
			29	.453125				61	.953125
		15	30	.46875			31	62	.96875
			31	.484375				63	.984375
$^1/_2$	8	16	32	.500	1	16	32	64	1.000

Did you get these answers?

$^1/_{64} = 0.015625$

$^5/_{32} = 0.15625$

$^6/_{16} = 0.375$

$^7/_8 = 0.875$

Adding decimals

When you add numbers containing decimals, align the decimal points in a vertical column.

Example: Find the sum of 23.01, 0.037, and 1.3.

$$\begin{array}{r} 23.01 \\ 0.037 \\ +1.3 \\ \hline 24.347 \end{array}$$

Subtracting decimals

When you subtract decimal fractions, align the decimal points as in addition and determine the difference.

Example: Subtract 2.84 from 15.1.

$$\begin{array}{r} 15.10 \\ -2.84 \\ \hline 12.26 \end{array}$$

Multiplying decimals

To multiply decimal numbers, place the multiplier (the number that multiplies the multiplicant) under the multiplicand, (the number that is to be multiplied by another number) disregarding the position of the decimal points. Multiply as with whole numbers; and in the product, count off as many decimal places as there are decimal places in both multiplier and multiplicand. Begin at the right side of the product and add zeros as necessary to get the correct number of decimal places needed.

Examples:

$$\begin{array}{r} .25 \\ \times 2.5 \\ \hline 125 \\ 50 \\ \hline .625 \end{array} \qquad \begin{array}{r} 11.25 \\ \times .75 \\ \hline 5625 \\ 78750 \\ \hline 8.4375 \end{array} \qquad \begin{array}{r} .05 \\ \times .5 \\ \hline .025 \end{array}$$

212. Calculating metrics

The metric system is an easy to use standard of measurement that most of the world now uses. Metrics play a major role in the manufacture of many tools, cars, and building materials. Further use includes the two-liter bottles of soft drinks that are sold worldwide. Even with all of this, the United States is still slow to convert to the metric system. Products are still being made to the English standard and many people still prefer to use it over the metric system.

The metric system has three principal units of measurement:

1. *Meter* as the measure of length.
2. *Liter* as the measure of capacity.
3. *Gram* as the measure of weight.

The unit of measure you use most often is the meter.

Terms used in the metric system are all in units of 10. Multiples of these are obtained by prefixing the words: deca (10), hecto (100), and kilo (1000). Divisions are obtained by prefixing the words: deci ($^1/_{10}$ or 0.1), centi ($^1/_{100}$ or 0.01), and milli ($^1/_{1000}$ or 0.001).

In the following table of units of measure, the meter is located in the center of the lists of names. At the left is a column of metric units and what they represent. Note that the difference is the location of the decimal point. The millimeter (mm) is the smallest metric unit of length that we discuss.

Units of Measure		
1	Kilo	1000.
1	Hecto	100.
1	Deca	10.
1	*	1.
1	Deci	.1
1	Centi	.01
1	Milli	.001

Now that we can identify the small divisions of a meter, let's see what we get when we multiply meters. Ten meters is a decameter (dkm), 10 decameters is a hectometer (hm), and 10 hectometers is a kilometer (km). These different measurements of lengths are listed in the following table.

Measures of Lengths		
10 millimeters	=	1 centimeter (cm)
10 centimeters	=	1 decimeter (dm)
10 decimeters	=	1 meter (m)
10 meters	=	1 decameter (dkm)
10 decameters	=	1 hectometer (hm)
10 hectometers	=	1 kilometer (km)

Here is a quick reference conversion table to convert from given inches to millimeters.

Inches to Millimeters							
Inches	Milli-meters	Inches	Milli-meters	Inches	Milli-meters	Inches	Milli-meters
1	25.4	26	660.4	51	1295.4	76	1930.4
2	50.8	27	685.8	52	1320.8	77	1955.8

Inches to Millimeters							
3	76.2	28	711.2	53	1346.2	78	1981.2
4	101.6	29	736.6	54	1371.6	79	2006.6
5	127.0	30	762.0	55	1397.0	80	2032.0
6	152.4	31	787.4	56	1422.4	81	2057.4
7	177.8	32	812.8	57	1447.8	82	2082.8
8	203.2	33	838.2	58	1473.2	83	2108.2
9	228.6	34	863.6	59	1498.6	84	2133.6
10	254.0	35	889.0	60	1524.0	85	2159.0
11	279.4	36	914.4	61	1549.4	86	2184.4
12	304.8	37	939.8	62	1574.8	87	2209.8
13	330.2	38	965.2	63	1600.2	88	2235.2
14	355.6	39	990.6	64	1625.6	89	2260.6
15	381.0	40	1016.0	65	1651.0	90	2286.0
16	406.4	41	1041.4	66	1676.4	91	2311.4
17	431.8	42	1066.8	67	1701.8	92	2336.8
18	457.2	43	1092.2	68	1727.2	93	2362.2
19	482.6	44	1117.6	69	1752.6	94	2387.6
20	508.0	45	1143.0	70	1778.0	95	2413.0
21	533.4	46	1168.4	71	1803.4	96	2438.4
22	558.8	47	1193.8	72	1828.8	97	2463.8
23	584.2	48	1219.2	73	1854.2	98	2489.2
24	609.6	49	1244.6	74	1879.6	99	2514.6
25	635.0	50	1270.0	75	1905.0	100	2540.0

The chart below shows the metric conversion from fractions of an inch. You can take 25.3995 (metric equivalent of 1 inch)—divide, multiply, and round off the answer to the fourth decimal point. You can also check the following table for a list of fractions of an inch with decimal and millimeter equivalents. These figures are useful in many ways; one of which is in finding twist drill sizes.

Conversion of Fractions and Decimals of an Inch to Millimeters					
Fraction of Inch	**Decimal of Inch**	**Millimeters**	**Fraction of Inch**	**Decimal of Inch**	**Millimeters**
1/64	0.015625	0.3968	33/64	0.515625	13.0966
1/32	0.03125	0.7937	17/32	0.53125	13.4934
3/64	0.046875	1.1906	35/64	0.546875	13.8903
1/16	0.0625	1.5875	9/l6	0.5625	14.2872
5/64	0.78125	1.9843	37/64	0.578125	14.6841
3/32	0.09375	2.3812	19/32	0.59375	15.0809
7/64	0.109375	2.7780	39/64	0.609375	15.4778
1/8	0.125	3.1749	5/8	0.625	15.8747
9/64	0.140625	3.5718	41/64	0.640625	16.2715
5/32	0.15625	3.9686	21/32	0.65625	16.6684
11/64	0.171875	4.3655	43/64	0.671875	17.0653
3/16	0.1875	4.7624	11/16	0.6875	17.4621
13/64	0.203125	5.1592	45/64	0.703125	17.8590
7/32	0.21875	5.5561	23/32	0.71875	18.2559

Conversion of Fractions and Decimals of an Inch to Millimeters					
15/64	0.234375	5.9530	47/64	0.734375	18.6527
¼	0.25	6.3498	3/4	0.75	19.0496
17/64	0.265625	6.7467	49/64	0.765625	19.4465
9/32	0.28125	7.1436	25/32	0.78125	19.8433
19/64	0.296875	7.5404	51/64	0.796875	20.2402
5/16	0.3125	7.9373	13/16	0.8125	20.6371
21/64	0.328125	8.3342	53/64	0.828125	21.0339
11/32	0.34375	8.7310	27/32	0.84375	21.4308
23/64	0.359375	9.1279	55/64	0.859375	21.8277
3/8	0.375	9.5248	7/8	0.875	22.2245
25/64	0.390625	9.9216	57/64	0.890625	22.6214
13/32	0.40625	10.3185	29/32	0.90625	23.0183
27/64	0.421875	10.7154	59/64	0.921875	23.4151
7/16	0.4375	11.1122	15/16	0.9375	23.8120
29/64	0.453125	11.5091	61/64	0.953125	24.2089
15/32	0.46875	11.9060	31/32	0.96875	24.6057
31/64	0.484375	12.3029	63/64	0.984375	25.0026
½	0.500	12.6997	1	1.000	25.3995

From time to time, you may need to work with dry volume. To be prepared, study the following cubic conversion chart.

Cubic Conversion Chart					
Cubic Meters				**Cubic Feet**	**Cubic Yard**
Cubic Yard			**Cubic Meters**		
Cubic Feet		**Cubic Meters**			
Cubic Inches	**Cubic Centimeters**				
1	16.39	0.028	0.76	35.3	1.31
2	32.77	0.057	1.53	70.6	2.62
3	49.16	0.085	2.29	105.9	3.92
4	65.55	0.113	3.06	141.3	5.23
5	81.94	0.142	3.82	176.6	6.54
6	98.32	0.170	4.59	211.9	7.85
7	114.71	0.198	5.35	247.2	9.16
8	131.10	0.227	6.12	282.5	10.46
9	147.48	0.255	6.88	317.8	11.77
10	163.87	0.283	7.65	353.1	13.07
20	327.74	0.566	15.29	706.3	26.16
30	491.61	0.850	29.94	1059.4	39.24
40	655.48	1.133	30.58	1412.6	52.32
50	819.35	1.416	38.23	1765.7	65.40
60	983.22	1.700	45.87	2118.9	78.48
70	1174.09	1.982	53.52	2472.0	91.56
80	1310.96	2.265	61.16	2825.2	104.63
90	1474.84	2.548	68.81	3178.3	117.71

Cubic Conversion Chart					
100	1638.71	2.832	76.46	3531.4	130.79
Example: 3 cu. yd = 2.29 cu. M					
Volume: The cubic meter is the only common dimension we use for measuring the volume of solids in the metric system.					

Example:

> Let's say you have a job to place concrete. If your forms are 16′ × 7′ × 6″, how many cubic meters of concrete are required? To find out, let's start with what we know—16′ × 7′ × 0.5′ = 56 cubic feet. Using the following cubic conversion chart, 50 cubic feet equals 1.416 cubic meters, and 6 cubic feet equals 0.170 cubic meters. Add the two together and you find that 1.586 cubic meters is the required amount of concrete.

When you're faced with a problem with liquid volumes in metrics, remember that the liter is the foundation of liquid measure. Refer to the following table, Gallon and Liter Conversion Chart and the back of a circumference ruler. Between these two you should be able to accurately solve any problem you may encounter.

Gallon and Liter Conversion Chart					
Gallon	Liter	Gallon	Liter	Gallon	Liter
.1	.38	1	3.79	10	37.85
.2	.76	2	7.57	20	57.71
.3	1.14	3	11.36	30	113.56
.4	1.51	4	15.14	40	151.42
.5	1.89	5	18.93	50	189.27
.6	2.27	6	22.71	60	227.12
.7	2.65	7	26.50	70	264.98
.8	3.03	8	30.28	80	302.83
.9	3.41	9	34.07	90	340.69
				100	378.54
1 US Gallon = 3.785412 Liters					

When you are working with units of weight in the metric system, the kilogram (kg) is the foundation of measure. The following chart is a conversion of US weights and metric weights. Study it so that when you work with blueprints made under the metric system (especially overseas), you do not make costly errors.

Weight Conversion Chart						
Ounces						**Grams**
Grams					**Ounces**	
Pounds				**Kilograms**		
Kilograms			**Pounds**			
Short Ton		**Metric Ton**				
Metric Ton	**Short Ton**					
1	1.10	0.91	2.20	0.45	0.04	28.1
2	2.20	1.81	4.41	0.91	0.07	56.7
3	3.31	2.72	6.61	1.36	0.11	85.0
4	4.41	3.63	8.82	1.81	0.14	113.4
5	5.51	4.54	11.02	2.67	0.18	141.8

Weight Conversion Chart						
6	6.61	5.44	13.23	2.72	0.21	170.1
7	7.72	6.35	15.43	3.18	0.25	198.4
8	8.82	7.26	17.64	3.63	0.28	226.8
9	9.92	8.16	19.81	4.08	0.32	255.2
10	11.02	9.07	22.05	4.54	0.35	283.5
16	17.63	14.51	35.27	7.25	0.56	453.6
20	22.05	18.14	44.09	9.07	0.71	567.0
30	33.07	27.22	66.14	13.61	1.06	850.5
40	44.09	36.29	88.14	18.14	1.41	1134.0
50	55.12	45.36	110.23	22.68	1.76	1417.5
60	66.14	54.43	132.28	27.22	2.12	1701.0
70	77.16	63.50	154.32	31.75	2.17	1981.5
80	88.18	72.57	176.37	36.29	2.82	2268.0
90	99.21	81.65	198.42	40.82	3.17	2551.5
100	110.20	90.72	220.46	45.36	3.53	2835.0

Example:

Convert 26 pounds to kilograms.

28 pounds = 20 pounds + 8 pounds.

From the chart: 20 pounds = 9.07 kilograms and 8 pounds = 3.63 kilograms.

Therefore: 28 pounds = 9.07 kg + 3.63 kg = 12.70 kg.

a. 1 pound is = 0.4535924 kg.

b. The short ton (US) is 2000 pounds.

c. The metric ton is 1000 kg.

213. Calculating linear measurements

Can you make change for a dollar? If you were a cashier in a restaurant and couldn’t make change quickly and accurately, you probably wouldn’t be very productive at your job. The same holds true as a structural journeyman. You need to be able to change feet to inches, yards to feet, inches to yards, and so forth.

Converting inches to feet

To change inches to feet, all you have to do is divide the number of inches by 12, since there are 12 inches in 1 foot. You then express this number as feet (and inches if there is any remainder).

Example:

55 inches ÷ 12 = 4 feet 7 inches

Converting feet to inches

This is just the opposite. To convert feet to inches, multiply the number of feet by 12. If you have combined feet and inches, just multiply the feet by 12 and add any remaining inches. This is how you would convert 12 feet 3 inches.

Example:

12 feet x 12 = 144 inches + 3 inches = 147 inches

Converting feet to yards

To convert feet to yards, divide the number of feet by 3. You do this because 3 feet equals 1 yard.

Example:

33 feet ÷ 3 = 11 yards

Converting yards to feet

To convert yards to feet, multiply the number of yards by 3. You do this because there are 3 feet in 1-yard.

Example:

5 yards x 3 = 15 feet

Converting decimals fractions to linear measurements

Up until this point, it has been relatively simple. It is going to get a little trickier now.

Converting decimal fractions of an inch to common fractions

You convert decimal fractions of an inch to the nearest common fraction by multiplying the decimal by 16 (if trying to find 16th of an inch). The number to the left of the decimal point is the number of sixteenths that you have. The number to the right of the decimal is a fraction of a sixteenth. If the number to the right of the decimal is .5 or greater, you need to add $^{1}/_{16}$ to the final answer.

For example, .48 x 16 = 7.68. The answer is 7.68 sixteenths. You can see that .68 is greater than .5, thus you add $^{1}/_{16}$ to the number on the left giving you $^{8}/_{16}$ and that reduces to ½.

Converting decimal fractions of a foot to inches

This is similar to what you just learned. To convert a decimal fraction of a foot to inches, multiply the decimal fraction by 12. If there is any decimal remainder, follow the steps above and multiply the remainder by 16 in order to change it into an inch fraction.

For example, to convert .75 feet to inches multiply .75 x 12 and the answer is 9 inches. On the other hand, if you convert .684 feet to inches, the answer is 8.208 inches. You then must multiply .208 by 16 to get 3.328 sixteenths. Since the number to the right of the decimal is less than .5, you round down to 3 sixteenths. Hence, the answer is 8-$^{3}/_{16}$ inches.

Suppose we want to convert 103 inches into feet and inches, down to the nearest $^{1}/_{16}$-inch. If we do it on a calculator, we divide 103 by 12 and the answer 8.58 feet. We then convert .58 feet into inches by multiplying it by 12 (.58 x 12 = 6.96 inches). We now have .96 inches left over. To convert .96 to the nearest $^{1}/_{16}$ inch, multiply it by 16 and round to the nearest whole number (.96 x 16 = 15.36). You take 15.36 and round it to 15. That gives you $^{15}/_{16}$ inch. Thus 22 inches converts to 1 foot 9 $^{15}/_{16}$ inches.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

210. Calculating fractions

1. For what do we use fractions?

2. What do you call the numbers that make up a fraction?

3. What is an improper fraction?

4. Identify each of these fractions as proper, improper, or a mixed number.

a. $^{9}/8$.

b. 2 $^{3}/4$.

c. $^{57}/64$.

5. Reduce these fractions to lowest terms.

a. $^{6}/8$.

b. $^{32}/64$.

c. $^{14}/32$.

d. $^{8}/32$.

6. Convert these fractions to mixed numbers when possible.

a. $^{27}/4$.

b. $^{121}/8$.

c. $^{65}/64$.

d. $^{2}/16$.

7. Convert these mixed numbers to improper fractions and reduce to the lowest terms.

a. $3\ ^1/_2$.

b. $6\ ^{18}/_{64}$.

c. $5\ ^7/_8$.

d. $1\ ^1/_4$.

e. $4\ ^9/_{16}$.

8. Prepare these figures for addition.

a. $21\ ^2/_{16}$, $7\ ^5/_8$, $18\ ^3/_4$, $11\ ^1/_4$, $15\ ^7/_8$, $4\ ^5/_8$.

b. $1\ ^3/_{32}$, $1\ ^1/_8$, $6\ ^7/_{16}$, $14\ ^1/_4$, $3\ ^5/_8$.

9. Find the sums for a. and b. of self-test question 10.

10. Solve the problems and reduce to the lowest terms.

a. $^{11}/_{12} \times\ ^7/_8$.

b. $4\ ^3/_8 \times 3\ ^5/_8$.

c. $^3/_4 \times\ ^5/_8$.

11. Solve these problems.

a. $^5/_{16} \div\ ^1/_8$.

b. $^4/_8 \div {}^2/_8$.

c. $16\ {}^3/_4 \div 3\ {}^1/_4$.

d. $25\ {}^4/_5 \div 5\ {}^1/_5$.

211. Calculating decimals

1. What do decimal numbers represent?

2. What do we use to locate a decimal number's position?

3. Add these mixed numbers and fractions: 36.734, 2.4, .008, $^{13}/_{16}$, and $6\ {}^{17}/_{32}$.

4. Multiply these:

a.
$$\begin{array}{r} 2.08 \\ \underline{\times 40.3} \end{array}$$

b.
$$\begin{array}{r} .03 \\ \underline{\times .38} \end{array}$$

c.
$$\begin{array}{r} 3.45 \\ \underline{\times 2.8} \end{array}$$

212. Calculating metrics

1. What three principle units of measurement does the metric system uses?

2. On what number is the metric system based?

3. Using the inches to millimeters table, convert from inches to millimeters:

   a. 53.

   b. 6.

c. 9.

d. 21.

e. 68.

4. Using the inches to millimeters table, and the fractions and decimals of an inch to millimeters tables, convert from inches to millimeters:

a. 6 7/8.

b. 29 47/64.

c. 86 11/32.

213. Calculating linear measurements

1. Convert the following measurements from inches to feet:

a. 27.

b. 97.

c. 151.

2. Convert the following measurements from feet to inches:

a. 5.

b. 7.

c. 11.

3. Convert the following measurements from feet to yards:
   a. 12.

   b. 18.

   c. 27.

4. Convert the following measurements to feet and inches (down to nearest $^{1}/_{16}$ inch):
   a. 153 inches.

   b. 27.53 feet.

   c. 33.75 yards.

5. Convert the following measurements from decimal fractions of an inch to common fractions:
   a. .5.

   b. .75.

   c. .94

6. Convert the following measurements from decimal fractions of a foot to inches:
   a. .33.

   b. .5.

   c. .67.

3–3. Equations and Formulas

Many jobs are difficult or impossible for you unless you know a few basic formulas that concern linear measurement or geometric functions. In this section, you are entering into a branch of mathematics that is used quite often by the structural journeyman. An understanding of this branch and the successful use of formulas helps you save time while solving problems. These formulas are not difficult; they deal primarily with basic mathematics.

214. Using equations and formulas

In this lesson, we discuss the rules for equations and formulas. We also discuss mensuration and triangles, plus parts of a circle and circle formulas. The knowledge you gain here will be a great asset to you in future lessons.

Rules for equations and formulas

There are some basic rules to help you understand equations and formulas.

Equations

An equation is a mathematical statement that expresses the equality of two or more quantities. For example, the statement 5 + 4 = 9 is an equation. It expresses—in an abbreviated form—the fact that the sum of 5 + 4 is equal to 9. If three quantities (a, b, and c) are given, the whole equals the sum of the parts; we can form the equation a + b + c = x to identify x as the unknown side of the equation.

Example:

> ***"a"*** represents a length of 1 inch; ***"b"*** 2 inches; and, ***"c"*** 3 inches.
>
> Now, you can solve the equation by substituting the numerical values and adding 1 + 2 + 3, which is 6.
>
> Thus, a + b + c = 6, because x is equal to the sum of the parts (a + b + c).

An equation is always divided into two parts by the equal sign (=). The two parts of an equation we call the members of the equation or the two sides of the equation. It is necessary for an equation to be balanced at all times. If we place two unequal weights in the pans of a common scale, the scale does not balance. Similarly, if you say 2 + 2 = 2 + 3, the equation does not balance. It should read 2 + 2 = 1 + 3, or other equal values. In an equation, we can make changes provided we maintain the equality. This means that you may add or subtract the same quantity from both sides of an equation, or multiply or divide both sides of an equation by the same quantity without changing the value of the equation.

Formulas

A formula is a special type of equation that expresses a certain fact, law, or relation by means of symbols or letters. There are several reasons why we use a formula in solving many shop problems. First, a formula is more compact, making it easier for the eye to distinguish the whole meaning of the law or rule at a glance. Secondly, it is easier for an individual to memorize a few symbols rather than a paragraph of explanations. For example, we usually state the law for determining the area of a rectangle as follows:

> The area of a rectangle is equal to the length of one side, multiplied by the width of the other side. We can, however, state this law in simpler forms by the formula **A = L x W**, where "L" represents the length and "W" represents the width.

In this formula, you can easily see how to figure the area of a rectangle. Notice that this formula eliminates the use of long terms that are difficult to interpret. In short, a formula is a simplified expression of the same law or rule.

Signs and symbols used in formulas

Formulas are equations that use signs and symbols to create what looks like mathematical shorthand. These signs and symbols indicate that a certain mathematical function must be performed. From your experiences in school, you should recall the meaning of the plus sign (+), minus sign (-), multiplication sign (×), division sign (÷), and equal sign (=). You should also recall that 2^2 means 2 × 2, or 2 squared, and that 2^3 means 2 × 2 × 2, or 2 cubed. Now in formulas such as **A = bh**, we mean that the area equals the base times height. In the formula **A = bh/2**, we mean that area (A) is equal to the base (b) times the height (h) divided by 2.

Mensuration

Mensuration is the part of geometry that that deals with measurement of lines, angles, surfaces, and solids. In laying out sheet metal components, you frequently make use of lines and angles in constructing various patterns for plane and solid figures. For example, a plane figure is any part of a plane surface bounded by any number of straight or curved lines, or a combination of the two such as squares, rectangles, triangles, and circles. Plane figures have two dimensions—length and width. Solids such as cubes, prisms, cylinders, pyramids, spheres, and cones are bodies that have three dimensions—length, width, and height.

Lines

A straight line is the shortest line that can be drawn between two points. When we use the term “line”, it is understood to mean a straight line. A curved line is a line no part of which is straight and yet which flows in a smooth and continuous fashion. A broken line is made up of a series of straight lines or dashes. Parallel lines are lines on the same plane that will never intersect, regardless of how far they extend. All lines are measured in linear units and have only one dimension—length.

Angles

An angle is the amount of opening between two intersecting lines. The point of intersection of the two sides (lines), such as point B’ (referred to as B prime) in figure 3–1, we know as the vertex. (On a triangle, the vertex is the furthest point opposite the base.) Angles are measured in degrees (°), which can be further subdivided into minutes and seconds. Point B’, in figure 3–1 is the vertex of two 90 degree (right) angles. The sum of these two 90 degrees angles is the straight line AC, which equals 180°. A line is perpendicular to another line if it forms an angle of 90 degree with the other line. In figure 3–1, line BB is perpendicular to line AC.

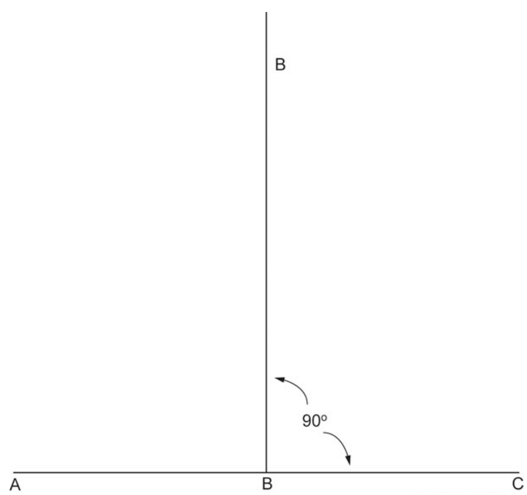


Figure 3–1. Perpendicular lines.

Plane figures

A plane figure is any part of a plane surface bounded by any number of straight or curved lines or a combination of the two. A plane figure that is bounded only by straight lines we call a polygon. Polygons include figures with three, four, or more sides; however, it is customary to divide them into three classes—those with three sides are triangles, those with four sides are rectangles, and those with more than four sides are polygons. Plane figures bounded by curved lines include circles and ellipses.

Triangles

A triangle is a three-sided plane figure, such as that shown in figure 3–2. The sides of a triangle are the lines that enclose it, and the sum of the included angles is always 180°. The base of a triangle is the side upon which it is supposed to stand; therefore, any side may be the base. The angle opposite the base is called the vertex angle, which is the point opposite to the base and farthest from it. The altitude or height of a triangle is the perpendicular distance from the base to the vertex. In figure 3–2, A is the vertex angle, line DC is the base, lines AD and AC are the sides, and line AB is the altitude. The triangle illustrated in figure 3–2 is an isosceles triangle, in which two sides are equal, as shown by DAC. Side DA is equal to side AC. The unequal side (DC) of an isosceles triangle we usually call the base.

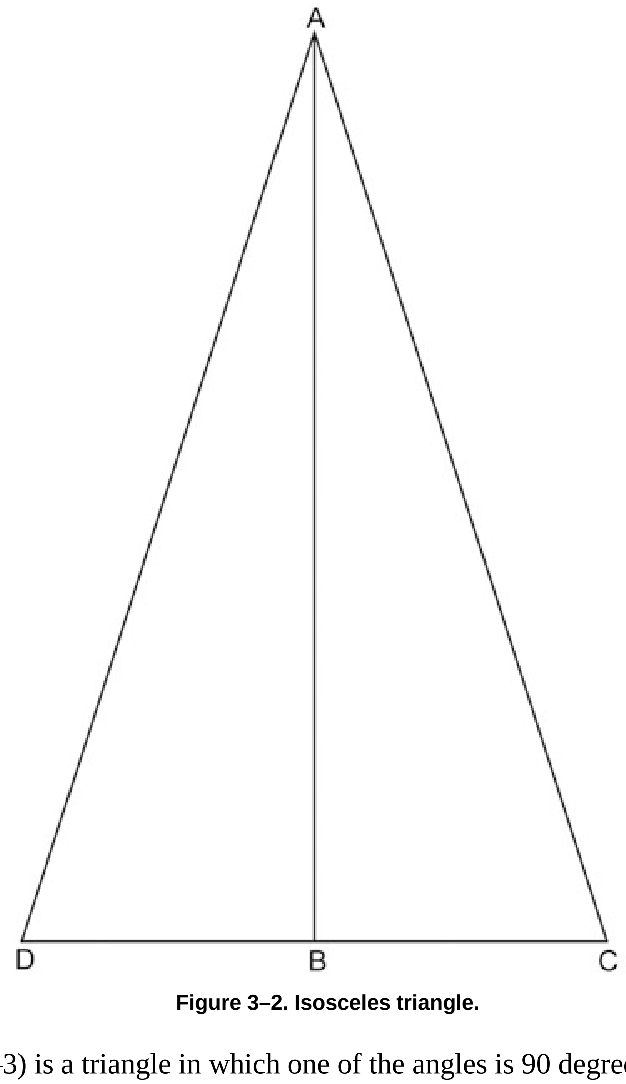


Figure 3–2. Isosceles triangle.

A right triangle (fig. 3–3) is a triangle in which one of the angles is 90 degree. The side opposite the 90 degree angle we know as the hypotenuse, and the other two sides we call legs. An acute triangle (fig. 3–3) is one in which each angle of the triangle is less than 90 degree. An obtuse triangle (fig. 3–3), is a triangle in which one of the angles is more than 90 degrees.

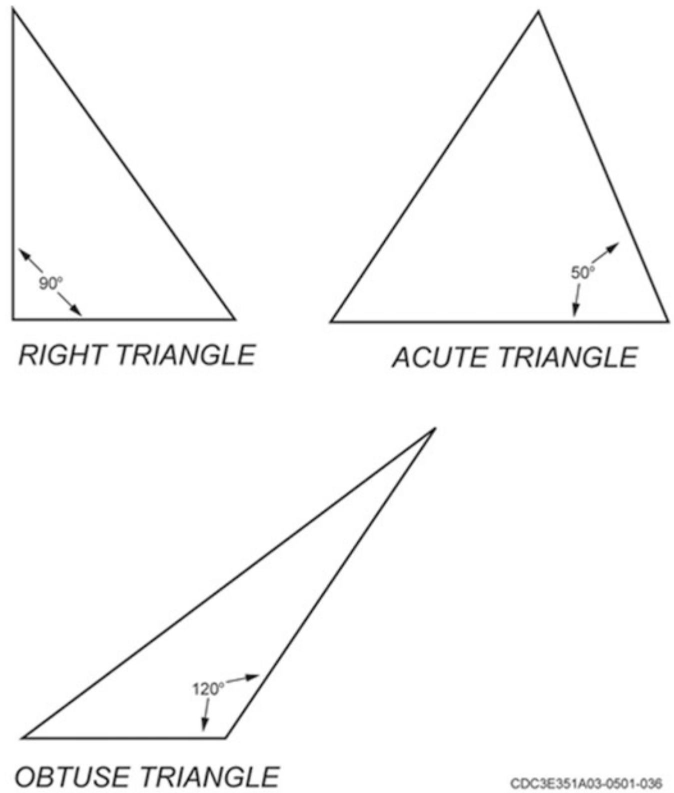


Figure 3–3. Triangles.

To find the area of any triangle, multiply the base times the height and divide by 2 (A = bh/2).

Example: Find the area of a triangle that has a base of 24 inches and an altitude or height of 12 inches. (*A* = area, *b* = base, *h* = altitude or height.)

Circles

A circle is a plane figure bounded by a curved line called the circumference. All points on the circumference are the same distance from the center. Figure 3–4 illustrates the lines and parts of a circle.

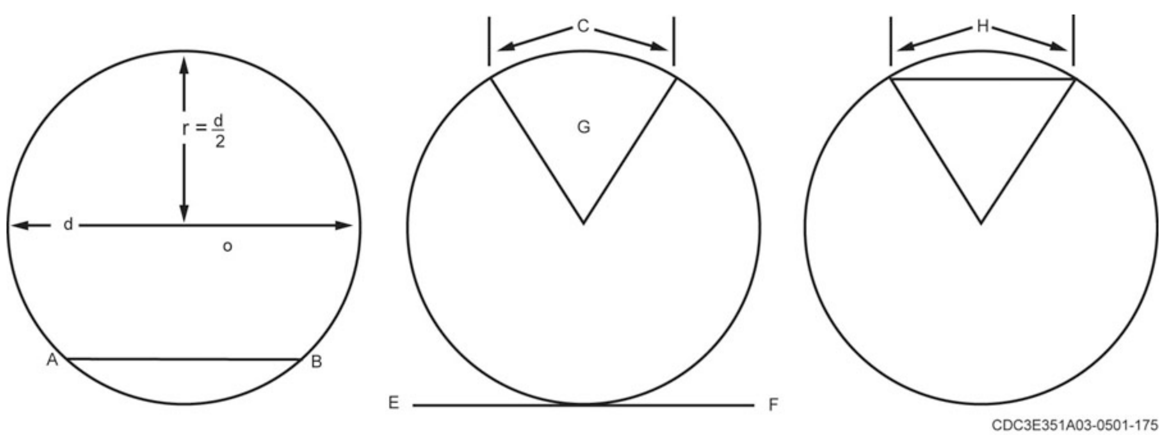


Figure 3–4. Circle parts.

The circumference of a circle is the length of the curved line that forms the circle; we may refer to it as the perimeter of a circle. We use the letter "C" to designate circumference in a formula. The circumference of any circle is divided into 360 equal units of measurement called degrees (360°);

however, in sheet metal work, we most often use linear measurements, such as inches, feet, centimeters, or the meter. When figuring the exact circumference of a circle, you often see the symbol called pi (π) on drawings. This symbol (π) represents the number 3.14159, which is the ratio number that you multiply by the circle's diameter to calculate the circle's circumference.

Although 3.14159 is the number we use to compute a circle's exact circumference, most sheet metal fabricators round it off to either 3.14 or 3.1416. Both of these methods work well for most sheet metal layout work. To simplify matters, we use 3.14 as our reference for π in the following formulas:

> In $C = \pi d$, the circumference is equal to 3.14 times the diameter. In the formula $A = \pi r^2$, the area of a circle is equal to 3.14 times the radius squared.

Example: What is the circumference of a circle that has a 5-inch diameter?

$$C=\pi d$$

$$C=3.14\times 5''$$

$$C=15.70''$$

The diameter of a circle is a line drawn through the center and ended by the circumference. The radius (r) of a circle is one-half the diameter (d), or the distance from the center to a point on the circumference. We can determine the area of a circle by multiplying pi (π) times the radius squared ($A = \pi r^2$). If you know "d", divide it by 2, which gives you the radius; then use the formula for area we just covered.

Example: What is the area of a circle that has a radius of 2 inches?

$$A = \pi r^2$$

$$A = 3.14 \times 2 \times 2$$

$$A = 12.56 \text{ square inches}$$

Circle parts

Refer to figure 3–4 to identify the following parts of a circle:

- Any part of the circumference of a circle, such as "C" and "H", is an *arc*.
- A *chord* (line AB) is a straight line joining any two parts on a circle.
- A *tangent* (line EF) is a straight line that only touches a single point on the circumference.
- A *sector* ("G") of a circle is the part bounded by two radii and an arc.
- A *segment* ("H") of a circle is the part that is bounded by an arc and a chord.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

214. Using equations and formulas

1. What mathematical statement do we use to express the equality of two or more quantities?

2. What sign divides an equation into two parts?

3. What is a formula?

4. What is mensuration?

5. What three dimensions do solids have?

6. What do we call the point of intersection of two lines forming an angle?

7. Name three kinds of triangles.

8. The formula A = bh/2 we use to find the area of what type of geometric figure?

9. What is a plane figure bounded by a curved line?

10. State the formula we use to find the circumference of a circle.

11. State the formula we use to find the area of a circle.

3–4. Material Estimation

Now that you know how to use estimating standards and are familiar with the different types of mathematical equations to which you may be exposed, we discuss material estimation. There are various formulas used to compute material estimates; however, this section provides you with some of the most common formulas that we use in the Air Force.

215. Using estimating formulas

Accurately planning a job is one of the most important skills a craftsman can have. Everything about a project costs money—from the materials to the manpower. The key is to plan your job to get the most accomplished with the least costs. This lesson provides you with estimating formulas for some of the most common type materials with which you will be working.

NOTE: Answers vary slightly depending on whether you round to the nearest hundredths or thousandths place.

Concrete

To compute the volume of concrete required for a concrete pad, multiply the length of the pad by its width times its thickness to get cubic feet (length x width x thickness). For example, a concrete pad is 30 feet in length by 20 feet in width and has a slab thickness of 4 inches. You first convert the 4 inches into feet by dividing 4 by 12 to get 0.333 feet. Next, multiply the 30 feet by 20 feet to get 600 square feet. Then multiply 600 square feet by 0.333 feet to determine the volume in cubic yards of concrete required for the pad—in this case it is 199.8 cubic feet.

Concrete is ordered and produced in quantities of cubic yards. To calculate the number of cubic yards required for the pad, divide the cubic feet of the pad by 27. This is required because there are 27 cubic feet in one cubic yard. Therefore, a concrete pad that has a volume of 199.8 cubic feet requires 7.4 cubic yards of concrete.

$$\frac{\textit{Length x Width x Thickness in feet}}{27} = \textit{Cubic yards}$$

30 feet (length) x 20 feet (width) x 4 inches (thickness) =

30 feet x 20 feet x 0.333 feet = 199.8 cubic feet (cf)

199.8 cf divided by 27 = 7.4 cubic yards

Once you compute the total number of cubic yards of concrete, you must add a little extra for waste—normally 5 percent for jobs requiring 200 cubic yards or more and 10 percent for smaller jobs. To calculate the excess needed for this pad, multiply the cubic yards by 10 percent (*7.4 x .10 = 0.74 cubic yards*). Add that amount to 7.4 to get the total amount required (*0.74 + 7.4 = 8.14 cubic yards*). Most companies will let you order concrete in quarter yard increments (i.e., 5 ¼ cubic yards), so round up to the nearest ¼ cubic yard.

NOTE: Always round up to the lowest increment that you can obtain. Some companies only sell ½ or whole yard increments.

Concrete masonry units

Concrete masonry units (CMU) are also known as concrete blocks. We cover two methods for estimating CMU without the tables.

Chasing the bond (3/4 and 3/2 rule)

The first method is *chasing the bond*, which uses the 3/4 rule and the 3/2 rule. Remember when you are estimating to always use *outside* measurements to calculate the number of blocks required per course. Our formulas are based on 8-inch by 8-inch by 16-inch block, which is the size used in most construction.

3/4 rule

Using the 3/4 rule (three full blocks per 4 feet in length) or .75, multiply the length of the wall by .75. For example, a retaining wall that is 10 feet high by 100 feet in length requires 75 blocks for the first course (*100 x .75 = 75 CMU per course*).

Length of course in feet x 3/4 *rule = number of CMU per course*

3/2 rule

Using the 3/2 rule (three full blocks per 2 feet in height), multiply the height of the wall by 1.5. For example, the height of the retaining wall is 10 feet. Multiply 10 by the rule 3/2 (1.5) which equals 15 blocks (courses) high (*10 x 1.5 = 15 courses*). See the following formula:

Height of wall in feet x 3/2 rule = *number of courses*

Total number of full block

To find the total number of CMU in the retaining wall, multiply the number of CMU per course by the number courses. In this example, it is 75 CMU per course times 15 courses (*75 x 15 = 1,125 CMU*).

Let's work another problem. Given a building that measures 20 feet by 8 feet by 8 feet (high), let's calculate the required amount of CMU needed.

20 + 20 + 8 + 8 = 56

56 x .75 = 42 CMU per course

8 x 1.5 = 12 courses

12 x 42 = 504 full blocks

Square foot method

The second method of estimating CMU is the *square foot method*. It is usually the quickest and simplest method but *not* always the most accurate. Remember in the first example, the retaining wall was 10 feet high and 100 feet in length. All you do is multiply *L* x *H = SF (10 x 100 = 1000 square feet).* To find the number of 8" x 8" x 16" block required, you must determine the square footage of one CMU which is .889 square feet per block. Next, you divide 1,000 square feet by .889 (*1000 ÷ .889 = 1,124.86 or 1,125 CMU*).

See the following formula:

Total square feet divided by square feet per CMU (.889) = total number CMU

Now calculate a building that measures 20 feet x 8 feet x 8 feet (high):

20 x 8 = 160 square feet x *2 (sides) = 320 square feet*

8 x 8 = 64 square feet x 2 (sides) = 128 square feet

Total = 448 square feet

448 square feet ÷ .889 square feet per CMU = 503.93 or 504 full block

Not to confuse you, but an alternate square foot method is to multiply the square footage of the building times the number of CMU per square foot (1.125 CMU/SF).

448 square feet x 1.125 CMU per square feet = 504 CMU

Duplicating factor (half blocks)

If you were planning a modular building, you would use the square foot method for quicker estimating, but now there is another step you need to know—the *duplicating factor*. This means that every course has a half block at each corner. For example, you estimated 504 full blocks (CMU) for this building. To estimate the full block accurately, you would deduct two full blocks per course (*2 x 12 = 24 full blocks*) or multiply 12 courses x .5 (half block) x four corners. Then deduct the 24 full blocks from the total full blocks as shown in the following formula:

12 courses x .5 x 4 corners = 24 full blocks

504 full blocks – 24 full blocks = 480 full blocks

NOTE: Multiply the number of full blocks being deducted by 2 to determine the number of half blocks (24 x 2 = 48 half block).

Estimating door and window openings

When you estimate CMUs, usually the window and door openings are designed to be modular and the window and doorframes are of the same design. If the design is not modular, you can expect a lot of cutting time. When you estimate for openings, just calculate the opening area and then subtract the opening area from the overall area of the wall or building to get the net area. Then multiply the number of CMU per square foot by the net area.

Waste factor

Add 10 percent for waste. If you calculated 480 full blocks, another 10 percent (48) for waste equals 528 full blocks. 48 half blocks plus 10 percent (5) equals 53 half blocks.

Brick

The following example shows the *square foot method* of estimating the number of bricks for a 4-inch wall measuring 8 feet high and 14 feet long. In this example, we are using a standard brick with a ½-inch mortar joint. The brick face with its mortar joints measures 2 ¾ inches high by 8 ½ inches long. The correct steps to follow are provided in the following list:

1. Find the surface area by multiplying the height and the length of a brick (include mortar joint). In this case, 2 ¾ inches x 8 ½ inches = 2.75 x 8.50 = 23.38 square inches per brick.
2. Find the number of bricks per square foot of wall. To do this, divide the square inches (144 inches) in a square foot by the square inches per brick (*144 ÷ 23.38 = 6.159 or 6.16*). In this case, the number of bricks is 6.16 brick per square foot of wall for a 4-inch wall.
3. Find the area of the brick wall by multiplying its height by its length. 8 feet x 14 feet = 112 square feet.
4. Multiply the area of the wall by the number of bricks per square foot. In this case, 112 x 6.16 = 689.92 or 690 bricks. Add 10 percent (69) for waste, which equals 759 bricks.

NOTE: If there are windows, doors, and other openings on the wall, you subtract the area of these openings from the overall area of the wall to get the net area. Then in step 4, you multiply the number of bricks per square foot by the net area.

Sheet panel

Use the following formula to estimate various types of sheet panels, such as plywood, gypsum board, fiberboard, and wall paneling. First, you must determine the area to be covered. To find ceiling area, you multiply the room length by its width. To find wall area, multiply the room perimeter by the height and subtract for any large openings (doors, windows, etc.). Combine all areas to find the total number of square footage. Add 5 percent for waste. Then divide by the square footage of the sheet panel used.

As an example, let's use a room that measures 12 feet × 16 feet with an 8-foot ceiling. It has one door that's 3 feet × 7 feet and two windows that measure 2 feet × 4 feet each. Following the steps given above, first determine the square footage of the ceiling, then the walls.

1. Multiply the length by the width (12 × 16) to get a total of 192 square feet for the ceiling.
2. Determine the wall's square footage by adding each wall length (12 + 12 + 16 + 16) for a total of 56 feet.
3. Multiply this by the wall height (*56 x 8*) to arrive at a total of 448 square feet.
4. Next, add the ceiling and wall's square footage together: 192 + 448 = 640 square feet.
5. Subtract the openings' square footage. Calculate the square footage by multiplying the length by the width: for the door opening, 3 feet × 7 feet = 21 feet; plus the window opening 2 × 4 × 2 windows = 16. The total square footage of the openings is 37. Subtract this figure from the total square footage to determine the area (*640 - 37 = 603 square feet*).
6. Add 5 percent for waste: 603 × .05 = 30.15 or 31. Add this to get the total you need: 603 + 31 = 634 total square feet.

To determine how many sheets of 4- by 8-foot gypsum board are required, divide the total square feet by 32 (the square feet in a 4- by 8-feet sheet) (*634 ÷ 32 = 19.81*). Round up to the next whole sheet and you find you need 20 sheets.

Remember, you can use this same basic formula to estimate any wall or ceiling covering material. First, determine the total square footage to be covered. Then, divide by the total square feet of the material you are using. This gets you the number of pieces of material you need. (**NOTE:** When you order gypsum board, keep in mind that many stores normally sell it in two-sheet bundles.)

Gypsum board fasteners and accessories

There are many methods you can use to compute how much material you'll need. This is just a reference to help you. For every 1,000 square feet of gypsum board, you need approximately:

- 1,000 screws for 16-inch on center application.
- 850 screws for 24-inch on center application.
- 5 pounds of nails.
- 135 pounds of ready-mixed joint compound.
- 370 linear feet of joint tape.

Ceiling tile

With the wallboard installed in your 12- × 16-foot room, install a suspended ceiling with 2- × 2-foot ceiling tiles. To estimate the ceiling tile you need, measure the ceiling's length and width. Next, multiply it to find the square footage (12 × 16 = 192). Divide the ceiling's square footage by the square footage of the material you are using, in this case, the tile measures 2 feet × 2 feet = 4 square feet. Then you have 192 divided by 4 = 48. You need 48 tiles to cover the ceiling.

If your room's size is an odd number (13- x 15-foot), increase the dimensions to the next higher dimension divisible by two (2) and divide the total square footage by the square footage of the tile. Thus, a 13 x 15-foot room would round up to 14 x 16 feet.

NOTE: You usually do not need to include waste with the above ceiling tile estimating methods. There will be excess tile where lights and ceiling diffusers are placed.

Floor tile

In the absence of a tile-estimating chart, you use the square foot method to estimate the amount of floor tile needed. The estimator's handbook provides varying waste allowances depending on the square footage to be tiled. The following table shows the waste allowances used:

Area to be tiled (square feet)	Waste Allowance (Percent)
1 to 50	14%
51 to 100	10%
101 to 200	8%
201 to 500	7%
501 to 1000	5%
Over 1000	3%

Going back to the 12- × 16-foot room, estimate how many floor tiles you need to cover the floor. Multiply the floor's length and width to find the square footage (12 × 16 = 192). For 12- × 12-inch tile, the square footage and the tiles you need are the same. For 9- × 9-inch tile you can use two different formulas: multiply the square footage by 1.77 or convert the square footage of the room into square inches and divide by the square inches of the tile. Add the appropriate waste allowance to your figure.

12- x 12-inch tile

To figure the amount of floor tile you need for the same room, figure the square footage of the area to be covered: 12 × 16 = 192 square feet. If you use 12- × 12-inch tile, you need 192 plus 8 percent (15.36 or 16 tiles) for 208 tiles.

9- x 9-inch tile

To estimate the number of 9- × 9-inch tiles you need, multiply 192 × 1.77 = 340 plus 8 percent (27.2 or 28 tiles) for a total of 368 tiles.

The other method is to convert the square footage into square inches. Do this by multiplying 192 with 144 (144 square inches per square foot). The answer is 27,648 square inches. Now, take this number and divide it by the square inches of the tile—in this case 81 (9 x 9 = 81). This equals 341.33 that you round up to 342 tiles. Add 8 percent (342 x 0.08 = 27.36 or 28) to 342. Using this method, you need 370 tiles. You can see that you arrive at different calculations depending upon the method you use.

Wall studs

To estimate the number of wall studs spaced 16 inches on center, multiply all exterior and interior wall lengths by ¾, plus one additional stud for each wall. Then add two more studs for each corner post, partition, and opening. For walls spaced 24 inches on center, use this same method except multiply by ½ instead of ¾. The table below shows the formulas used for different on center spacings.

On Center Spacing	Multiply Wall Length by:	Add
12	1.0	1
16	0.75	1
24	0.50	1
NOTE: Add two more studs for each corner post, partition, and opening.		

Let's estimate how many studs spaced 16 inches on center we need for an exterior wall that is 20 feet in length with two corner posts and one door and one window opening:

20 × ¾ = 15, add one additional stud plus 2 for each corner, plus 2 for each opening equals 24.

Wall plates

We estimate wall plates by measuring a room's total linear feet, then multiplying that measurement by 3 (1 sole plate and 2 top plates), and then adding 10 percent for waste. Let's estimate the plates for a 14- by 14-foot room.

- First determine the linear measurement of the room's perimeter. To do this, add the wall lengths together (14 + 14 + 14 + 14 = 56 linear feet).
- Multiply the linear measurement by three and add 10 percent for waste.
    - *56 × 3 = 168. Add 10 percent (17) for a total of 185 linear feet of plate material.*

Lumber

We usually buy hardwood and softwood lumber in board feet measurements. A board foot is lumber that is 1-inch thick, 12-inches wide, and 12-inches long. In figuring lumber, you must always remember to use the nominal dimension (rough-cut) sizes. There are many formulas for figuring estimates. The one that follows is the most basic:

Thickness in inches × width in inches × length in feet ÷ 12 = board feet

The thickness and width are in inches, but the length is in feet. Let's calculate how many board feet are in one 1- × 6-inch board that is 12 feet long. To do this, we multiply 1 × 6 × 12 and divide by 12 to end up with 6 board feet. For a 2- × 8-inch board 16 feet long, we just multiply 2 × 8 × 16 and divide by 12 to get 21.33 or 21 1/3 board feet.

Let's say you need to verify the total board feet for lumber being delivered to your section by a contractor. Start by figuring the amount of board feet in one board and multiply this by the number of pieces delivered. Example: 100 pieces of 1 inch × 6 inches × 12 inches. Multiply 1 × 6 × 12 and you should get 6 board feet. Multiply 6 board feet × 100 pieces and you should come up with 600 board feet.

As you progress within the structural field, you're going to learn other formulas. It doesn't matter which formula you use to figure board feet as long as it's accurate.

Roofing material

The types of roofing materials we cover are asphalt felts for built-up roofs, single-ply membranes for low-slope roofs and asphalt strip shingles for pitched roofs.

Asphalt felt paper

To estimate material for built-up roofing with parapet walls, measure from the outside walls on all four sides. This provides allowances for the flashing systems on each wall. For roofs without parapet walls, measure from roof edge to roof edge.

In estimating flat roofs, don't deduct for openings less than 100 square feet. When you make deductions, only deduct one-half the opening size when the opening is more than 100 square feet and less than 500 square feet. However, make full deductions when the openings are 500 square feet or more.

Once you have the dimensions, multiply the length by the width to find the square footage. Divide the square footage by 100 to determine how many squares you need.

Saturated felts for built-up roofing come in rolls. Depending on the weight of the felt, the amount of coverage varies. A roll of number 15 felt covers about 4 squares; a roll of number 30 felt covers 2 squares, respectively. We also refer to these felts as 15-pound and 30-pound felt because that is their weight per square (a square is equal to 100 square feet area). Generally, we use 30-pound felt as the base ply and 15-pound felt for the additional ply layers (on built up roofs).

To estimate the pitch and asphalt materials you require, follow the manufacturer's specifications. Usually, they indicate how much material you need for a given area—and, of course, the quantities vary according to the number of plies.

Single-ply membranes

This is a lot less complicated than built-up roofs. These roofs, as the name implies, are made up of a single ply of roofing membrane. Let's assume that you have a roof that is 50 feet wide by 100 feet long. Let's assume that you order a single-ply membrane that is 4 feet 4 inches wide and 100 feet long and specifications require 3-inch side laps. You can use the following formula:

Roof width divided by roll width (minus lap) = number of rolls

50 feet divided by 4.08 feet (4' 4" – 3" lap = 4.08) = 12.25 rolls

You can't just order 12.25 rolls, so you'll have to round up to 13. Experiment with different widths to reduce the amount of left over material. You can see in the above example that you would have ¾ roll left over.

NOTE: Order the largest width possible to minimize the number of laps needed.

Asphalt shingles

Estimating strip shingles has become a little more complicated with the advent of new heavyweight shingles. In the past, you could simply calculate how many squares were needed based on a simple formula. All lightweight shingles used to come 27 strip shingles in a bundle and 3 bundles equaled a square. That being the case, if you needed 15 squares, you would multiply 15 x 3.

Below is a simple formula to use that works no matter the size shingle. **NOTE:** Hip roofs require more waste be added than gable roofs. As a rule of thumb, add 10 percent waste for gable roofs and 15 percent waste for hip roofs.

$$\frac{\textit{100 SF}}{\textit{Shingle length (inches) x exposure (inches)}} \textit{ x 144 square inches = \# of shingles per square}$$

For example, using a 40-inch wide shingle with a 7 ½-inch exposure, let's calculate how many shingles are needed for a 1,675 square foot gable roof.

100 SF divided by (40 x 7.5 = 300) = .333

.333 x 144 = 47.95 or 48 shingles per square

1,675 divided by 100 = 16.75 squares

16.75 x 48 = 804 shingles plus 10 percent (804 x .10 = 80.4 or 81) = 885 shingles

This is an accurate formula to use; however, most specifications that come with the shingles state the approximate shingles per square and how many bundles equal a square. You just need to figure out how many squares you are covering.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

215. Using estimating formulas

1. How much ready mix concrete must you order for a 15-foot by 55-foot slab that is 4 inches thick (rounded to ¼ cubic yard)?

2. Estimate how many courses, blocks per course and total blocks you need for a 9-foot 4-inch by 64-foot wall (do not include duplicating factor or waste).

3. Using the square foot method, how many CMU (full and half) do you need for a building that measures 12 feet by 16 feet and is 10 feet high?

4. Estimate the number of bricks you need for a 7-foot by 12-foot wall using a ½-inch mortar joint and 2 ½-inch by 8-inch brick.

5. Estimate the number of 4-foot by 12-foot gypsum board sheets you need for a 12-foot by 20-foot room with an 8-foot ceiling. The room has one 6-foot by 7-foot double door.

6. Estimate the number of 2-foot by 2-foot ceiling tiles you need for a 15-foot by 19-foot room.

7. Estimate the number of 12- by 12-inch floor tile you need to cover a floor measuring 16 by 28 feet.

8. How many studs do you need to frame a building that is 22 feet by 48 feet on 16-inch centers with one door opening?

9. How many linear feet of wall plates do you need for the building in question 8?

10. How many board feet are in 150 boards with each board being 16 feet long by 2 inches by 4 inches?

11. How many rolls of single-ply membrane do you need for a roof that measures 24 feet by 50 feet when specifications call for 3-inch side laps using membrane that is 5 feet 4 inches wide and 50 feet long?

12. How many shingles do you need to cover a 1,435 square foot hip roof using 38-inch wide shingles with a 6 ½-inch exposure?

Answers to Self-Test Questions

208

1. The average time necessary for a qualified worker, working at a normal pace, under capable supervision and experiencing normal delays, to perform a defined amount of work, of a specified quality, while following acceptable trade methods.
2. They are divided into different handbooks by craft.
3. They are at the top of each page in the chapter.
4. It shows all of the task time standards contained in the chapter.
5. EPS task time that is applicable to all crafts.
6. They are factored into the estimate to allow the workers sufficient time for job preparation, hazardous work, craft allowances, travel, and partial day influence associated with the particular type of work being performed.

209

1. It is used for any work (contract or in-house) that may disrupt aircraft or vehicular traffic flow, base utility services, fire and intrusion alarm protection systems, or routine installation activities.
2. Just prior to starting the work. If you encounter any delays or the project (job) conditions change, you must ensure you reprocess the work clearance.
3. The requester.
4. The operations flight chief or the engineering flight chief or their designated authority.

5. Anytime you are welding equipment or have open flames away from your shop approved welding area.
6. To identify special precautions that must be taken when using welding/cutting equipment in an attempt to prevent mishaps.

210

1. To show a portion of something such as an inch or foot.
2. The top number is the numerator and the bottom number is the denominator.
3. A fraction with numerator larger than the denominator.
4. a. Improper fraction.
   b. Mixed number.
   c. Proper fraction.
5. a. $^{3}/_{4}$.
   b. $^{1}/_{2}$.
   c. $^{7}/_{16}$.
   d. $^{1}/_{4}$.
6. a. 6 $^{3}/_{4}$.
   b. 15 1/8.
   c. 1 $^{1}/_{64}$.
   d. Cannot be converted.
7. a. $^{7}/_{2}$.
   b. $^{201}/_{32}$.
   c. $^{47}/_{8}$.
   d. $^{5}/4$.
   e. $^{73}/_{16}$.
8. a. 21 $^{2}/_{16}$, 7 $^{10}/_{16}$, 18 $^{12}/_{16}$, 11 $^{4}/_{16}$, 15 $^{14}/_{16}$, 4 $^{10}/_{16}$.
   b. 1 $^{3}/_{32}$, 1 $^{4}/_{32}$, 6 $^{14}/_{32}$, 14 $^{8}/_{32}$, 3 $^{20}/_{32}$.
9. a. 76 $^{52}/_{16}$ = 79 $^{1}/_{4}$.
   b. 25 $^{49}/_{32}$ =26 $^{17}/_{32}$.
10. a. $^{77}/_{96}$.
    b. 15 $^{55}/_{64}$.
    c. $^{15}/_{32}$.
11. a. 2 $^{1}/_{2}$.
    b. 2.
    c. 5 $^{2}/_{13}$.
    d. 4 $^{25}/_{26}$.

211

1. Tenths, hundredths, thousandths, ten-thousandths, etc.
2. Decimal point.
3. 46.48575.
4. a. 83.824.
   b. 0.0114.
   c. 9.66.

212

1. Meter, liter, and gram.
2. Ten.
3. a. 53 inches = 1346.2 mm.

b. 6 inches = 152.4 mm.

c. 9 inches = 228.6 mm.

d. 21 inches = 533.4 mm.

e. 68 inches = 1727.2 mm.

4. a. 6 $^{7}/_{8}$ inches = 174.6245 mm.

   b. 29 $^{47}/_{64}$ inches = 755.2527 mm.

   c. 86 $^{11}/_{32}$ inches = 2193.1310 mm.

213

1. a. 27 inches = 2 feet 3 inches.

   b. 97 inches = 8 feet 1 inch.

   c. 151 inches = 12 feet 7 inches.

2. a. 5 feet = 60 inches.

   b. 7 feet = 84 inches.

   c. 11 feet = 132 inches.

3. a. 12 feet =4 yards.

   b. 18 feet = 6 yards.

   c. 27 feet = 9 yards.

4. a. 153 inches = 12 feet 9 inches.

   b. 27.53 feet = 27 feet 6 ⅜ inches.

   c. 33.75 yards = 101 feet 3 inches.

5. a. .5 inch = ½ inch.

   b. .75 inch = ¾ inch.

   c. .94 inch = $^{15}/_{16}$ inch.

6. a. .33 feet = 4 inches.

   b. .5 feet = 6 inches.

   c. .67 feet = 8 inches.

214

1. An equation.
2. An equal (=) sign.
3. An equation that expresses a certain fact, law, or relation by means of symbols or letters.
4. The branch of geometry that deals with the measurement of lines, angles, surfaces, and solids.
5. Length, width, and thickness.
6. Vertex.
7. Right, obtuse, and acute.
8. Triangle.
9. A circle.
10. $C = \pi d$.
11. $A = \pi r^2$.

215

1. Multiply 15 x 55 x 0.333 = 274.725 cubic feet. Divide 274.725 by 27 = 10.175 cubic yards. Multiply 10.175 by .10 for waste (1.0175 or 1.02). Add 10.175 and 1.02 = 11.195 or 11.2 cubic yards. Round up to the nearest quarter = 11.25 cubic yards.
2. Multiply 9 feet 4 inches by 3/2 rule (9.33 x 1.5 = 13.995 or 14 courses). Next, multiply 64 feet by ¾ rule (64 x .75 = 48 blocks per course). Now multiply the blocks per course by the number of courses (48 x 14 = 672 full blocks).

3. 12 x 10 = 120 square feet x 2 (sides) = 240 square feet. 16 x 10 = 160 square feet x 2 (sides) = 320 square feet. 160 + 320 = 560 total square feet. 560 ÷ .889 = 629.92 or 630 full blocks. Duplicating factor: 15 courses x .5 x 4 = 30 full blocks (60 half blocks). Deduct 30 full blocks from 630 (630 – 30 = 600 full blocks. Add waste: 600 + 60 = 600 full blocks; 60 + 6 = 66 half blocks.
4. Find the brick surface area (including mortar joint): 3 x 8.5 = 25.5 square inches per brick. Find number of bricks per square foot of wall: 144 ÷ 25.5 = 5.647 or 5.65. Find the area of the brick wall: 7 x 12 = 84 square feet. Multiply wall area by the number of bricks per square foot of wall: 84 x 5.65 = 474.6 or 475 bricks. Add 10 percent for waste: 475 + 48 = 523 total bricks.
5. Determine ceiling area: 12 x 20 = 240 square feet. Determine wall area: 12 + 12 + 20 + 20 = 64 x 8 = 512 square feet. Add ceiling and wall area: 512 + 240 = 752 square feet. Subtract door opening area: 752 – 42 = 710. Add 5 percent for waste: 710 + 36 = 746 total square feet. Divide total square feet by gypsum board square feet: 746 ÷ 48 = 15.541 or 16 sheets.
6. Round room dimensions up and multiply to find area: 16 x 20 = 320 square feet. Divide ceiling square feet by tile square feet: 320 ÷ 4 = 80 tiles.
7. Determine room area: 16 x 28 = 448 square feet. Since tile size is 1 square foot, the number of tiles and the number of square feet are the same. Add 7 percent for waste: 448 + 32 = 480 12-inch tiles.
8. Multiply 22 × ¾ = 16.50 + 1 = 18 studs; multiply by 2 (walls) = 36. Multiply 48 × ¾ = 36 + 1 = 37 × 2 (walls) = 74. Add 2 for each corner = 8 studs. Add 2 for each opening = 2 studs. Total number of studs is 120.
9. Determine linear feet: 22 + 22 + 48 + 48 = 140 linear feet. Multiply linear feet by 3: 140 x 3 = 420. Add 10 percent for waste: 420 + 42 = 462 linear feet of plate material.
10. Multiply 16 × 2 × 4 = 128 divide by 12 = 10.67 board feet in one board. Multiply 150 × 10.67 = 1600 board feet.
11. 24 feet ÷ 5.08 (5’ 4” – 3” lap) = 4.72 or 5 rolls.
12. 100 square feet ÷ (38 x 6.5 = 247) = 0.40; multiply 0.40 by 144 = 57.6 or 58 shingles per square. Multiply shingles per square (58) by number of squares (1,435 ÷ 100 = 14.35 squares) to get 832.3 or 833 shingles. Add 15 percent for hip roof waste allowance: 833 + 125 = 958 total shingles.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

23. (208) How are engineered performance standards handbooks broken down?
a. Single unit sections that identify the crafts.
b. Single unit sections that identify the craft tasks.
c. Numerous chapters that represent the different crafts.
d. Numerous chapters that represent the different divisions of craft tasks.

24. (208) Which area in the engineered performance standards (EPS) *must* you reference to obtain a detailed description of the specific amount of work contained in the task time standard?
a. General data factors.
b. Task Time Standards – Listing.
c. Task Time Standards Development Backup.
d. EPS Task Time Standards – Descriptions and Unit Hours.

25. (208) Which area in the engineered performance standards (EPS) *mus*t you reference to acquire a step-by-step list of the task time standards by reference number?
a. General data factors.
b. Task Time Standards – Listing.
c. Task Time Standards Development Backup.
d. EPS Task Time Standards – Descriptions and Unit Hours.

26. (209) In which situation *must* you process an AF Form 103, Base Civil Engineering Work Clearance Request?
a. Digging a 6-inch-deep hole.
b. Performing recurring maintenance work.
c. Replacing overhead tiles in a bath room.
d. Performing emergency maintenance in a basement.

27. (209) Which of the following individuals may use Block 18 on the AF Form 103, Base Civil Engineering Work Clearance, to describe *specific* precautionary measures to take before or during work accomplishment request?
a. Requester.
b. Clearance reviewer.
c. Readiness supervisor.
d. Operations management personnel.

28. (209) Which situation requires you to have an AF Form 592, USAF Welding, Cutting, and Brazing Permit?
a. Welding objects that are hanging overhead.
b. Cutting metal objects that are hanging overhead.
c. Cutting ferrous metals or welding away from your shop’s approved welding area.

d. Welding equipment or welding away from your shop's approved welding area with open flames.

29. (210) When you add the following fractions together how many inches do they total? (3 ⅞, 28 ¼, 4 ½ and 1 ⅜)
a. 36 ⅜.
b. 37.
c. 37 ⅜.
d. 38.

30. (210) How many inches are left after you subtract 36 ⅝ inches from 71 ¼ inches?
a. 34 ⅜.
b. 34 ⅝.
c. 35 ⅜.
d. 35 ⅝.

31. (210) How many total inches are there when you multiply 4 ½ by 22 ¾ inches?
a. 88 ¾.
b. 90 ½.
c. 102 ⅜.
d. 114 ¼.

32. (210) When you divide 104 ¾ inches by 4 ¼, what is the divided size?
a. 22 $^{9}/_{11}$ inches.
b. 23 $^{9}/_{11}$ inches.
c. 24 $^{11}/_{17}$ inches.
d. 25 $^{11}/_{17}$ inches.

33. (211) Which number is the decimal equivalent of ⅝?
a. .58.
b. .85.
c. .625.
d. .875.

34. (211) When adding numbers containing decimals, you *must* always keep the decimal points aligned
a. vertically.
b. horizontally.
c. from smallest to greatest.
d. from greatest to smallest.

35. (211) When multiplying decimal numbers, how do you determine the decimal location in the product?
a. Add the decimal places in the multiplier and multiplicand.
b. Multiply the decimal places by the multiplier and the multiplicand.
c. Divide the number of decimal places in the multiplier from the multiplicand.
d. Subtract the number of decimal places in the multiplier from the multiplicand.

36. (212) Which metric system term is a unit of weight measurement?
a. Gram.
b. Liter.
c. Meter.
d. Pound.

37. (212) Which unit of measure is equal to ten meters?
a. Millimeter.
b. Decameter.
c. Hectometer.
d. Kilometer.

38. (213) How many feet and inches are in 112 inches?
a. 9 feet 3 inches.
b. 9 feet 4 inches.
c. 10 feet 2 inches.
d. 10 feet 3 inches.

39. (213) How many total inches are in 15 feet 7 inches?
a. 151.
b. 157.
c. 180.
d. 187.

40. (213) Identify the fraction of an inch equivalent of 0.67 inches (to the nearest $^{1}/_{16}$ inch)?
a. $^{5}/_{8}$.
b. $^{11}/_{16}$.
c. $^{3}/_{4}$.
d. $^{13}/_{16}$.

41. (213) How many inches are there in 9.875 feet?
a. 108 ⅞.
b. 113 ¼.
c. 118 ½.
d. 123 ¾.

42. (214) If you add ten to one side of an equation, what *must* you do to balance the other side of the equation?
a. Divide it by ten.
b. Multiply it by ten.
c. Add ten to it.
d. Subtract ten from it.

43. (214) Two lines that intersect to form a 90° angle are said to be
a. acute.
b. obtuse.
c. parallel.
d. perpendicular.

44. (214) The sum of the included angles of a triangle is always
a. 45°.
b. 90°.
c. 135°.
d. 180°.

45. (214) The formula for finding the circumference of a circle is
a. $C = \pi c$.
b. $C = \pi d$.
c. $C = \pi c^2$.
d. $C = \pi d^2$.

46. (215) How many *blocks* per course are there in a 92-foot-long wall?
a. 69.
b. 92.
c. 115.
d. 138.

47. (215) How many 4-foot by 10-foot *sheets* of gypsum board do you need to cover the walls and ceiling of a room that measures 10 by 16 feet with an 8-foot ceiling; with one door that measures 3 by 7 feet?
a. 14.
b. 15.
c. 16.
d. 17.

48. (215) How many 2- by 2-foot ceiling *tiles* do you order for a room that measures 23 feet 3 inches by 31 feet 9 inches?
a. 178.
b. 183.
c. 192.
d. 203.

49. (215) Estimate how many *studs* you need to frame a 12- by 16-foot building (16 inches on center) with one door opening.
a. 42.
b. 45.
c. 53.
d. 56.

50. (215) How many *board feet* are in 125 boards that measure 2 by 4 inches by 16 feet?
a. 766.67.
b. 1,333.33.
c. 12,000.
d. 16,000.

Please read the unit menu for unit 4 and continue ➔

Student Notes

Unit 4. Tools, Equipment and Safety

AS A STRUCTURAL JOURNEYMAN, you'll use many types of tools and equipment. All Air Force structural shops share the same standards. This means that you could be stationed stateside or overseas and still use similar tools and equipment to safely perform any assigned task. A key point to remember as a structural journeyman is the hand tools and equipment that you are issued are Air Force property and can only be used for authorized work.

There are a wide variety of tools and equipment available to complete our duties due to that fact, this unit only discusses the most common types of tools and equipment that are used for carpentry and metalworking, while also providing the general procedures for their uses. This unit is not intended to replace manufacturer's specifications or your work center's policy. Refer to Technical Order 32–1–101, *Use and Care of Hand Tools and Measuring Tools,* Air Force Occupational Safety and Health Standard 91–501, *Air Force Consolidated Occupational Safety Standard*, and the manufacturer's instructions for more information.

4–1. Hand Tools

Your skill in using the best hand tool for the job determines how your finished project looks. In addition, you must maintain your hand tools properly. By doing so, you can produce top quality work and your tools will last longer. Part of maintaining them is preventing damage by always using them for their intended purpose and storing them in a toolbox, chest, or bag. Always clean and lightly oil tools that have sharp cutting edges, such as saws, chisels, or drill bits, after each use to prevent rust. Another good source of matenance and use guidance is the manufacturer's instructions. The first hand tools we'll discuss are measuring and layout tools.

216. Using measuring and layout tools

Many tasks involve cutting materials to a particular size and shape. Measuring tools make accurate measurements, and layout tools make accurate line patterns. By using them properly, you reduce waste and save time. We don't discuss every tool imaginable. If we did, you would spend countless hours reading. Thus, we just touch on the ones that have value added. Before we discuss the tools themselves, let's take a look at how to read graduated scales.

Graduated scales

You'll find that the measuring devices used for most structural work are graduated in two different measuring systems. One is the English system; it uses inches and feet. The other is the metric system; it uses centimeters and meters, and is based on increments of ten. The most popular system used in the United States is the English system, while most overseas countries use the metric system. It is very important for you to understand these systems. For example, you will frequently measure distances or thickness in fractional parts of an inch (e.g., eighths, sixteenths, thirty-seconds, and sixty-fourths) or you may need to know how many millimeters or centimeters an item is.

Reading scales graduated in fractions and inches

In figure 4–1, you can see the fractional marks that make up a scale. As you study the scale, also called a rule, shown in the upper part of this figure, notice that one side is graduated in eighths of an inch and the other side in sixteenths. The rule illustrated in the lower part is graduated in thirty-seconds and sixty-fourths of an inch. You must learn to read figures like these correctly because correct measurement is essential for jobs involving layout, fabrication, repair, and installation of metal articles and components. As a brief review of your ability to read graduated scales, use the upper rule in figure 4–1 to locate the marks representing 1 inch and 1 $^{7}/_{8}$ inches. In the lower rule, locate the marks representing $^{17}/_{32}$ inch and $^{35}/_{64}$ inch.

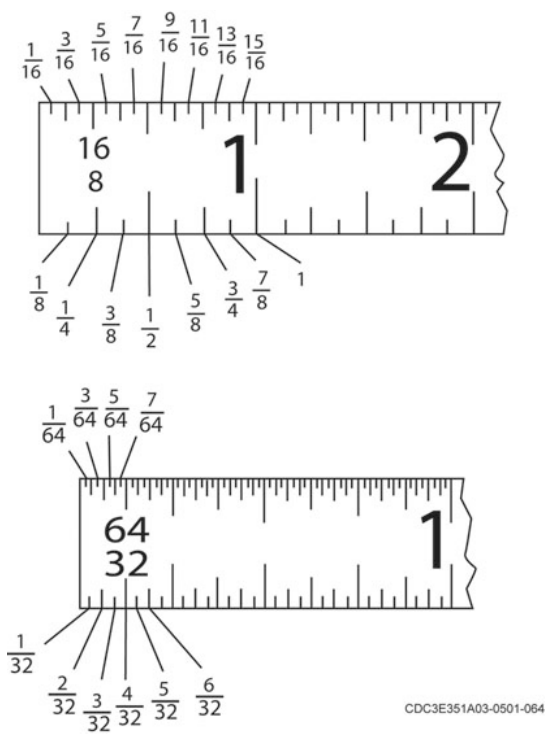


Figure 4–1. Graduated scales.

To further improve your skill in reading graduated scales, refer to the 6-inch rule illustrated in figure 4–2 and verify each of the following:

1. Position 9 is 6 inches.
2. Position 7 is 4 inches.
3. Position e is 3 ⅛ inches.
4. Position c is 1 $^{13}/_{16}$ inches.
5. Position 5 is 2 ⅝ inches.

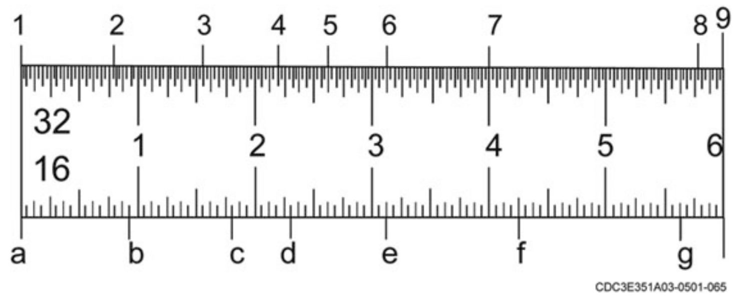


Figure 4–2. 6-inch rule.

Reading scales graduated in decimal inches and meters

Now that you've achieved the ability to read fractions of an inch, let's go to the next step, which is comparing the inch (e.g., sixty-fourths, thirty-seconds, sixteenths, fourths, and halves) with the inch in tenths and the meter shown in figure 4–3. If you check closely, you'll find most framing squares have one scale in tenths. Some steel rules (inch based) are graduated in 10ths, 20ths, 50ths, and 100ths. You'll need to practice reading these scales quickly and accurately to simplify the notation of measurement.

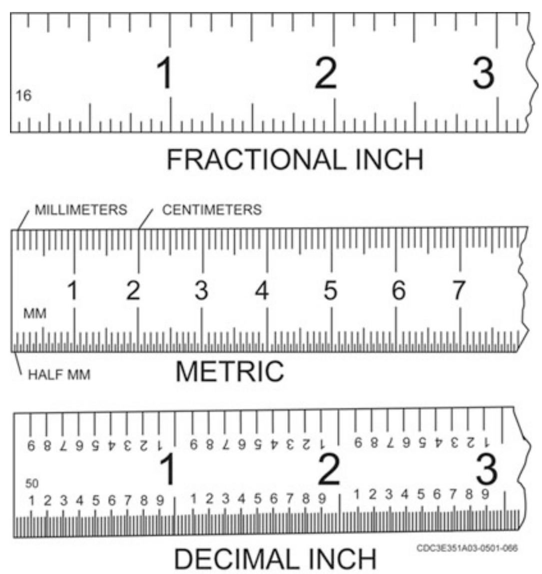


Figure 4–3. Metrics comparison.

Reading combination measuring tapes

You must also use care in correctly reading measuring tapes that are graduated in feet and inches. For example, the measurement of a panel to be cut may be 2 feet wide and 7 feet 3 ½ inches long. (**NOTE:** Measurements are abbreviated to simplify notation, as shown below.)

Abbreviations of:
2 feet wide and 7 feet 3 ½ inches
2 ft by 7 ft 3 ½ in
2' x 7' 3 ½"

Rules

The term “rule” is accepted as a general term and is used to describe a great number of measuring devices. More specifically, a rule is a strip of wood, metal, or other suitable material made in standard lengths. You’ll find them marked along one or more edges into specified parts, divisions, or units of measure. We commonly use the English system of linear measure, which uses inches and feet as units of length. You can divide the inch into smaller parts by means of either common or decimal fractional divisions. You find the fractional divisions for an inch by dividing the inch into equal parts. The more common divisions are halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. We also express fractions of an inch in decimals, for example, ⅛” = 0.125”, ¼” = 0.250”, ½” = 0.500”, etc.

Steel rules

Steel rules are available in common lengths of 6, 12, and 15 inches and may be rigid or flexible. They may also have information on the backside, such as a decimal equivalent scale. To measure with a steel rule, use it as shown in figure 4–4. You’ll be using several layout and measuring devices that incorporate a rigid steel rule (e.g., combination set, framing square, and circumference rule). We discuss these later in this section.

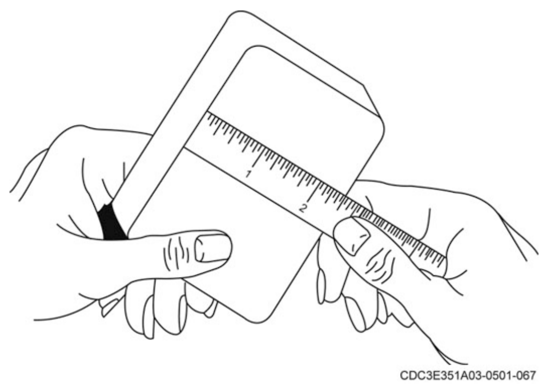


Figure 4–4. Using a 6-inch rule.

Folding rule

A typical folding rule is shown in figure 4–5 with the following five characteristics:

1. Unfolds to 6 feet.
2. Graduated in sixteenths of an inch.
3. Made of wood.
4. Has brass tips called striking plates.
5. Has positive locking brass joints.

These rules are often used during masonry construction to establish the heights of the corner leads.

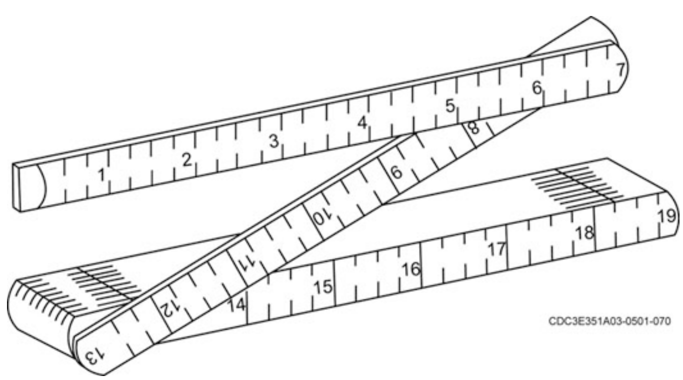


Figure 4–5. Folding rule.

Circumference rule

The circumference rule shown in figure 4–6 provides a "shortcut" method for computing the circumference of a circle. This rule is available in 36 and 48-inch lengths. The upper edge is graduated in inches in the same manner as a regular steel rule. The lower edge gives you the approximate circumference of any circle within the range of the rule. The circumference scale is equivalent to the diameter multiplied by π (3.14159 or the rounded off versions, 3.1416 or 3.14.) It all depends on how accurate the circumference measurement needs to be. Notice in figure 4–6 the reading on the lower edge directly below the 3-inch mark. It is a little less than 9 ½ inches, which is the approximate circumference of a circle with a 3-inch diameter.

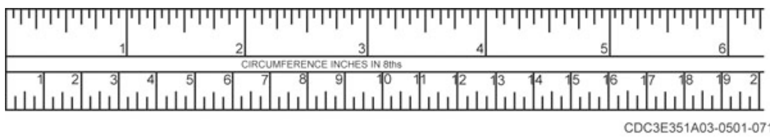


Figure 4–6. Circumference rule.

Steel tapes

Steel measuring tapes are available in lengths from 6 to over 100 feet and from 1 to over 50 meters. We make two kinds of measurements with steel tapes—inside measurements and outside measurements. You'll find some steel tapes designed to make both inside and outside measurements.

The steel measuring tape shown in figure 4–7 is graduated in eighths of an inch and is wound into the case by the hinged handcrank. These tapes are useful to measure items such as long ducts, gutters, and gravel guards. When using one of these longer tapes, be sure to examine the hook or ring on the end of the tape for the actual beginning point. Since measuring tapes are available with a variety of ends (e.g., hooks, rings, or a combination of both), it is possible to make a measurement error of approximately $^{1}/_{16}$ inch. The inch and foot graduations are printed on the tape from the outside of the ring. When measuring from a point that is not at the end of the tape (e.g., with the ring hooked on a nail), you must compensate for the thickness of the ring.

Power return steel tape

The steel tape you use most frequently is the pocket-sized power-return tape (pocket tape) shown in figures 4–8 and 4–9. The tape case contains an internal spring that returns the tape when you complete a measurement. This flexible tape has a slight curvature that causes it to stiffen when extended. Power-return steel tapes are available in popular lengths ranging from 6 to 30 feet and from 1 to 10 meters.

The common English graduations are in sixteenths and thirty-seconds of an inch. The common metric graduations are millimeters and centimeters. Each tape has a self-adjusting hook that automatically compensates for its thickness, so you don't have to figure in a correction when making measurements. The case is designed for making inside measurements. When making inside measurements, simply add the measurement shown on the side of the tape case to the visible readout. The visible readout is the end of the tape to the index point at the case. In figure 4–8 for example, the visible measurement of the box shows 2 ½ inches, which added to the 2 inches for the tape case would be a total inside measurement of 4 ½ inches. An example of an outside measurement is illustrated in figure 4–9. Notice that the self-adjusting hook extends, and the readout measurement is the inches or feet at the exact edge of the surface.

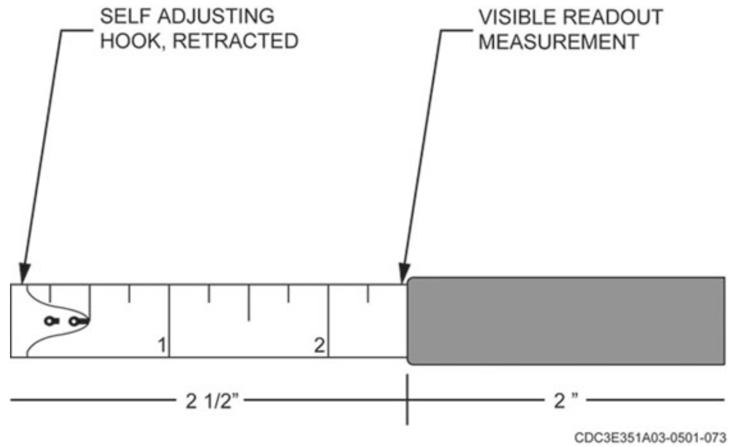


Figure 4–8. Making inside measurements with a power-return steel tape.

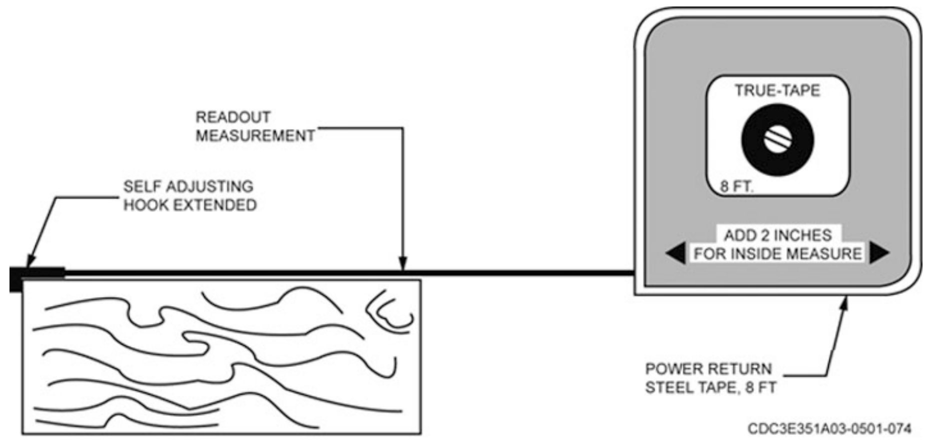


Figure 4–9. Making outside measurements with a power-return steel tape.

Combination set

The combination set (fig. 4–10) is used for several measuring and line layout operations. It consists of a rigid steel rule, called the blade, and three separate head attachments: square and miter head, center head, and turret protractor head.

The illustration shows all three head attachments installed on the blade, but it is not used this way. You use the blade with only one head attached at a time.

The blade has a central groove to permit the heads to slide to any desired setting. Each head has a locknut that you hand tighten to lock the head to the blade. The central groove is not visible in figure 4–10 because it is located on the reverse side of the blade shown. However, in figure 4–11, you can see the central groove in each view of the blade. The steel blade usually is graduated in eighths, sixteenths, thirty-seconds, and sixty-fourths of an inch and you can pull it out of the attachments to use as a measuring rule.

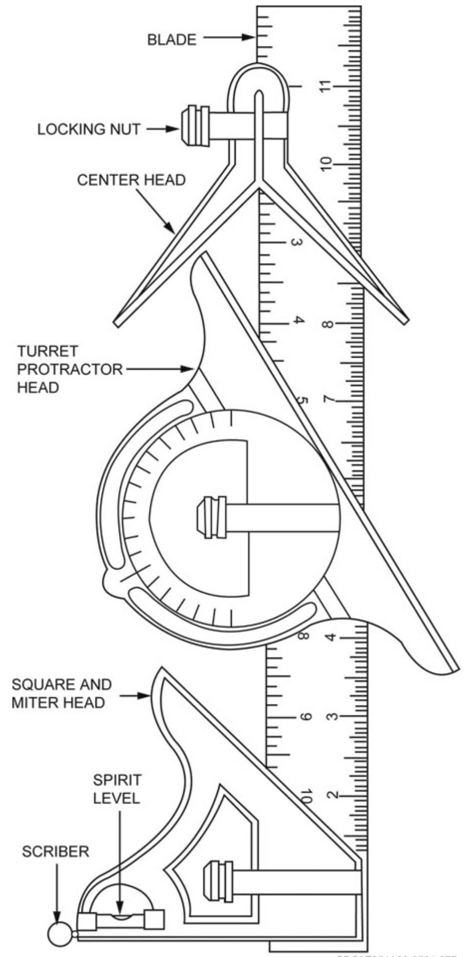


Figure 4–10. Combination set.

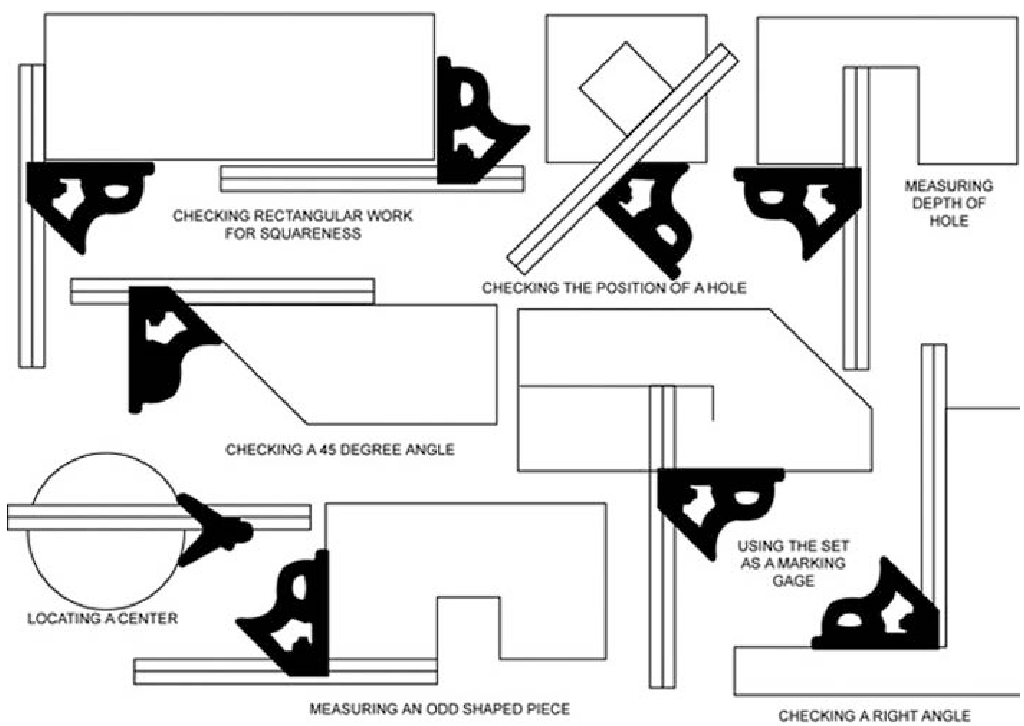


Figure 4–11. Using a combination set.

Square and miter head

When the square and miter head is installed on a blade, we call it a combination square because the head has 90° and 45° angles. Figure 4–11 shows several uses. In each of these, the square and miter head has been moved to the desired position on the blade and locked at that position with the locking nut. Another convenient feature is the spirit level. Since it is often necessary to square one piece with another and, at the same time, tell whether one or the other is level or plumb, you can use the square and miter head as a simple level. As a further convenience, you can find a small scribe contained in the square and miter head that you could easily remove to use for marking (scribing) lines on metal.

Center head

You can use the center head, shown in figures 4–11 and 4–12, to scribe a line through the center of a circular object or to measure the diameter. Notice how one edge of the blade bisects the angle of the center head. To locate the center of a circular object, you need to scribe two lines where the blades intersect the object being measured. The center is the place where the two scribe lines intersect.

Figure 4–12. Using a center head.

NOTE: Hold the head of a combination set snugly against the object while marking.

Turret protractor head

The turret protractor head refer back to (fig. 4–10) is graduated in degrees so that you can use it to determine the number of degrees in an unknown angle. Another use is to draw angles of known degrees, or to transfer and lay out identical angles. In the terminology of sheet metal work, we use the words *angle* and *bevel* often interchangeably. For example, a long section of gravel guard of a flat roof has a V-shaped groove for a stiffener. The turret protractor can be used to duplicate bevels such as the V-shaped grooves of gravel guards. When making the groove angles on a cornice brake, you may hear them referred to as angles or bevels.

Framing square

The steel framing square is also known as a rafter square and a carpenter's square. It has many specialized uses and is available with various graduations. You can see the parts of the framing square in figure 4–13 and identify its parts in the following table.

Part	Description
Body	Usually 24 inches long and 2 inches wide.
Tongue	Usually 16 inches long and 1 ½ inches wide.
Heel	90 degree angle where the body meets the tongue.

One side of the square we call the face and the other side we call the back, both being divided in inches. The face has the manufacturer's name stamped on it and is graduated in eighths on the inside and sixteenths on the outside. The back is graduated in twelfths on the outside and one inside edge is graduated in tenths on one side and sixteenths on the other side.

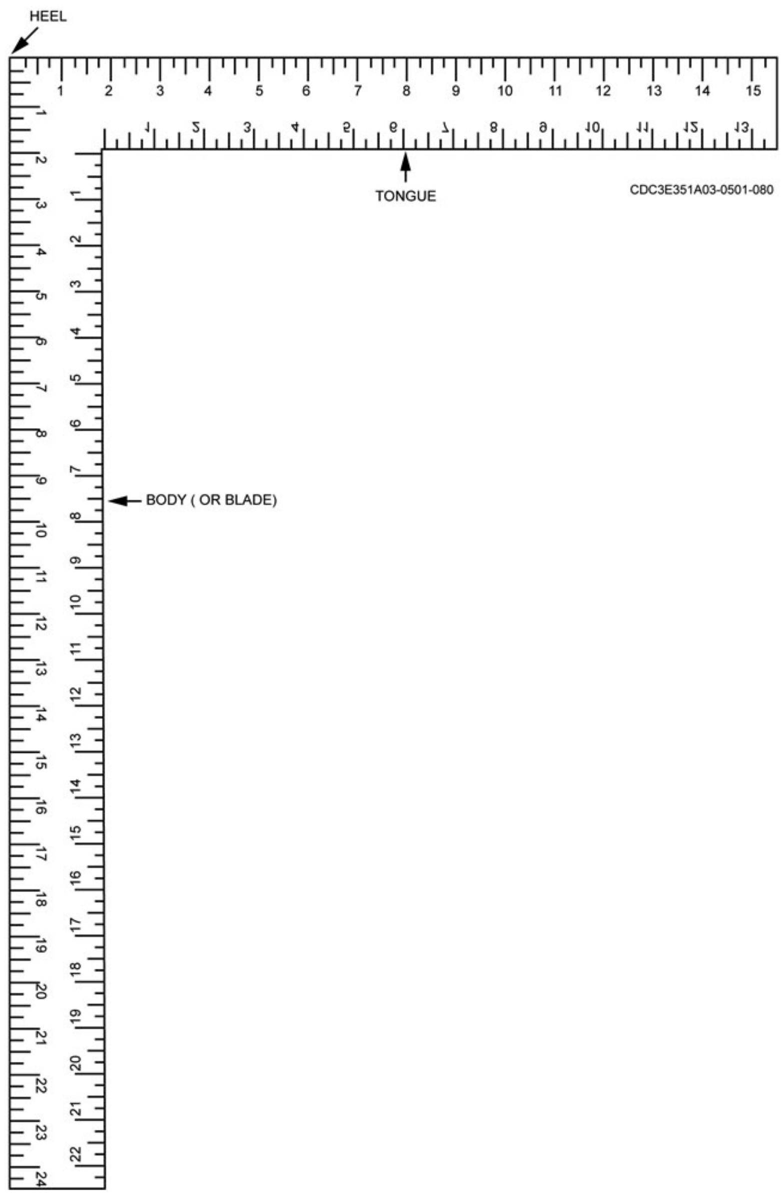


Figure 4–13. Framing square.

Tables

There are a lot of different tables stamped on both sides. Most structures personnel hardly ever use them, except for the *rafter* table. You can find it on the face; use it to find the length of several types of rafters. The *octagon scale* is also on the face (tongue); use it to lay out eight-sided timbers from square ones (i.e., 8" x 8").

You can find the *Essex board* foot table on the back. Use it to calculate the board feet of lumber. The *brace* table, used to find the length of diagonal braces, is also on the back, along with the hundredths scale. Use the hundredths scale to find 1/100ths of an inch. You can use it to convert fractions to decimals and vice-versa.

Use

Craftsmen of all kinds have used the framing square for centuries. Squares are so common there are entire books written on their different usages. You'll primarily use squares for laying out angles for roof rafters, stair framing members, and to layout 45 degree and 90 degree angles on lumber. Another use of the square is for finding the opposite point on the circumference of a circle. This method is useful when locating holes for round duct dampers or placing ears on pails as a couple examples. Using figure 4–14, assume that you want to find a point opposite point A. With the tongue of the square located on point A and the heel placed at any other point on the circumference (**C**), the body crosses the circle at point B, which is directly opposite point A. A second example, illustrated by the dashed lines, shows that you can locate the heel of the square at any convenient point on the circumference of the circle.

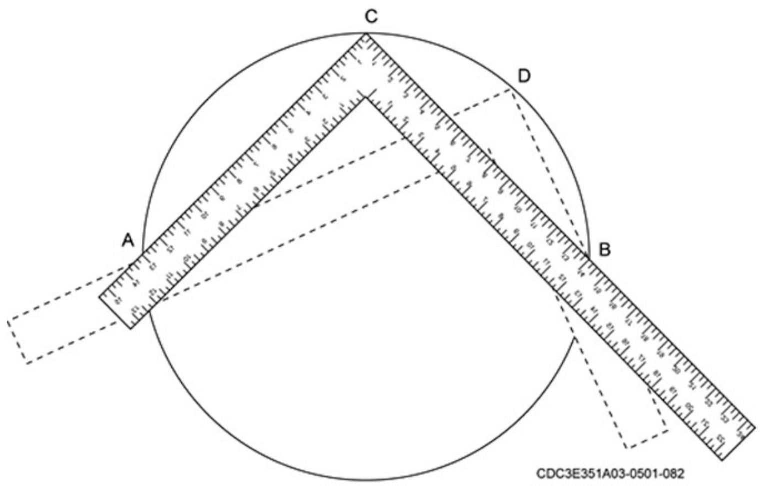


Figure 4–14. Using a framing square to locate the opposite side of a circle.

Pencil compass and dividers

The dividers shown in figure 4–15 are the wing type and the spring type. Each consists of two pointed branches or legs that are joined at the top by a pivot. The two straight legs are tapered to a needlepoint. We use dividers to scribe circles and arcs and transfer measurements from the steel rule to the job.

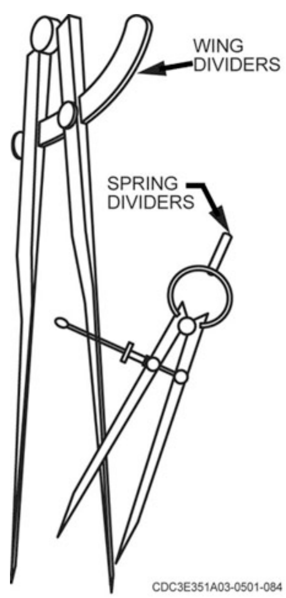


Figure 4–15. Dividers.

Scribing circles and arcs

For you to draw an arc or circle with either dividers or a compass, hold the thumb attachment on top with your thumb and forefinger. With pressure exerted on both legs, swing the movable point in a clockwise direction and draw the desired arc or circle as shown in figure 4–16. You can avoid the tendency to slip by slightly inclining the compass or dividers in the direction you are rotating them. On aluminum or stainless steel, use the divider only to scribe arcs or circles that are to be removed later by cutting. Draw arcs or circles that you are not to remove by cutting with a pencil compass to avoid scratching the material.

Transferring measurements

We suggest the following procedure for using dividers and compasses to transfer measurements from a steel rule. To set either tool, first hold it in one hand and place the point of one leg in a graduation on the rule. Now adjust the other leg until the point rests on the graduation of the desired measurement on the steel rule.

NOTE: If you started from the 1-inch mark, be sure to adjust the end measurement accordingly. This spread represents a measurement that you can transfer to patterns or metal.

T-square and triangles

Figure 4–17 shows triangles and a T-square on a drawing board. Use the edges as a straight edge for marking horizontal lines and as a base line for the triangles. When you hold the T-square firmly, it is easy to use triangles to draw 30 degree, 45 degree, 60 degree, and 90 degree angles from the base line. Triangles usually are made of plastic and are available in various sizes and angles. The 8-to-12 inch sizes are popular to develop and layout most sheet metal patterns.

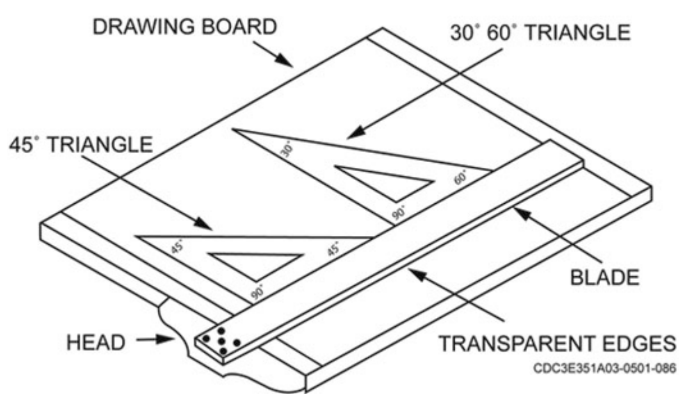


Figure 4–17. T-square and triangles.

Protractor

It is sometimes necessary to measure or draw angles other than the common 30 degree, 45 degree, 6 degree 0 degree, or 90 degree varieties. When this need arises, you can use a protractor (fig. 4–18). The protractor is a semi-circular scale divided into 180 equal parts (i.e., degrees). Its function is similar to that of the turret protractor head of the combination set that you studied earlier in this unit, except that a protractor lies flat and is used on the drawing board or pattern layout table with a T-square. Most protractors have two scales (one above the other) that start at opposite ends. Two scales are the equivalent of a left and a right protractor combined. To measure or draw an angle with a protractor place the index point, which is located on the base line (near the left-hand index finger in the illustration), at the vertex of the angle. For example, if you place the base line of the protractor on a straight line and draw another line from the index point to the 100 degree and 80 degree point, the smaller angle on the right will be 80 degree, and the larger angle on the left will be 100 degree.

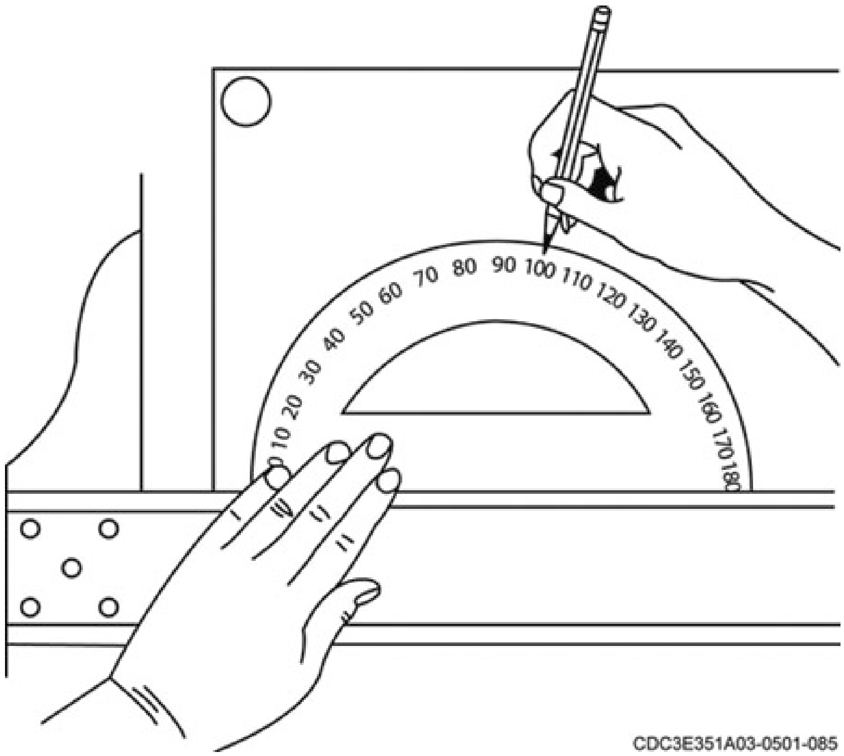


Figure 4–18. Using a protractor and T-square.

Irregular curves

We use irregular curves—plastic devices sometimes called French curves—to draw lines with irregular curvature. In figure 4–19, the irregular curve is being used to connect points on the grid. Notice that the curvature needed to connect the last two points will not be the same as the curvature that connected the other points. To use the irregular curve, move it along the points until you line up at least three points. Draw a line connecting the points, while still continuing the previously drawn portion of the line.

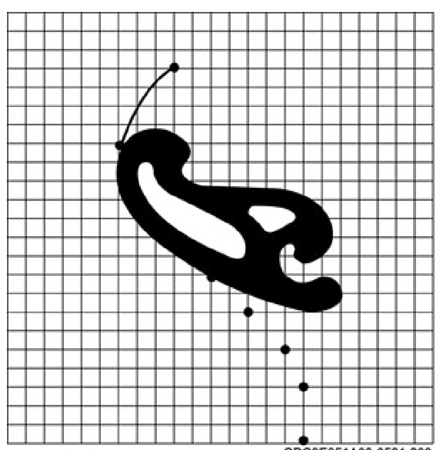


Figure 4–19. Using an irregular or French curve.

Trammel points

Sometimes ordinary dividers are not large enough for a particular application. In this case, you use a set of trammel points (fig. 4–20). We use trammel points (also called beam compasses) to form patterns for large circles and arcs or to transfer dimensions from one location to another.

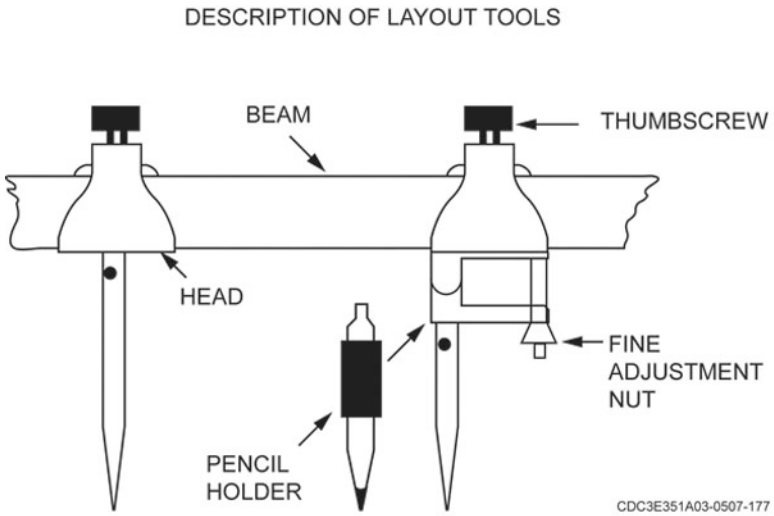


Figure 4–20. Trammel points.

217. Using wood-boring braces, bits, and twist drills

A wood-boring brace is a tool that uses interchangeable bits for different purposes. Boring refers to cutting larger holes in wood, whereas we often refer to drilling as making holes in metal or smaller holes in wood. We identify the bits by the job they do. In this lesson, we discuss the brace and the bits that you may use with it and with other power drills.

Brace

We use a brace (fig. 4–21), which we also call a *ratchet-brace* or *bit brace*, to turn auger bits, expansive (expansion) bits, countersink bits, and screwdriver bits. Sizes range from 8–12 inches; however, we use a ratchet-brace with a 10-inch sweep for most work. Sweep refers to the circle diameter made when you make a complete turn of the brace handle. You do not have to make a complete circle with the ratchet-brace because a ratcheting system is built into it. You can more easily work in corners or near joining walls with the ratchet brace.

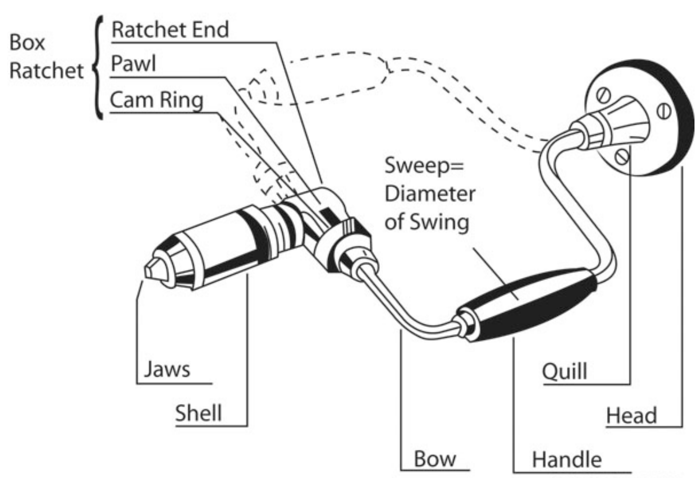


Figure 4–21. Ratchet-brace.

Wood-boring bits

Each wood-boring bit used in the ratchet-brace has a tapered, straight-sided end piece called a tang. The tang stops the bit from slipping in the ratchet-brace because of knots, hard pieces of wood, or a dull-cutting bit. Other wood-boring bits are available for regular power drills.

Auger bit

You use an auger bit with the ratchet-brace to bore holes in wood. Such bits usually range from ¼ to 1 inch in diameter; larger sizes are available for special purposes. The number on the auger bit's tang (shank) shows the size. Sizes are indicated in $^{1}/_{16}$ inch increments; for example, a ¼-inch auger bit would have the number "4" stamped on the tang and a 1-inch bit would have the number "16." There are three feed-screw-cutting threads available for auger bits: fine, medium, and coarse. How fine or how coarse the feed screw determines the auger bit speed. A fine screw thread cuts slow and is recommended for finish work, such as door lockset installation. A coarse thread cuts fast and is recommended for rough work, such as boltholes.

Expansive bit

We use an adjustable expansive bit to make different sized holes over 1 inch in diameter. They are usually purchased with two interchangeable and adjustable cutter heads. One cutter we use to bore holes from $^{7}/_{8}$ to 1½ inches in diameter, and the other cutter we use for holes 1½ to 3 inches in diameter.

Brad-point bits

These bits vary by manufacturer, but they all feature a sharp point in the center and two wing-like spurs that are machined out of the drill's spiral flutes.

Spade bits

These bits leave a rougher hole than most other bits, but they are the least expensive. These bits have flat steel heads with two short spurs and a long triangular center point. This design actually creates more of a scraping action, rather than a cutting one and also leaves the wood fibers torn, rather than cut.

Forstner bit

This bit is the most precise. They have a center point for locating the bit; however, rather than having one or two cutting spurs that score the surface, these bits have two large cutting rims. With these bits, you can cut overlapping holes or partial arcs at the edge of a board and also drill at steep angles as examples.

Twist drill bits

Twist drill bits are made to cut their way through a variety of material to include plastic, wood, metal, or composite material. Most twist drills are made from high-speed steel, although their composition ranges from carbon steel to high-speed alloy steel with special coatings. The carbon steel type is good for light duty work while the high-speed steel type is a better choice for sheet metal work. It withstands heat better and stays sharper longer than carbon steel type. The drill bits with special coatings are the best. They withstand heat and stay sharp longer than the non-coated type. Some of the coatings include titanium, cobalt, gold ferrous oxide, zirconium nitride, and titanium-nitride.

If you're drilling holes in hard or thick metal, apply a few drops of cutting oil in the hole to lubricate the bit and prevent excessive heating. If you use cutting oil, high-speed twist drills will keep right on cutting even though they are hot. Excessive heating can also result from using a dull twist drill bit or from too much or too little pressure on the twist drill. If a high-speed twist drill becomes overheated, let it cool slowly; don't try to cool it in water, oil, or fast-moving air because it may crack.

Twist drill bit sizes are expressed in millimeters, decimals, fractions, numbers, and letters. The size is stamped on the shank of the bit. For example, a $^{3}/_{16}$-inch bit, which is often used in sheet metal work, has a decimal equivalent size of 0.1875 inch.

Figure 4–22 show's a twist drill bit's nomenclature, including the shank, body, heel, flute, and land.

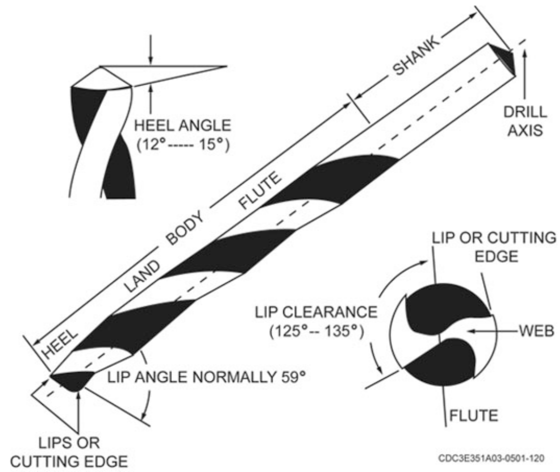


Figure 4–22. Twist drill nomenclature.

Masonry twist drills

There are several types of masonry twist drills for drilling holes in concrete, brick, and other masonry surfaces. A popular type of masonry twist drills is illustrated in figure 4–23. They are designed to fit in the chuck of portable electric or battery pack drills. These masonry twist drills have tungsten-carbide-cutting tips and come in a variety of sizes. The most popular sizes range from ¼ to ¾ inch. An electric or battery powered hammer drill is the best tool to use for drilling into most types of masonry material.

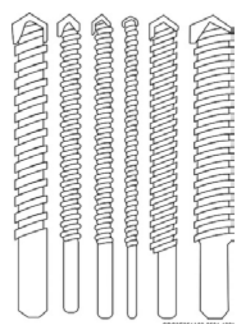


Figure 4–23. Masonry twist drills.

Countersinks

We use countersinks to bevel edges of holes so that rivets, bolts, or screws with countersunk heads can be inserted flush with the surface of the material of which it is driven. Figure 4–24 shows a countersink that can be used with hand or power drills. These countersinks are available in various bevel angles to match the bevel of the fastener to be installed.

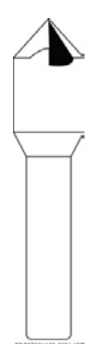


Figure 4–24. Countersink.

Rotary files

Rotary files (fig. 4–25) have ¼-inch-diameter shanks that can be "chucked" in a hand drill, a portable drill, or a drill press. Rotary files with spiral cutting flutes, which are smaller than the spiral flutes or reamers, are used more often to ream or enlarge holes than to remove metal burrs.

Although in most cases you use a twist drill to enlarge a hole in sheet metal, sometimes it's better to use a rotary file instead. Selection of the size and shape of the rotary file depends on the job. For example, you can use the rotary files illustrated in figure 4–25 to ream holes, elongate slots, and file irregularly shaped edges.

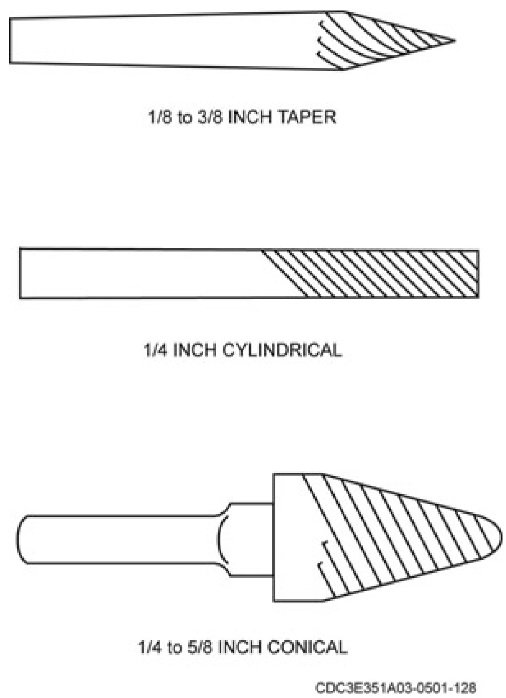


Figure 4–25. Rotary files.

218. Using cutting tools

As a structural journeyman, you use many kinds of cutting tools. You have to know which kinds work best for the different materials that you have to cut. In this lesson, we discuss handsaws, planes, chisels, rasps, files, and snips.

Handsaws

Wood handsaws come in two general classes—one for cutting parallel to wood grain (ripping) and one for cutting at right angles to wood grain (crosscutting).

Ripsaw

A ripsaw cuts wood with the grain. It has teeth shaped like tiny chisels for fast cutting on the downward stroke. It usually has 4½ or 5½ teeth per inch of blade length. The teeth are filed at right angles to the blade from both sides. Do *not* use a ripsaw to cut across the wood grain.

Crosscut saw

A crosscut saw cuts wood across the wood grain. It has teeth shaped like knives to give a smooth cut on the downward stroke. The common amount of teeth for most jobs is 7 to 11 teeth points per inch of blade length. The more teeth per inch, the finer is the cut produced. The crosscut teeth are filed with both sides of the teeth at an angle.

Shark tooth saw

A shark tooth saw cuts on the upward and downward stroke. It looks similar to other handsaws, but its teeth are shaped different. It is available in different teeth per inch sizes for crosscutting or ripping.

General information

The teeth points per inch determine cut coarseness (less teeth means a coarser cut). Lightly coat the blade with oil to prevent rust and help it glide through wood during cutting. The saw teeth must have the proper *set* (every other tooth bent slightly in opposite directions) to prevent it from binding in the wood. This is to produce a cut or *kerf* that is slightly wider than the saw blade thickness.

Use

Where finish is important, cut lumber with the face side up, otherwise the face if turned down will be splintered as the saw passes down along the cut. This is not important for rough work. The following arerecommended ways to use a wood saw:

- Place the lumber on a sawhorse and mark the cut location.
- You can use your thumb as a guide and press the blade against your thumb when starting the cut (keep your thumb above the teeth to prevent cutting yourself). Start the saw cut on the waste side of the line by making a few upward or pulling strokes.
- Then, make several short, downward strokes until the kerf is deep enough to prevent the saw from slipping out. You can now move your hand out of the way.
- Use the full saw length as the cutting progresses. The cutting is usually fast enough if you use a slight amount of pressure on the saw.

A crosscut saw works best when you hold it at a 45 degree angle. The ripsaw cuts best when you hold it at a 60 degree angle (fig. 4–26).

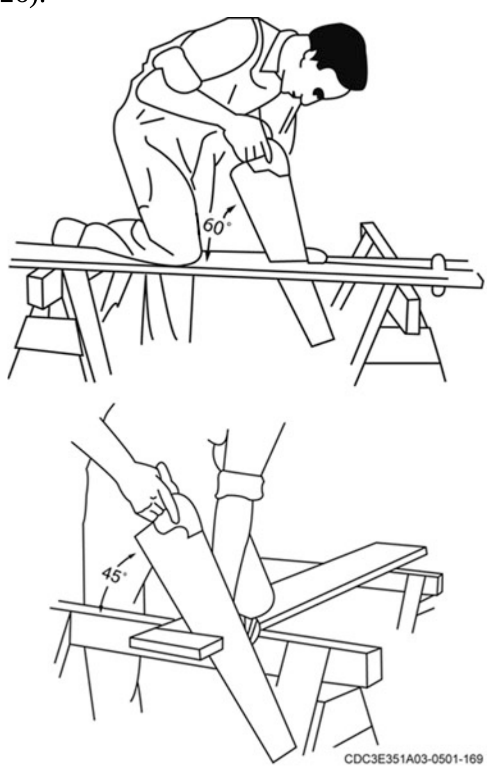


Figure 4–26. Saw angles.

Keyhole/compass saw

The keyhole and compass saws look very much alike. The main difference is that the compass saw blade is wider. They usually have a handle that allows for a quick blade change. They were originally designed to cut keyholes and circular shapes. Today, we use them to make irregular shaped cuts where working space is limited and for cutting openings in drywall for electrical outlets.

Coping saw

The coping saw is made up of a C-shaped metal frame that holds a narrow (usually ⅛-inch-wide) blade. The blade is fitted to the frame by loosening the handle and attaching the blade to a pin on the front of the saw frame and the saw handle. Tightening the handle applies tension and holds the blade in place. Place the blade on the frame with the teeth pointing away from the handle. The coping saw is designed for cutting very sharp inside or outside curves, usually on thin wood stock. To cut inside curves, drill a hole through the stock to insert the blade through and then attach the blade to the frame.

We often use the coping saw for making corner joints (coping joint) for molding in a building that doesn't have square walls. The finished joint looks like a mitered corner, but one piece of the molding is "coped" to fit over the other piece.

Hacksaw

The hacksaw in figure 4–27 consists of a frame, handle, and blade. The length and number of teeth per inch, or pitch, identify the type blade. Blade length varies from 6 to 16 inches, but the 10-inch size is most common.

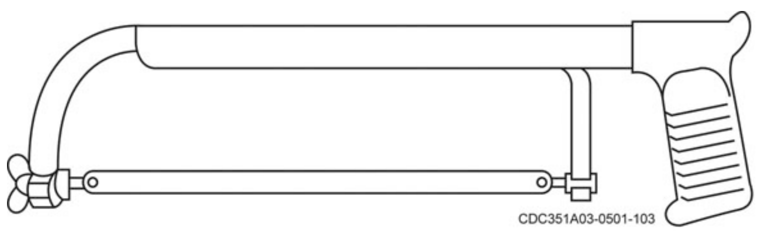


Figure 4–27. Hacksaw.

Blades with 14, 18, 24, and 32 teeth per inch are available. Blades are made of high-grade tool steel that may be flexible or all hard. The flexible blades have only hardened teeth, whereas all-hard blades have hardened teeth and blades.

Blade selection involves finding the right type for the job at hand (fig. 4–28). An all-hard blade is best suited for sawing brass, tool steel, cast iron, and heavy cross sections of material. Flexible blades are recommended for sawing hollow shapes and material with thin cross sections.

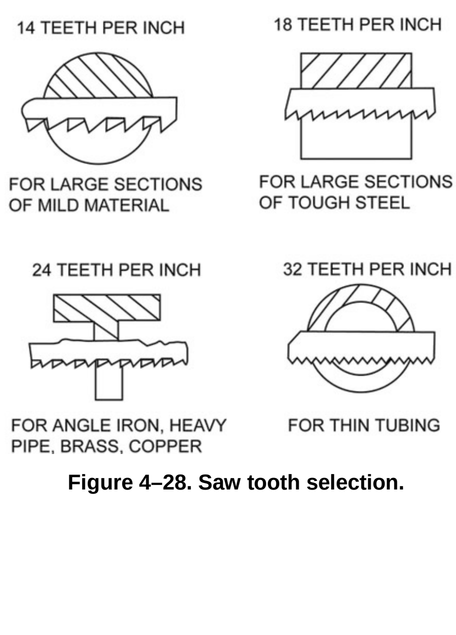


Figure 4–28. Saw tooth selection.

A blade with 14 teeth per inch is recommended for cutting cold-roll and structural steel. The 18-teeth-per-inch blade is recommended for solid stock aluminum and cast iron. The 24-teeth-per-inch is recommended for cutting thick wall tubing, pipe, channel iron, and angle iron, as well as brass and copper. The blade you use most often is the 32 teeth per inch; we recommend it for thin-wall tubing and light gauge sheet metal.

Always remember to install the blade in the frame with the angle of its teeth forward, or away from the handle. When you saw, hold the saw at an angle that lets at least two teeth contact the cutting surface at all times. Use long strokes and apply just enough pressure on the forward stroke to make each tooth cut. Forty or 50 strokes per minute is recommended. If you cut too fast, the blade generates excess heat that can draw the temper out of the blade, as well as dull the teeth quickly.

Hand planes

Hand planes shave off a small amount of wood from the wood's surface. We often use planes for maintenance work. There are planes available to fit doors or sliding window "sash" units, to reduce interior trim size, and to square end grain.

Bench planes

Bench planes are available in several different sizes. Longer planes are better used to true a surface whereas small planes are used for final smoothing or initial roughing out. Bench planes are named according to their length: jointer, fore, jack, and smooth, with jointer being the longest. The jackplane is perhaps the most commonly used bench plane. We use the jackplane for all-purpose projects.

Plane adjustment

The typical bench plane features are shown in figure 4–29. Placing one hand on the rear handle and the other hand on the front knob gives you an even cut (shave). The front knob also guides the plane direction. The main body includes the bottom, sides, and a frame (sloping part that holds the plane iron). The frame bottom is the sole. We refer to the sole's front end as the toe, to the rear end as the heel, and to the opening where we place the blade as the mouth. The plane's iron cap is screwed to the upper face and forces wood shavings upward and through the plane's mouth. This keeps the mouth from becoming choked or jammed.

To assemble the plane, place the plane iron in the frame with the bevel down. Use the adjustment nut or the lateral adjustment lever to set the plane iron's cutting edge. Turning the adjustment nut moves the plane iron up or down. The lateral adjustment lever leans the plane iron to the right or left. To adjust a plane iron, hold the plane upside down and sight along the sole from the toe end, then work the adjusting nut until the blade edge appears through the mouth. Then, move the lateral adjustment until you align the blade edge with the sole. Continue using the adjusting nut to give you the blade protrusion you want. The blade protrusion depends upon the cut depth that you want to make.

Block plane

These are small planes designed for one hand use. They are usually between 6 and 7 inches long and do not have a plane iron cap like bench planes. The block plane blade is mounted in the frame at a low angle with its beveled edge turned upward. This design and size makes it ideal for smoothing surfaces on small boards and for cross-grained squaring or trimming of wooden end-stock (boards).

Use

Regardless of the type plane, their use is basically the same.

Edge planing

Clamp the board close to the edge in a bench vise. Hold your plane level and at a slight angle to the edge. Begin planing the board until you obtain a continuous shaving along the board's length. Use a straight edge to check the board's edge length for squareness. Once you get a square straight edge on one side, you can use the straight edge to mark a line on other side. Then plane it down to the line.

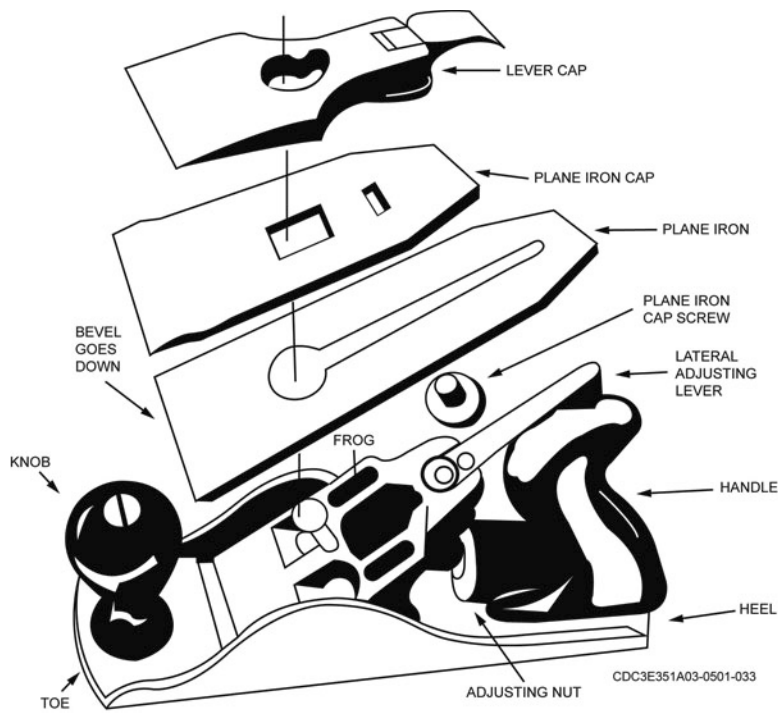


Figure 4–29. Bench plane.

Chisels

There are various types of chisels that you, as a structural journeyman, use. The types we discuss here are wood and cold chisels.

Wood chisels

We use wood chisels primarily to cut mortises in wood and for cutting joint connections. The common way to identify a wood chisel size is by its width. Most are available in widths from ⅛ to 2 inches wide. The most common widths used are ¼, ½, ¾, 1, and 1½ inch.

To use the chisel to cut and remove wood, do the following:

- Grip the chisel handle firmly with one hand and place the chisel in position.
- Grip a soft-faced hammer or mallet with your other hand and strike the chisel handle head.
- Use light hand pressure to remove small amounts of wood.

To make good quality cuts, keep your chisels sharp. To make finish joints, trim, shape, or concave cuts, you can turn the chisel's bevel side up or down. If you cut with the bevel side up, the chisel tends to bite into the wood and is usually harder to control. If you cut with the bevel side down, you usually have more control over the cut. Here are six important safety instructions for you to follow:

1. Always keep both hands behind the cutting line.
2. Always store a chisel so that the sharp edge cannot cut anything.
3. Never carry a chisel in your pocket.
4. Never use a chisel as a screwdriver.
5. Never use a chisel as a pry bar.
6. Never cut towards yourself or another person.

Cold chisels

The most common cold chisel is the flat-blade type (fig. 4–30). You can use this chisel in restricted areas for such jobs as making a slot or starter hole in sheet metal for snips or shears. Other uses for cold chisels include splitting rusted nuts from bolts and cutting wire, strap iron, small bars, and rods. You can use a cold chisel to cut any metal that is softer than itself. The chisel size is identified according to the width of the cutting blade. In sheet metal work, the cold chisels used most include the ¼-inch, ½-inch, and 1-inch sizes. Cold chisels are usually made of octagonal (eight-sided) tool steel bar stock and are carefully hardened and tempered.

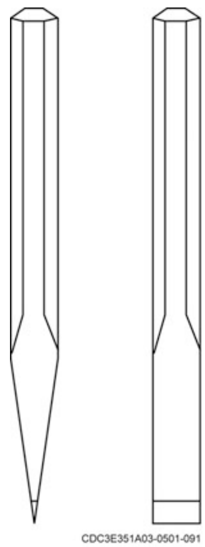


Figure 4–30. Flat cold chisel.

Maintenance

Through normal use, the head of the cold chisel will spread out until it looks like a ragged mushroom. This spread-out head is rough and can "ream out" the inside of your hand if the chisel slips. Also, blows of the hammer may break off pieces from the overhanging mushroom and cause injury. Keep the head of the chisel dressed to eliminate these hazards.

Wood rasps and files

We use wood rasps and files for shaping or smoothing wood surfaces. They look similar except rasps have coarser teeth.

Rasps

Rasps are available in four coarseness levels: rough-cut, bastard-cut, second-cut, and smooth-cut. Wood rasps are usually flat or half-round. The coarse teeth rapidly remove wood, making them ideal for rough work. You can also use files for rough work, but they are better suited for finish work because they have finer teeth that remove less material per stroke but leave a smooth finish.

Files

Files can be classified by their overall shape, teeth cut type, and teeth coarseness. All shops should have a complete set of files like the ones shown in figure 4–31. The following is a list of different file types:

- Flat file—used to file flat surfaces and for other fast-cutting operation.
- Mill file—especially adapted for finish filing.
- Triangular or "three-cornered" file—used in filing internal angles and cleaning out corners.
- Square file—most useful in finishing the bottom of slots.
- Round file or rattail—used for enlarging round holes.
- Half-round file—used where other files won't fit.

The type of teeth cuts found on files includes single cut, double cut, rasp, and curved tooth. The coarseness of the teeth includes rough, course, bastard, second cut, smooth, and dead smooth. Figure 4–32 shows a few examples of the single and double cut files. The double cut file is a good choice for general work where a rough finish is permissible. You can apply heavy pressure on the file to remove material quickly. The single-cut file is recommended for sharpening cutting tools, such as shear and snip blades. Apply light pressure to single-cut files to get a smooth finish.

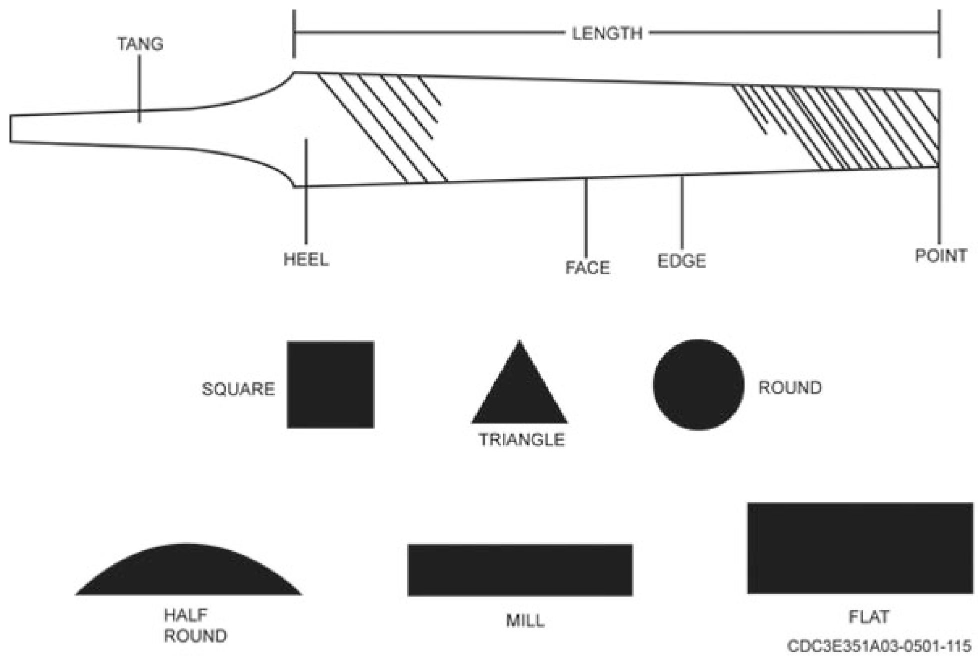


Figure 4–31. File types.

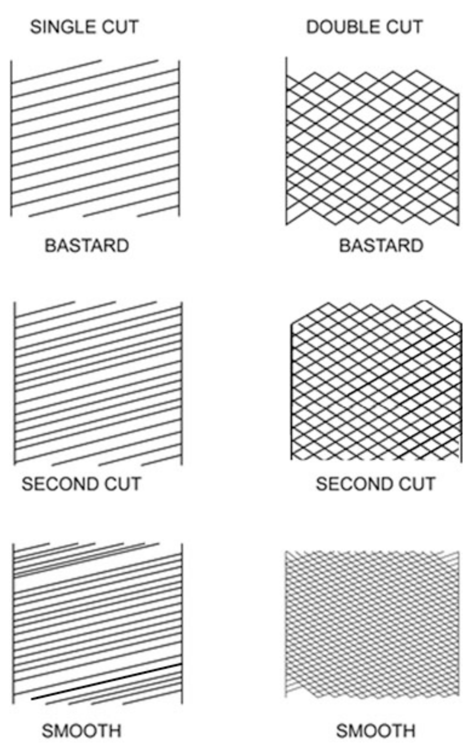


Figure 4–32. Types of file cuts.

Using a file or rasp

To use a file or rasp, we recommend that you secure your work in a clamp or vise at approximately elbow height, if possible. To prevent vibration, place the object to be filed close to the vise jaws or clamp it near the workbench edge. There are two ways to use a file or rasp—straight and draw.

Straight filing

To straight file, place one finger or thumb near the file tip to guide the file. Use your other hand to grip the handle and apply pressure. You begin the filing or rasping by applying pressure with your hands as you push forward. If you are filing hard metal, do not pull back on the file. Apply pressure *only* on the forward filing stroke.

NOTE: Place a file handle on the "tang" or sharp end of the file or rasp before you use it unless the tool is manufactured with rounded ends.

Draw filing

Draw filing is similar to straight filing except you hold the file or rasp at an angle to the surface being filed. Move the file or rasp back and forth over the work length; this produces a finer finish than straight filing. If a file becomes clogged with material, clean it with a file card or wire brush. The file card removes hard-packed chips and metal pieces that clog the teeth.

Maintenance

Files are very useful tools, but their life and usefulness depend a great deal on the way they're used and maintained. Clean them frequently with a file card or brush and keep them separate from other tools to prevent damage to the other tools.

Snips and shears

There are many uses for hand-operated snips and shears. You must use snips when the shape, construction, location, and position of the work do not allow you to use machinery. Snips and shears are designed to cut flat sheets of metal. Cutting wire or rods can damage the cutting blades. Keep snips in good working condition by using them properly, sharpening when necessary, and applying a light coat of oil to prevent rusting and allow moving parts to operate smoothly.

Straight snips

Straight snips (fig. 4–33) have straight jaws that are designed to cut straight lines on thin sheet metal—20 to 30-gauge range. The size of the snips to use is based on the size of the jaws; that ranges from 2 to 4 ½ inches.

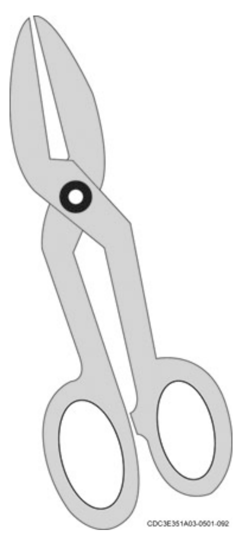


Figure 4–33. Straight snips.

Bulldog snips

Bulldog snips (fig. 4–34) have straight jaws that are sloped to allow them to be used for cutting straight lines, curves, and irregular surfaces. The jaws are available in various sizes and designed to cut 16-gauge sheet metal and mild steel and 18-gauge stainless steel. They are available with right-hand cut for right-handed people and with left-hand cut for left-handed people.

Figure 4–34. Bulldog snips.

Aviation snips

Figure 4–35 shows a pair of aviation snips. There are three types of aviation snips. Each one is designed to cut a certain way. You can tell them apart by their color. The green handles are designed for cutting curves to the right, red handles for cutting curves to the left, and straight cutting snips usually have yellow handles. Both right-handed and left-handed people can use the same set of snips. All three types have hardened cutting blades and compound lever action handles that are designed to cut mild steel as thick as 16-gauge. You'll find these snips useful to cut small holes and irregular outlines in heat-treated aluminum alloy or stainless steel. They can also be used for cutting any shape of hole in ducts or panels at a job site.

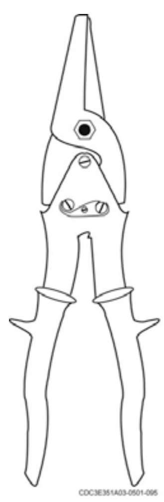


Figure 4–35. Aviation snips.

219. Using hammers, mallets and dollies

We often use hammers, mallets and dollies in the sheet metal shop for such jobs as riveting, raising metal, setting seams, and driving punches and chisels. We also use hammers and mallets for carpentry work to include rough framing, forming, and interior construction. Nonetheless, you will surely use one type of hammer or another during your tour as a structural journeyman.

Maintenance

It's important to select the right hammer or mallet for the job. The maintenance required to keep a hammer in good working condition consists of keeping the heads smooth and making sure the handle is good and is secured to the head properly. As a safety precaution, make sure the wedge in the handle hasn't worked loose. If it has, the head could come off during use. Figure 4–36 shows the parts of a hammer.

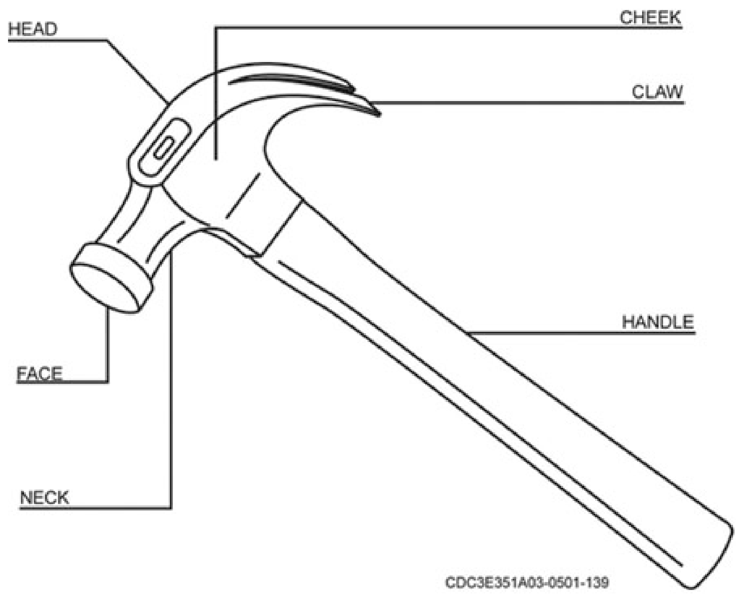


Figure 4–36. Hammer parts.

Hammer types

All hammers must have a handle. The handle can be wood, steel, or fiberglass. All are balanced to give good swinging action and to minimize any transfer of shock to your arm while hammering. Some have a rubber or neoprene handgrip to provide better grip and shock control. A high quality well-balanced hammer can prevent your arm from tiring during long hammering periods.

Straight-claw hammer

We use a straight-claw hammer, also called a framing hammer, for rough work with the 20 and 22-ounce sizes being very popular. (**NOTE**: The hammer weight is based on head weight. The steel quality used in the hammerhead withstands contact with hard surfaces without chipping or marring.) The claw must be sharp enough for pulling nails.

A straight-claw hammer's face may be either serrated or smooth. Because a serrated face can cause damage to the wood when you're nailing, don't use it for finish work. A serrated-faced head is best for rough framing because the head is less likely to slip and bend nails. We can use a smooth faced head for rough framing, but it is better suited for trim and other work where you can see the material to be nailed.

Curved-claw hammer

We use the curved claw hammer mostly for finish work. Its curved claw is designed for pulling nails. Such hammers are available in weights ranging from 7 to 20 ounces. The 13 and 16 ounces hammers are popular for general-purpose carpentry work.

Tack hammer

The tack hammer drives tacks into material such as wood. Most have a magnetic head that holds the tack in place as you apply pressure to start the tack into a material's surface. By starting a tack this way, you keep from smashing your fingers.

Ball peen hammer

The ball peen hammer (fig. 4–37) has a variety of uses around a sheet metal shop. We use it for forming soft metal, peening rivet heads, and striking metal in out-of-the-way places. If you're driving punches, cold chisels, and other similar cutting tools, always use a ball peen hammer of the right size.

Drywall hammer

A drywall hammer is used to install gypsum board. Its face is designed so that, when you strike the finish blow to a nail, it dimples the surface without breaking the paper. You can use the top edge of the head as a gauging device to obtain distance between drywall sheets. You can use a "V" notch cut into the blade portion for pulling nails.

Swinging technique

The above hammers are designed for you to hold the hammer firmly close to the end of the handle. Whenever you swing the hammer, put your entire arm and shoulder in motion. Also rotate your wrist just before the hammer strikes the nail or the object being hit. This provides more speed to the hammerhead and less effort from your arm.

Sledge hammer

Use a sledgehammer for heavy-duty work such as driving tent stakes and doing demolition work (e.g., knocking down wood framed partition walls). They usually weigh between 2 and 20 pounds and have handles that are 15 to 36 inches long. We use small sledgehammers for driving spikes (i.e., extra large nails) or with cold chisels for cutting pieces of metal. (**NOTE:** Sledgehammers are designed for striking wood or metal; don't use them for breaking rock or concrete.)

Tinner's riveting hammer

The tinner's riveting hammer (fig. 4–37) has a square, slightly curved face with beveled edges to keep the head from marking the metal. The peen side is double tapered with a slightly rounded end. You use this hammer often in riveting.

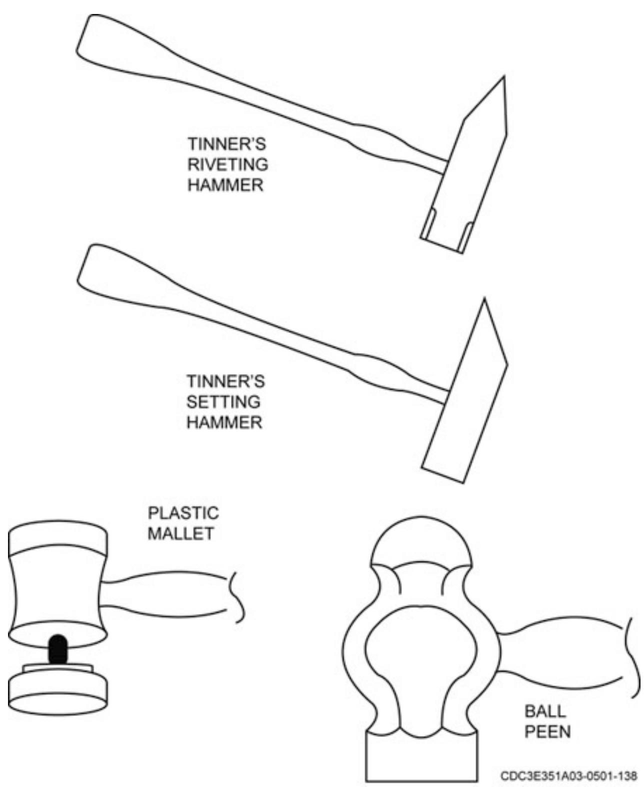


Figure 4–37. Hammer types.

Tinner's setting hammer

The tinner's setting hammer (fig. 4–37) has a square flat face for flattening seams without damaging the metal. We use the single-tapered peen for setting down seams.

Mallets

Mallets strike an object without damaging it. They are available with a head that can be wood, plastic, neoprene, rawhide, or rubber. Mallet heads vary in size, weight, and handle length. Each type makes it ideal for certain tasks. A wooden or rawhide mallet is useful for driving wood chisels. The rubber mallet is ideal for striking nailing machines. A neoprene- or plastic-head mallet (fig. 4–37) is ideal for general shop woodworking. Some mallets have screw-on heads that make head replacement easy.

You need to be aware that hammer faces of hard metal may damage soft metals such as copper, aluminum, and light-gauge sheet metal. For preliminary shaping of these metals, we recommend you use a wooden or plastic mallet to shape them. Then finish up with the proper metal hammer. Typical examples when you would use mallets are in forming grooved seams and wired edges that require a great deal of handwork in fabrication.

Dollies

Hand dollies, commonly called bucking bars in sheet metal shops, may be shop made or purchased commercially. Available in various sizes and shapes, they may be used in forming metal or in riveting where access to the job is difficult or at jobs away from the shop where stakes aren't available.

220. Using punches

There are many types of tools we use to punch holes in sheet metal. In this lesson, we discuss the use of hand and lever-operated punches.

Hand punches

We use many types of hand punches in sheet metal shops, but the ones in figure 4–38 are the ones we use most often. Keep the heads and points in good condition. To begin, use the center punch to make a small depression in metal before drilling or punching, thus keeping the twist drill from "walking" as you drill. Use the prick punch to establish location points in laying out patterns on sheet metal. The starting punch is tapered for strength, has a blunt tip, and is used to loosen tight-fitting pins for removal from a hole.

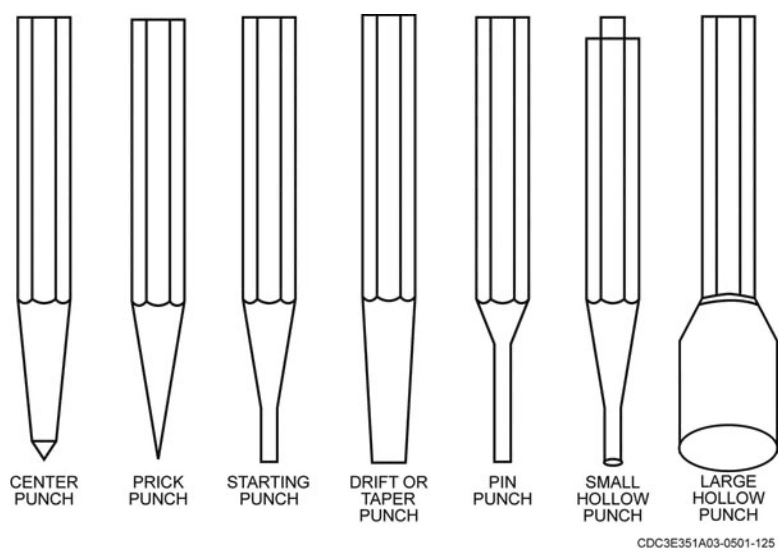


Figure 4–38. Hand punches.

You can also use a drift punch (i.e., taper punch) to loosen tight-fitting pins, although its slender shape is not as strong as the starting punch. We often use it to align holes in two pieces of metal before installing screws, bolts, or rivets. The pin punch has no taper; we use it to drive out rivets that have had the heads drilled off and to drive pins out of holes that are too deep for the starting punch or drift punch. The starting punch, drift punch, and pin punch are blunt-end punches and are sometimes called solid punches. We use hollow punches with suitable backup material to pierce holes in thin metal.

Hand-lever punch

Hand-lever punches use interchangeable dies and hand operated lever action to pierce holes in sheet metal. There are two basic types and they look and function in a similar way. Figure 4–39 shows one type that can use dies from $^{1}/_{16}$ to $^{3}/_{32}$ inch. The other type is similar but it has longer handles and is often referred to as the iron hand-lever punch. The iron hand-lever punch can use dies from $^{3}/_{32}$ to ½ inch. Both punches have short throats; we use them when the hole locations are near the edge of the material. Either punch will pierce holes much faster in light-gauge metal than it is possible to do with twist drills. When you change punches and dies, be sure to match the sizes. Too large a punch for a die damages the cutting edges, and too small a punch pierces the hole but dimples the materials.

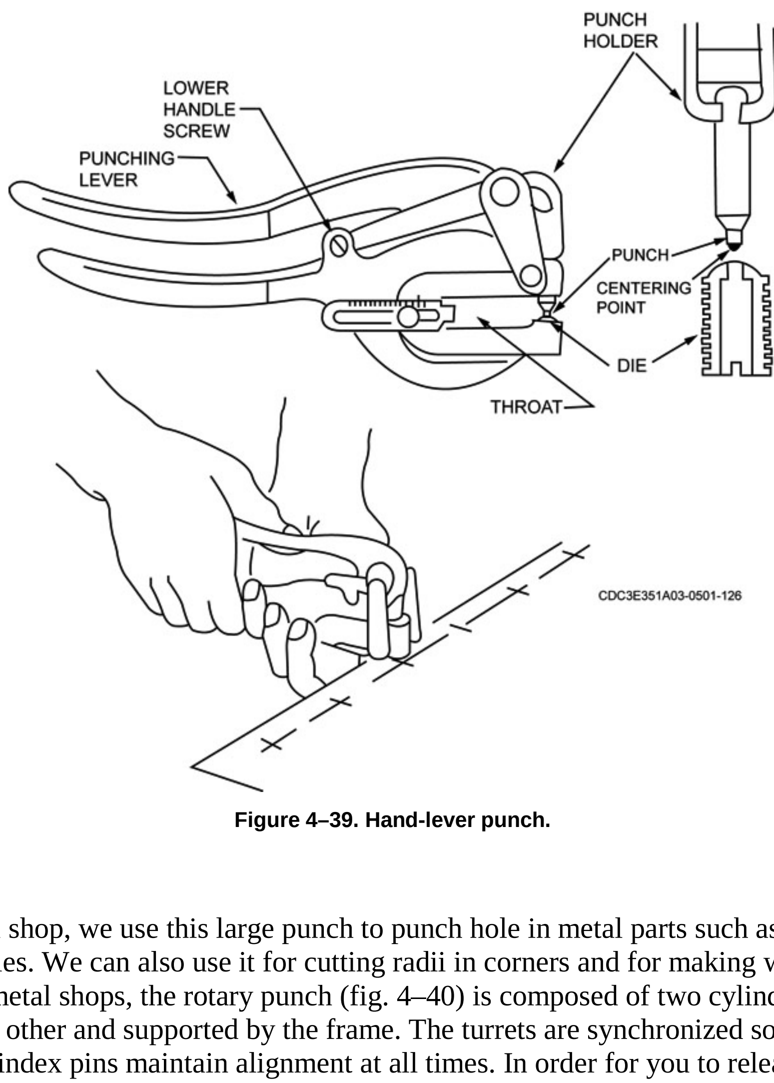


Figure 4–39. Hand-lever punch.

Rotary punch

In the sheet metal shop, we use this large punch to punch hole in metal parts such as baffle plates and tops for drain tables. We can also use it for cutting radii in corners and for making washers. Found in many Air Force metal shops, the rotary punch (fig. 4–40) is composed of two cylindrical turrets, one mounted over the other and supported by the frame. The turrets are synchronized so that they rotate together, and the index pins maintain alignment at all times. In order for you to release the index pins from their locking position, rotate the lever (on the right side of the machine) 180 degree. This withdraws the index pins from the tapered holes and lets you turn the turrets to any size punch you want.

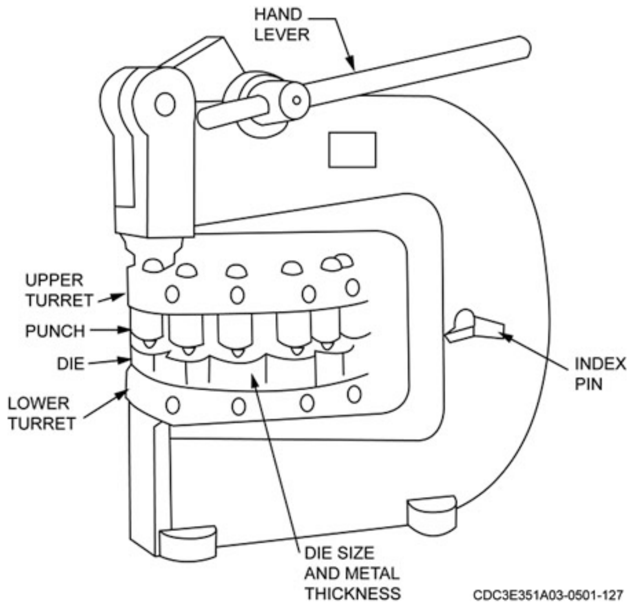


Figure 4–40. Rotary punch.

To operate this rotary punch, place the metal between the die and punch. Then pull the hand lever (on the top right side of the machine) toward you, forcing the punch through the metal. When the lever returns to its original position, the metal will be stripped off the punch. Stamped on the front of each die holder is the diameter of the punch and its maximum capacity for punching mild steel. Each punch has a point that fits in the center punch mark to assure you of the definite location to be pierced.

To align the punch and die accurately, you determine where the adjustment is necessary by punching through several thicknesses of stiff paper. This shows which side of the die has the greater clearance. If the cut is uneven, loosen the lock screws and tap the die in the opposite direction. When the paper is cut evenly all around, tighten the punch securely with the lock screws between the dies.

Preventive maintenance

Preventive maintenance for the rotary punch consists mainly of the following seven actions:

1. Keep it cleaned, lubricated, and adjusted.
2. At intervals specified on the maintenance record folder, inspect the rotary punch to see that the index pin works freely and locks both turrets easily. If necessary, clean and oil the index pin and aligning holes in the turrets.
3. Make sure each punch and die lowers and raises freely when you pull the hand lever forward. Clean and oil any punch that sticks. Remove any sticking punch, clean the punch and its sleeve, and lightly coat them with oil before reassembly.
4. Inspect the hand lever and connecting linkage for cleanliness and freedom of operation; if necessary, clean and oil the moving parts.
5. Inspect each punch for proper alignment with its corresponding die by punching several thicknesses of stiff paper.
6. Wipe off all excess oil, clean all painted surfaces with a dry rag or a rag moistened with soap and water, and wipe all unpainted surfaces with a slightly oiled rag.
7. The final step is to make the appropriate entries in the maintenance record folder.

NOTE: When operating the rotary punch, be sure to keep your fingers away from the punch and die and return the hand lever to the full UP position after each operation.

221. Using vises and clamps

Vises and clamps are the primary tools you use to temporarily support or hold materials on which you are working. Vises are usually bolted to shop workbenches. Clamps are portable and are usually smaller and lighter than vises. Clamps may consist of 1-inch wide, large-diameter rubber bands; wooden handscrew clamps; pipe clamps; or bar clamps. We use clamps for assembling a wooden project; we use vises for holding rough work, such as pipes and angle iron, for cutting or drilling.

Bench vise

A bench vise (fig. 4–41) is a very important piece of equipment in a structural shop, especially for sheet metal fabrication. To keep from marring your material, place wooden blocks between the vice jaws and your material before you tighten up the vice. Bench vises are manufactured in many sizes and designed for different jobs. A vise with a 4 or 5-inch jaw is commonly used in sheet metal shops to hold material for filing, forming, or sawing. The removable jaws are each secured with two screws and are usually grooved to keep the material from slipping. When you work with soft metal, use jaws made of brass or aluminum; these are not so likely to mar the material being held. If jaws of soft metal aren't available, use blocks of wood. (**NOTE:** Always use blocks of wood when using this type of vise to hold wood and keep from damaging it.)

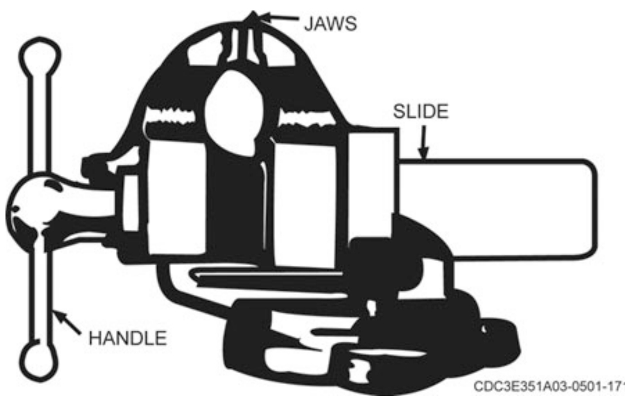


Figure 4–41. Bench vise.

Vises are usually secured to the workbench with screws or bolts; they have swivel bases to allow change of work positions for better access to the job. Avoid over tightening the jaws because the jaws and the slide work on a worm gear; if you tighten the vise excessively, the worm gear gets worn and doesn't work correctly. You can remove the worm gear for cleaning, inspecting, and oiling by turning counterclockwise until you disengage the gear from the vise.

Woodworking vise

A woodworking vise is usually found in Air Force structural shops. Its main purpose is to hold material together during gluing. **NOTE**: Leave the material in the vise until the glue sets.

The vise is usually mounted at any workbench edge with heavy lag screws or bolts. It is mounted with its top edges flush with the workbench. Flush mounting the vise keeps it out of the way in case you need the workbench top for large projects. The inside jaws are lined with wood to protect the work being held in the vise. To tighten or loosen the vise jaws, you crank a handle on the vise.

C-clamp

We use the C-clamp to hold material that is being sawed, glued, or planed. A C-clamp's size is determined by the clamp's opening width; most range from 1 to 8 inches in size. A C-clamp's depth usually ranges from 1 to 4 inches, depending upon the clamp opening size, but some special deep-throated clamps are available and offer various depths.

To keep the C-clamp jaws from marring your project surface, insert some scrap material (i.e., usually wood) between your project and the jaws before final clamping. The scrap material also spreads the clamping pressure over a greater area for better clamping action.

Hand-screw clamp

The hand-screw clamp is a woodworking clamp. It has two hardwood jaws, two screw spindles, and two handles. Its size is determined by the jaw length, which usually ranges from 6 to 14 inches. You can open most hand-screw clamps to hold materials from 3-to-10 inches thick, depending on clamp size.

To use a hand-screw clamp, turn the handles either to the left or right. This action turns the spindles and causes the jaws to move. Keep turning the handles until the jaws match your material's depth and angle. Then, place the clamp into position and tighten it. A handscrew clamp usually does not need scrap material to protect the clamped material from marring because the clamp jaws are already made from wood. An advantage that a screw clamp has over other clamps is that it can be adjusted to various angles and still provide good clamping action for gluing.

Bar/pipe-bar clamp

We often refer to a bar clamp and pipe-bar clamp as a cabinet or furniture clamp. These clamps are constructed in two different ways. A bar clamp has jaws mounted on a flat, steel bar 12-to-48 inches long. The pipe-bar clamp has jaws mounted on ½ or ¾ inch-diameter steel pipes. One pipe-bar clamp end must be threaded to hold the "fixed" jaw assembly; the remaining pipe can be cut to the desired length. To use either clamp, you set your project material against the fixed clamp jaw and then slide the movable jaw against the other side of your project and turn the handle to tighten the clamp.

NOTE: Before you set up the clamp, return the swivel-head assembly to the rear of the fixed-head assembly. This allows you to put more clamping pressure on your project when you tighten the clamps.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

216. Using measuring and layout tools

1. Identify the measurements at b, d, e, and f on the rule in figure 4–2.

2. What is the general term we use to describe a great number of measuring devices?

3. What are the types of rules we use in metal work?

4. What information can we get from the lower edge of a circumference rule?

5. Why must a correction be made on the readout of a steel measuring tape (with a hinged handcrank)?

6. List the four parts of the combination set.

7. Which head attachment of the combination set can you use to determine the number of degrees in an unknown angle?

8. What are the parts of a framing square?

9. How do the measurements on the face and the back of a framing square differ?

10. What are the principal uses of a framing square?

11. Match the layout tools in column B with the identifying phrases in column A. Items in column B may be used only once, more than once, or not at all.

Column A	*Column B*
____ (1) Has two pointed branches joined at the top by a pivot.	a. Trammel points.
____ (2) Used when ordinary dividers are too small.	b. Irregular curves.
____ (3) Used to draw 30°, 45°, 60°, and 90° angles.	c. Templates.
____ (4) Used to measure or draw angles other than 30°, 45°, and 60°.	d. Protractor.
____ (5) Used to connect points not in a straight line.	e. Pencil compass and divider.
	f. Level.
	g. T-square and triangles.

217. Using wood-boring brace, bits and drills

1. What tasks can you do with a brace and the different bits it uses?

2. How is an auger bit’s size indicated?

3. Which bit is the most precise and is used to cut overlapping holes or partial arcs on the edges of boards?

4. What do you do if your high-speed twist drill overheats?

5. Where is the size stamped on most twist drills?

6. What three types of materials can you drill with masonry drill bits?

7. Why do we use countersinks?

8. What tool(s) do we use to hold rotary files?

218. Using cutting tools

1. Match each saw in column B that is described in column A. Items in column B may only be used once, more than once, or not at all.

Column A	*Column B*
____ (1) Cuts on the upward and downward stroke.	a. Shark tooth saw.
____ (2) Cuts across wood grain.	b. Coping saw.
____ (3) Cuts inside and outside curves. Good for cutting joints in molding.	c. Ripsaw.
____ (4) Cuts with the wood grain.	d. Crosscut saw.
	e. Compass saw.

2. What hand plane do we use for all-purpose projects?

3. How do you place the plane iron into the frame?

4. What is the common way to identify a wood chisel's size?

5. What two driving tools can you use to strike the head of chisel handles?

6. What are the four coarseness levels available for a wood rasp?

7. Describe how you "straight file" hard metal.

8. Why do you place work that is to be filed near the jaws in a vise or clamp it to a workbench?

9. What is the difference between straight filing and draw filing?

10. What are snips and shears designed to cut?

219. Using hammers, mallets and dollies

1. What determines hammer size?

2. Why do you *not* use a serrated-faced hammer for finish work?

3. What hammer usually has a magnetic head?

4. What hammer do you use to drive wooden stakes into the ground?

5. What are two examples of when you would use a mallet for the preliminary shaping of soft metals?

220. Using punches

1. What punch(s) do you use to loosen tight-fitting pins?

2. What punch do you use to mark points on sheet metal layouts?

3. What punch do you use to punch a $^{1}/_{16}$-inch hole near the edge of light-gauge sheet metal?

4. When using an iron hand-lever punch, what results if the punch you use is smaller than the die?

5. What type of material do you use in testing rotary punch alignment?

6. Can you adjust the top turret of the rotary punch in figure 4-40 to punch through a die that is too large? Why?

221. Using vises and clamps

1. When using the bench vise to hold soft metal, what should the bench jaws be made of to prevent marring the metal?

2. Why do you mount a woodworking vise under a workbench with the top edges of the jaws flush with the workbench?

3. Why do the jaws of a woodworker's vise have wood mounted on the inside surfaces of the jaws?

4. What are the two reasons for using scrap pieces of material in a C-clamp when you are gluing stock together?

5. What clamp can you use to clamp material together, if the material is cut at an angle?

6. Why do you return the swivel-head assembly on a bar or pipe-bar clamp to the rear of the fixed jaw?

4–2. Portable Power Tools

The use of portable power tools enhances your ability to perform your assigned duties; unfortunately, it also increases the hazards associated with your assigned tasks. In this section, we discuss general safe operating procedures for some of the more common types of tools that you are likely to see at your base. The material presented here is for reference only. Always refer to local operating procedures and the manufacturer's instructions for the tool you are using.

222. Using portable power tools

You can use portable power tools to do many of the same jobs as shop installed equipment. As the name implies, they are portable, meaning you can take them wherever you go. You need a power source, such as electricity (corded) or rechargeable batteries (cordless). If you use an electric cord, make sure that you place it so that it does not get entangled in the power tool or create a tripping hazard.

Cordless tools are used quite frequently today because they are convenient, strong and durable. A rechargeable battery that usually attaches to the tool handle powers them. The batteries vary in voltage anywhere from 4 to 24 volts with stronger ones being developed all the time. Generally speaking, the higher the voltage, the stronger the tool.

As with any tool, you need to know how to use and care for them properly. This lesson covers the basic use for the power tools listed. For specific instructions, always refer to the manufacturer's instructions for the tool you are using.

Circular saw

As a structural journeyman, the circular saw (fig. 4–42) is one of the tools that you use most. You can use it to cut lumber, plywood, and wall paneling with a standard wood blade or use it to cut masonry and metal with specially designed abrasive blades. The blade diameter determines the saw's size, which ranges from 4½ to 16 inches. Normally, the 7¼ or 8¼ -inch size is most common in structural shops. Most circular saws have adjustments that allow you to set the cutting depth and the cutting angle. The maximum cutting depth varies with the blade diameter.

CAUTION: Make sure that you tighten all adjustment knobs before using the saw. When ripping, you can use the rip guide or set up a straight edge jig to get straight cuts. Adjust the blade so that it extends ⅛ – ¼ inch below the material that you intend to cut.

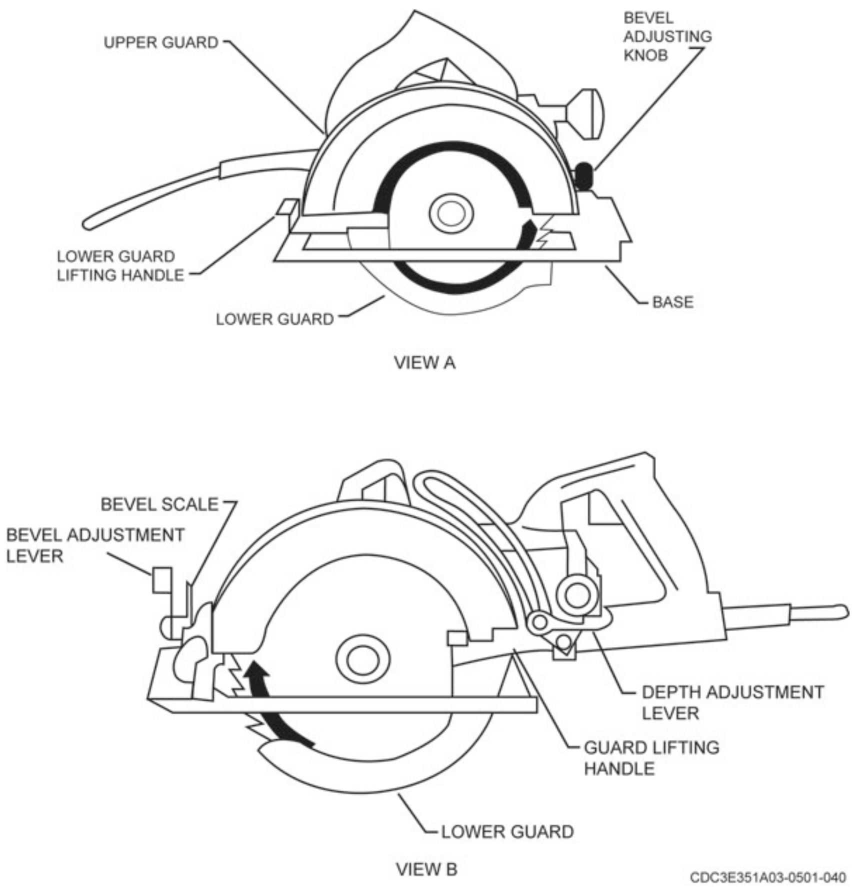


Figure 4–42. Circular saws.

Saw use

To ensure that you produce smooth, clean cuts safely, there are simple seven steps that you must follow:

1. Make sure that material to be cut with a circular saw is supported or fastened so that it will not shift or move during the cutting operation. You also want to make sure that the waste lumber falls clear and does not bind the saw blade.
2. Adjust the blade depth as we previously mentioned (⅛ – ¼ inch).
3. Mark the lumber where you intend to cut.
4. Ensure that you wear all personal protective equipment (PPE) specified by your work center. As a minimum, wear safety glasses and hearing protection.

5. Start the saw by placing the front portion of the saw (base) on the material to be cut and firmly gripping the handle and knob on the front, then press the trigger switch. (**NOTE**: Keep the saw blade a short distance back from the edge of the material when starting it. This prevents the saw from “kicking-back” on the material’s edge).
6. When you press the trigger switch, most circular saws tend to jerk slightly; but then they operate smoothly as the blade speed increases. After you press the trigger switch, allow the saw motor to reach full speed and then push the saw slowly into the material. If you are cutting off long material, have a helper support the material to keep it from moving or dropping, which could close the cut and bind the saw blade. (**NOTE:** Do not stand directly behind the saw while cutting operations are in progress.)
7. Continue to observe the cut line as you push the saw through the material being cut. The saw blade must be on the waste side of the line; otherwise, the material being cut will be short the width of the blade. Most circular saws provide a notch (fig. 4–43) on the front end of the base to aid in blade alignment. (**NOTE:** Any side-to-side movement during the cutting process may cause the blade to bind, resulting in a kickback. If the saw does bind, stop the saw and slide the saw back to where it runs without binding.)

You will not be able to use the front notch to guide the blade once you get near the end of the cut. However, you will be able to watch the blade as it travels along the cut line for the remainder of the cut. Once the cut is complete, be sure to keep the blade away from your body.

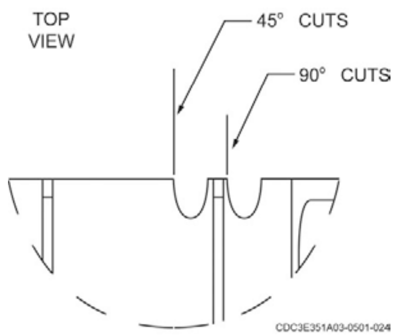


Figure 4–43. Blade alignment notches.

When using the circular saw to cut material at an angle, it may be necessary to retract the blade guard by hand using the handle provided. Just be sure to release the handle after you start the cut.

It’s important to note that circular saws cut on the upstroke. That means that the saw blade rotates upward through the material being cut. What this means to you is that as the blade comes through the material, the material may splinter along the layout line. Different factors such as material being cut, kind of blade, material thickness, and others affect the degree of splintering so you need to take one of the following special three precautions when cutting finish lumber (i.e., lumber that will be exposed).

1. Mark and cut the material from the backside.
2. Mark the material on the face side and score along the layout lines with a sharp knife.
3. Place masking tape along the face side, mark, and cut as usual. Be sure to pull the masking tape off towards the cut, otherwise the tape may cause the lumber to splinter.

There may come a time when you have to make internal cuts into a piece of material, such as countertops for sinks. You can easily make these cuts with a circular saw using the following six steps:

1. Layout the cut line and adjust the blade depth.

2. Ensure you wear PPE, hold the blade guard open, and rest the front edge of the base on the work area with the saw blade inline with the cut line.
3. Ensure the saw blade teeth are clear of the material and start the saw. Slowly lower the blade into the material making sure that you carefully follow the line until the entire base rests flatly on the material.
4. Continue cutting until you reach the corner. Release the trigger switch and wait until the saw blade stops rotating before you remove the saw from the cut.
5. Reverse the direction and cut into the opposite corner.
6. Repeat procedures for each side. You can then cut the corners completely with a handsaw or saber saw (jig saw).

Maintenance

To prolong the life of your saw, you need to keep it clean. You must blow out all the air passages periodically with dry compressed air (be sure to wear eye protection). Use a soft damp cloth to clean all plastic parts—*never* use solvents on plastic parts. An authorized repair center must accomplish any other maintenance or repair.

Drills

This is another tool that you use quite often during your time in this career field. There are a variety of types and styles—too many to list. We cover some general information on the types available and how to use them.

The drills that you see are classified as light or heavy-duty. You can usually tell them apart because light-duty drills usually have a pistol grip, whereas heavy-duty drills may come with a spade-shaped or D-shaped handle (fig. 4–44). Drills are sized according to their chuck (part of toll that holds the bit) size. Chucks ¼ and ⅜-inch are the most common sizes for light-duty drills. Chucks ½-inch and larger are usually reserved for heavy-duty drills.

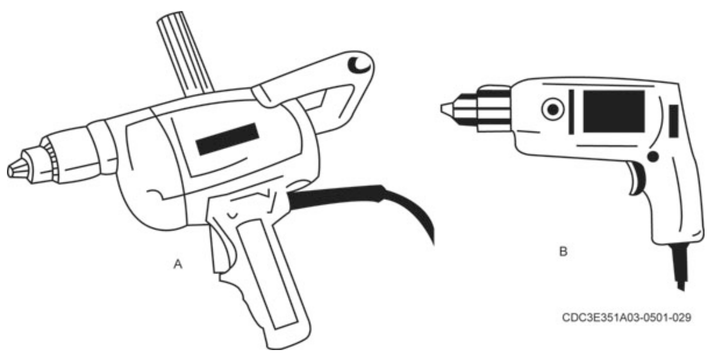


Figure 4–44. Drills.

Most of the good quality drills have a variable speed option, torque selector, and reversible controls to change rotation direction. Generally speaking, slow speeds are better for drilling larger holes or for driving fasteners whereas faster speeds are better for drilling smaller holes. The torque adjuster acts as a clutch. When the object being driven reaches a desired setting, the clutch triggers to keep from over tightening the object. The reversing switch comes in handy when you remove screws or withdraw bits from tight holes.

General drilling procedures

1. Ensure you set the speed selector, torque setting and reversing switch to the desired settings.
2. Select the proper size bit or twist drill and insert it into the drill chuck. You must make sure that you tighten the chuck using the chuck key or hold the chuck when using a drill with a keyless chuck.

3. If drilling small pieces of wood or metal ensure you secure the material with clamps or a vise to prevent it from spinning. A spinning object can cause severe injury to yourself or an observer.
4. Mark exact center of hole. When drilling into wood, you have the option of center punching if the hole must be accurate. When drilling into metal, center punch the hole to keep the drill from wandering off.
5. Place tip of bit in position, hold the drill square (at a right angle) to the work, and start the motor.
6. Apply the desired amount of pressure. This comes with experience. You must be sure not to force (i.e., apply too much pressure) the bit. This may cause the bit to overheat or break. Apply an even, steady amount of pressure to keep the bit cutting. Too little pressure dulls the bit because of excess friction that is created by the bit sliding over the surface.

NOTE: If the drill bit catches in the hole, immediately release the trigger and then remove the bit from the drill. You must then determine the cause. Never squeeze the trigger on and off repeatedly as an attempt to free the bit; this will ultimately damage the motor. You may, however, use the reversing switch to the back the drill bit out of the hole.

7. Reduce the pressure just before the drill cuts through the work material. This helps to avoid splintering the wood or catching in metal.
8. Withdraw the bit when it completely penetrates the material being drilled and is spinning freely.

Drilling in wood

Apply the following instructions to the above steps when drilling into wood:

1. When using twist drills, withdraw them from the hole periodically throughout the drilling operation to clear the chips from the flutes. This helps avoid overheating and burning the wood.
2. To keep from splintering the backside of the wood, ensure you clamp a backing block securely in place. If you don’t use a backing block, ease up on the pressure as the tip breaks through and continue drilling from the backside (this applies more importantly when using spade bits or hole saws).

Drilling in metal

These instructions apply in addition to the general drilling instructions listed above.

1. Ensure that you use a good quality high-speed steel twist bit that is sharp.
2. Start drilling with a slow speed and increase the speed as the drill cuts. The harder the metal, the slower must be the speed. It’s the opposite for soft metal—the softer the metal, the faster must be the speed.
3. To drill a large hole, it is easier to drill a smaller hole first, and then enlarge it to the desired size.
4. Use a lubricant, such as cutting oil, on the drill tip. This not only helps keep the bit cool, but it increases drilling action and prolongs the life of the bit.

Driving wood screws

Depending on the type of screw and wood used, you will more than likely have to drill a pilot hole into the wood. Always refer to the guidance provided with the screw when selecting the size twist drill to use. The table below list suggested sizes.

Screw Size	Pilot hole diameter	
	Hardwood	Softwood
#6	7/64 inch (0.109)	1/16 inch (0.062)
#8	1/8 inch (0.125)	5/64 inch (0.078)
#10	9/64 inch (0.140)	3/32 inch (0.094)
#12	5/32 inch (0.156)	7/64 inch (0.109)

Continue the procedure of driving wood screws with the following steps:

1. Install the proper bit into the chuck and tighten.
2. Adjust the torque setting (if available) and set speed to low.
3. Use your fingers to start the screw into the hole, ensuring that it is straight.
4. Place the bit onto the screw and squeeze the drill's trigger. You must be sure that you have pressure applied to the screw.
5. Once the screw is seated, remove the bit from the screw.

A little trick when screwing into hardwood is to place a lubricant on the screw threads. You can use soap or some type of wax, such as paraffin wax.

Maintenance

Be sure to keep the tool clean. Use a soft damp cloth to clean all plastic parts—*never* use solvents on plastic. On most drills, have them lubricated every 100 hours of use. Only authorized service centers should perform the lubrication. At this time, they would also inspect for worn or damaged parts.

Reciprocating saws

We primarily use the reciprocating saw (fig 4–45) for rough work, such as cutting holes and openings for pipes, stacks, or roof vents. Most new models have a variable speed control from 0 – 3000 or more strokes per minute (SPM). The lower speeds are recommended for most metal cutting operations; whereas, higher speeds are reserved for cutting wood.

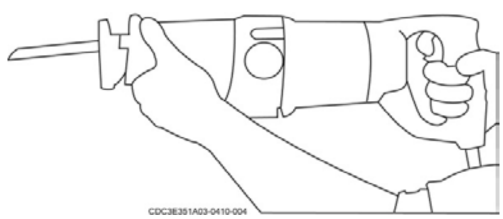


Figure 4–45. Reciprocating saw.

The reciprocating saw is handheld and portable for cutting through wood, metal, plastic, gypsum, ceramic, or other material types, if you use the correct blade. Most saws have a dual-cutting action—reciprocal (straight back and forth) and orbital. Use reciprocal cutting for all metal cutting and for cutting wood when the finish appearance is more important than speed. We use the orbital action for fast cutting of wood.

The reciprocating saw's lower end has a pistol grip, center portion (body), and a head. The head contains the saw assembly where we install interchangeable blades. The blades are available in different types for various purposes (fig. 4–46). For example, carbon steel blades are best for cutting wood, fiberboard, asphalt, aluminum, magnesium, embedded nails, and similar materials. A high-speed blade is best for cutting metal, including conduit, steel pipe, channels, fiberboard, and hard rubber. When you cut metal using the saw use a blade that allows at least three (3) teeth to be in contact with the thickness of the material.

Figure 4–46. Reciprocating saw blades.

NOTE: The saws are provided with a base or shoe (pivoting guide shoe). Ensure that you *never* operate the saw without this shoe in place.

Saw use

Here are five simple steps to follow when using a reciprocating saw.

1. Ensure cut line is clearly marked. Firmly secure small or loose work pieces.
2. Select the correct blade for the task. Use the shortest blade suitable for the thickness of the work.
3. Ensure power is disconnected from the tool and insert blade. You must ensure the blade is in the blade clamp correctly and then securely tighten the clamp.
4. Set the speed and blade motion to the desired settings. Connect the power source.
5. With PPE in place, begin the cutting operation. Only apply slight pressure. More pressure does not make the cut progress any faster.

NOTE: Ensure you hold the shoe firmly against the work piece throughout the cutting operation.

Sawing wood

Since the blade cuts on the upstroke, place the wood face side down when cutting.

Plunge cuts

You can use this saw for plunge cutting wood, plywood, wallboard, and plastic materials; however, drill a starter hole whenever possible—never attempt to plunge cut metal.

To make plunge cuts, clearly mark the cut line. Firmly hold the saw and position it so that it rests on the pivoting guide shoe with the blade aligned (not touching) with the cut line. Start the saw, use the shoe as a pivot point and raise the rear of the saw to bring the blade in contact with the line. Continue raising the saw until it is perpendicular to the work surface and then continue cutting along the line.

Sawing metal angle, beams, and channels

Start the cut on the surface of the metal where the greatest number of teeth contacts it. You can add cutting oil along the cut line to extend the blade life.

Maintenance

Use dry compressed air to periodically blow out all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents. As with the circular saw, all other maintenance and repair actions should only be accomplished by an authorized service center.

Power miter saw

The power miter saw (fig. 4–47), which we also call a power miter box, makes straight and mitered cuts. It looks very much like a portable circular saw mounted into an adjustable base. The base is adjustable to make cuts from 0 to 45 degree in either direction. Some saws also have an adjustment to tilt the saw motor to make compound miters. Like the portable circular saw, the blade determines its size, which is usually 10 or 12 inches. You can set the saw to make duplicate cuts. We use it mostly for finish work, but you can also use it to cut lumber for rough framing.

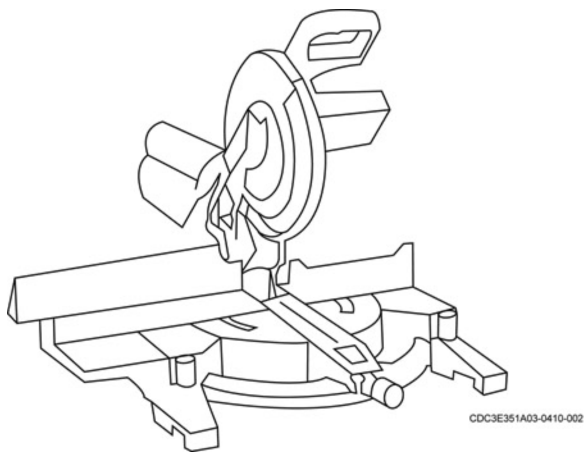


Figure 4–47. Power miter saw.

Saw use

For basic miter cuts, do the following steps:

- Adjust the base to the desired angle and secure it in place.
- Position the wood firmly against the fence on the base.
- **NOTE:** When cutting bowed pieces, ensure that you place the material on the table with the cut line against the fence (fig. 4–48). If you place it with the cut line away from the fence, the work piece will bind the blade near the end of the cut.
- Grip the handle, squeeze the trigger, and slowly pull down on the handle.
- The blade guard will automatically start to retract back.
- Continue pulling down slowly until the blade makes contact and cuts through the wood.
- Release the trigger and guide the handle back to the fully up position.
- Remove the wood and any scraps from the saw.

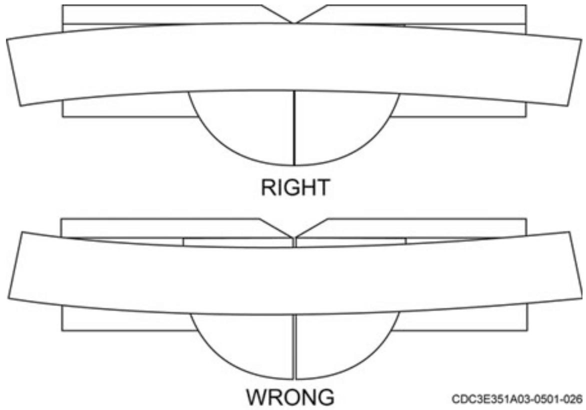


Figure 4–48. Cutting bowed lumber.

Maintenance

Be sure to only use blades that are designed for crosscutting. The blades must be rated for the saw being used. To replace the blade, disconnect the power source and loosen the screw. Rotate the blade guard back and remove the blade. Insert the new blade, making sure that the teeth are pointed down in the front, and reattach the screw.

Use dry compressed air to periodically blowout all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents. As with the other tools mentioned, all other maintenance and repair actions should only be accomplished by an authorized service center.

Frame and trim saw

The portable frame and trim saw (fig. 4–49), also known as a bucksaw, can perform all functions of the power miter saw, plus more. It is easily transported and set up on a job site. Most are mounted onto a fold-up platform that has a lockable wheel set on the bottom. You must be familiar with the owner's manual or receive specific training from your supervisor to use this tool.

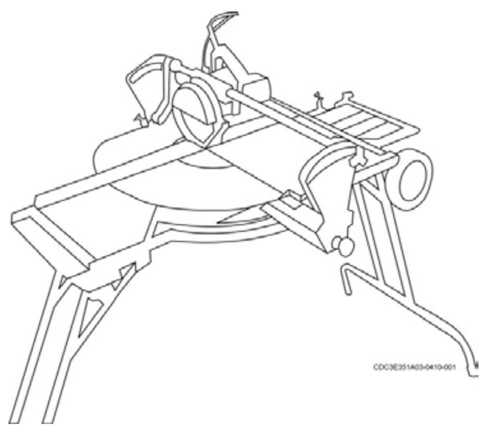


Figure 4–49. Frame and trim saw.

Cross cutting

To perform cross cutting, you must ensure the track arm is indexed to the zero (0) degree positive stop and that the track arm clamp knob is tightened. With PPE on, place the work piece on the table up against the fence. Hold the work piece firmly in place with your left hand and pull the saw blade across the work piece with your right hand. Once the blade cuts through the material release the trigger switch and return the cutting head to its original position.

Miter cutting

This is performed in the same manner as above. The only exception is that you must first position the track arm to the desired angle on the miter scale and then lock it in place.

Bevel cutting

Once again, you perform this in the same manner as you do cross cutting with a minor change. Index the track arm at the zero (0) degree positive stop mark on the miter scale; however, tilt the cutting head for a bevel cut (between 0 – 45 degrees).

Compound miter/bevel cutting

This operation you accomplish by using a combination of the methods described above.

Maintenance

Periodic maintenance is the key to preserving the life of your tool.

Check/replace brushes

With the power source disconnected, check the brushes after the first 50 hours of use. After the first check, check them after every 10 hours of use. The brush holders are on the motor housing (refer to the owner's manual for specific instructions). If the carbon on either brush is worn to $^{3}/_{16}$-inch in length or if either spring or shunt wire is damaged or burned, replace both brushes.

Cleaning the tool

Use dry compressed air to periodically blow out all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Rotary hammer

Rotary hammers (fig. 4–50), which we also call hammer-drills, use a combination of rotary action and hammer blow type action with carbide tipped bits (masonry drill bits) to quickly drill holes into masonry surfaces, such as concrete, brick, and tile. Some have a chuck that only accepts bits made with a specific shank design. Others have the same type chuck that is used on other portable drills. Many hammer drills have special features that include a switch to turn off the hammer action, ability to use regular twist drill bits, reversible rotation, and variable speed control. Some allow you to attach accessories such as a depth stop or D-handle. A depth stop usually attaches to the side or top of the drill and allows you to identify how deep you are drilling. Set to the desired depth, the depth stop contacts the item being drilled and prevents you from drilling any deeper.

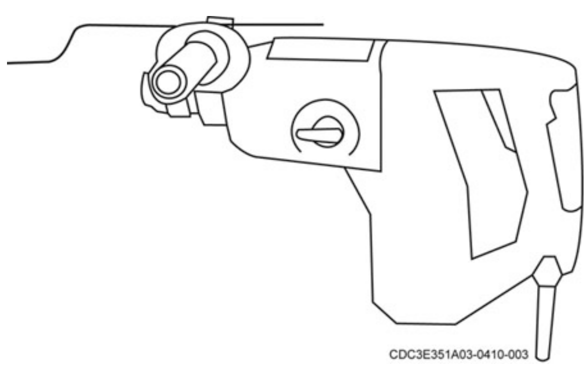


Figure 4–50. Rotary hammer.

Use

Follow the same guidance for general drilling when you use this tool. The only exception is to wear hearing protection as well as safety glasses. This drill can create some loud noises.

Maintenance

Use dry compressed air to periodically blow out all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Hand grinder

Hand grinders have a lot of different uses. We use them to cut or deburr metal, remove rust or paint, and to grind off slag from welds. You can purchase various wheels such as abrasive stones or discs, deburring wheels, wire brush wheels, and buffing wheels. Their use is relatively simple, but we discuss some recommended safe operating procedures.

It is *not* recommended to use hand grinders that are over 5 inches for cutting metal. As with all power tools, wear your PPE. In addition to safety glasses and hearing protection, you may have to wear additional protection, such as a face shield when using a wire brush wheel. Always refer to your unit's safety policy.

General info

- Ensure that the work piece is secured and supported—never hold the work piece against your body.
- Ensure that the trigger switch is in the off position before connecting power.
- Ensure that you use the auxiliary handle at all times. You can adjust this handle for use on either side or on top for most grinders.
- Always operate the tool with the wheel guard in place. Different wheel guards are available to match the different wheels used. Wheel guards protect you from flying particles, thus, you must position them between the operator and the wheel.
- Before using the tool, let it run for about a minute and observe the wheel rotations. Look for flutter or excessive vibration. This may indicate a bad wheel or poor installation.
- To stop the grinder, release the power switch and allow the wheel to stop rotating before you put the tool down.

Use

1. Firmly grasp the handle and motor body.
2. Lift up the motor body until only the front section of the wheel contacts the work. (**NOTE:** Always lift the grinder wheel off the work before starting or stopping the motor.)
3. Use light pressure; never force the wheel against the work.

CAUTION: Never grind aluminum or other soft metals with an ordinary abrasive wheel. There are special wheels designed for aluminum. Ordinary stone type wheels load up with aluminum and soft metal particles that may cause the wheel to explode.

Maintenance

Use dry compressed air to periodically blow out all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Portable bandsaw

We use the portable bandsaw (fig. 4–51) to cut various types of metal objects including pipe, angle iron, and square stock. Newer bandsaws are variable speed and simple to use.

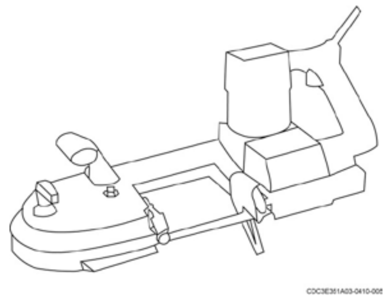


Figure 4–51. Portable bandsaw.

Blades

Always refer to the instruction manual for the correct type of blade. The blades for stationary band saws are usually a different thickness than the blades used on portable bandsaws; thus, you cannot use them interchangeably. When selecting a blade, choose one that allows at least two teeth to be in contact with the material thickness. You'll need finer blade teeth for thinner or harder material being cut, and you'll need courser blade teeth for the softer material. When selecting blades, remember that hi-speed steel blades stay sharp longer than alloy steel blades.

Lubricants

Once again, refer to the instruction manual for the tool you're using. Most manufacturers never allow the use of a liquid lubricant when using the portable bandsaw as the blade guide bearings or rubber tire pulleys may be damaged. Also, the liquid lubricants may increase the risk of shock. If lubricants are needed, use a stick wax to lubricate the blade. Aluminum, brass, and thick materials cut best with a lubricant whereas cast iron should be cut dry. To apply the wax, let the saw run and apply the wax to both sides. Repeat intermittently as needed.

Blade removal and installation

Most blades come on and off the same, but there are variations in the different makes. To remove the blade, ensure the power is disconnected. Release the tension on the saw blade and remove the blade from the pulleys and then from the blade guide.

Before installing a new blade, be sure to remove any metal chips or wax that may have accumulated on the blade guides and pulley tires. To install the blade, first install the blade in the blade guides and then position it on the pulleys. You need to make sure that the teeth point toward the rear (toward the work rest) in the direction of travel. Adjust the tension control to place tension on the blade. The next step is to start and stop the saw to or three times to seat the blade on the pulleys. Most new bandsaws adjust the blades automatically, but if not, refer to your instruction manual for the correct procedure.

Bandsaw use

1. Ensure the material being cut is secured firmly.
2. Set variable speed control (if equipped) to the desired speed.
3. With PPE in place, hold saw with the work stop (rest) in contact with the work and the blade teeth clear of the work.
4. Turn the saw on and slowly lower it on the work. Do not add any pressure to the saw. Let the saw's weight do the cutting. Additional pressure only slows down the blade.
5. Keep the saw straight and the work stop against the material being cut. If the work stop is not in contact with the work, the saw will jerk forward. Be sure to keep clear of the end of the work piece that may fall after the cut.
6. Once the saw reaches the end of the cut, do *not* allow the saw to fall against the work.

Maintenance

Keep the tool clean. Use dry compressed air to periodically blow out all air passages (wear safety glasses). Remove wax and chip particles from the blade guides and pulley tires. Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Powder-actuated fastening tool

A powder-actuated fastening tool drives metal pins (fasteners) into concrete, masonry or steel. Structural workers use a type similar to the one shown in figure 4–52 to secure wooden sole plates. Consider other fastening methods before you decide on the powder-actuated fastening method because the exploding powder charge that drives the fastener has the potential to cause a fatal injury.

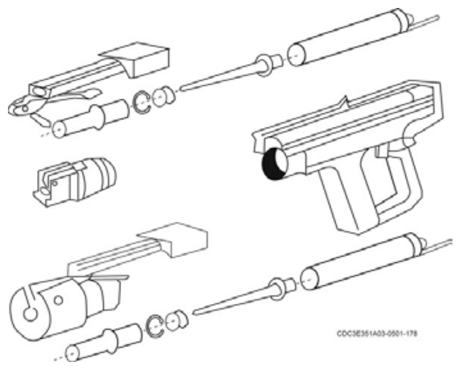


Figure 4–52. Powder-actuated tool.

This serious potential for injury is one important reason why the Air Force has specific guidance for powder-actuated tools under AFOSHSTD 91–10, chapter 4, *Carpentry and Structural Maintenance*. This standard explains that any powder-actuated tool used for Air Force operations must meet all requirements of American National Standards Institute (ANSI) Standard A10.3, *Powder-Actuated Fastening Systems*. They are authorized for use if they have a manufacturer's label and model identification, and include the manufacturer's instructions. The standard also explains that all operators must have a qualification card (license) in their possession to use the tool. This license gives them authorization to use a particular powder-actuated fastening tool. To become a licensed operator, you must receive training and understand the operating principles, safety features, and fastening limitations. See your trainer or supervisor about getting a license on any powder-actuated tool that your shop uses.

Operator guidance

There are many powder-actuated tools that are available; they all require a trained and licensed operator. A good way to stay proficient is to periodically review the manufacturer's instructions and use the tool. In addition, you can use this basic guide in the following table:

Always	Never
• Have your qualification license with you. • Use the tool according to the manufacture's instructions. • Wear safety protection and follow all safety procedures. • Check the tool each day that you use it for proper operation, including safety devices. • Store tools unloaded in a locked container. • Store powder loads according to Air	• Use a common nail made to be driven with a hammer in a powder-actuated fastening tool. • Bypass a safety feature. • Use the tool in an explosive or flammable atmosphere. • Put your hand or any body part against the muzzle of a loaded tool. • Drive a fastener into a spalled or cracked concrete surface where a previous fastener has failed. • Let people gather around while you are using the tool. • Point the tool at anyone.

Always	Never
Force Manual (AFMAN) 91–201, *Explosive Safety Standards*. • Make sure that nobody is on the other side of a wall before you drive a fastener into it. • Drive fasteners at right angles. • Consider posting a sign to let people know that a powder-actuated fastening tool is in use. • Use a fastener recommended by the manufacturer.	• Load the tool until you are ready to use it. • Leave a loaded tool unattended. • Carry a loaded tool from job to job. • Throw an unfired powder load into a trash can. • Drive fasteners into high carbon steel, cast steel, glazed tile, tile, tool steel, glazed brick, hollow tile, spring steel, glass block, live rock, or any other hard or brittle material. If you do, the fastener can go totally through the material, or it can be deflected back at you. • Drive fasteners closer than 2 inches from a concrete edge. • Drive fasteners closer than ¼ inch from a steel edge.

Powder charges

Powder charges (loads), which we also call *boosters* or *caps*, provide the explosive charge and are usually packaged in color-coded loading strips for easy identification. Learn the color codes for the make fastener that you are using. Always use the correct booster to prevent misfires, split casings, airborne casing fragments, and poor fastening performance.

Tool use

Always refer to the instruction manual for the tool you are using. These procedures are general in nature and are provided for reference only.

1. Study the manufacturer's instructions for safe use. Ensure you wear PPE (i.e., safety glasses and hearing protection).
2. Ensure the fastener will not penetrate completely through the object into which it is being driven.
3. Ensure all parts of the tool are in place and functioning correctly.
4. Select the correct fastener for the work required.
5. Select the booster that has a power level that drives the fastener into the material properly. Always use the lowest power level that accomplishes the job.
6. Load the tool with the fastener and booster in accordance with the manufacturer's instructions.
7. Keep the tool pointed towards the work, press it in the desired place, and squeeze the trigger.

CAUTION: If the tool does not fire, you must continue to hold it against the work surface for 30 seconds. Then follow the manufacturer's instruction for further guidance. Never try to pry out a live powder load. It could explode in your hands and cause a fatal injury. Instead, tag it with a "DO NOT USE" sign, place it in a safe location, and immediately notify your supervisor or tool equipment custodian.

Cleaning and maintenance

Follow the manufacturer's instructions for cleaning and maintenance on powder-actuated tools. Most manufacturers recommend that you clean the tool daily after each use or after every 1,000 fastenings. Some common areas include removing carbon build-up from the muzzle's air vents to allow the excess gas pressure to escape, thus preventing excessive recoil.

Rotating laser level

The rotating laser level is a portable tool (unit) that is usually powered with rechargeable batteries. It projects a perfectly straight line that you can use to level or plumb items. It works by using spinning mirrors to project a laser beam through the air so that it appears as a solid line on any surface. You must pre-position and level the laser unit for accurate line projections.

Level adjustments

Make your level adjustments just after you pre-position the unit. If the unit is not level, it will not project a true plumb or level line (some units have a self-leveling feature). You can level most units to project a vertical (level) or horizontal (plumb) line. If you adjust the leveling knobs, the bubble vials (located 90° to each other) bring the unit to a point for use. For training, see your trainer or supervisor. The manufacturer’s instructions also have the details on leveling. You can usually find information on how and where to set-up, adjust, and repair laser levels in the instructions as well.

Interior and exterior uses

There are many interior and exterior uses for the laser level. The typical interior use is laying out wall angles and leveling a suspended ceiling. You start by pre-positioning and leveling the laser level. Next, turn it on and it projects a perfectly level laser beam line at the desired elevation on all four walls at the same time. Other interior uses include laying out lines for walls, posts, doors, windows, stairs, deck railings, trim, floor and wall coverings. Exterior work includes leveling footing and foundation forms, block, and brick walls. By using a laser level, you get an instant and perfect line that saves both time and effort.

Laser level safety

The main safety concern with laser levels is exposure to laser light. Here are some safety precautions for you to be aware of when using a laser level.

- Never use a laser level unless you have been trained to do so.
- Never stare directly at the laser light.
- Never point the laser beam at others.
- Always try to set up the laser light above or below eye level.
- Always turn off the laser when you don’t need it.
- Always consider posting signs to show that a laser light is in use.
- Avoid exposure to the laser. Laser radiation is emitted from the level.

Maintenance

Keep the tool clean. Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center. With some units, you can recalibrate the laser; however, you must refer to the owner’s manual for specific guidance.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

222. Using portable power tools

1. What determines the size of a portable circular saw?

2. To what depth must you adjust the circular saw blade?

3. What may result if there is any side-to-side movement during the cutting process while operating a circular saw?

4. When drilling into metal, what must you do to prevent the drill from wandering off?

5. What must you do if the drill catches in the hole?

6. When using twist drills in wood, why do you periodically withdraw the bits from the hole to clear the chips from the flutes?

7. When drilling in metal, what is the recommended speed for hard/soft metal?

8. When cutting metal with a reciprocating saw, what type of blade do you use?

9. When cutting through wood with the reciprocating saw, how do you place the wood?

10. What must you ensure when cutting bowed lumber with the power miter saw?

11. What type of cutting operations can you perform with the frame and trim saw?

12. When using a hand grinder to cut metal, what are the recommended grinder sizes?

13. When cutting cast iron with a portable band saw, what type of lubricant do you use?

14. When using a portable band saw, how much pressure do you add to the saw during the cutting operation?

15. What must you be in order to operate a powder-actuated fastening tool?

16. What procedures must you take if the powder-actuated fastening tool does not fire?

17. List some safety precautions to be aware of when operating a laser level.

4–3. Shop Equipment

As a structural journeyman, you are exposed to various types of shop equipment during your Air Force career. Equipment items vary from base to base; however, in this section, we discuss the most common types of shop equipment found in the Air Force inventory. Equipment that is permanently fastened to a shop floor or workbench top is what we consider shop equipment.

As with the previous section, this information is provided to give you a general understanding of how to use and maintain some of the most common equipment items for carpentry and metalworking. You must always refer to the manufacturer's instructions for the equipment on which you are working. Make all adjustments with the equipment disconnected from the power source. Be sure to follow all safety precautions including wearing hearing and eye protection.

223. Using dual-purpose shop equipment

The shop-installed equipment discussed in this lesson we refer to as dual purpose because you can use it for both woodworking and metalworking; however, do not use the same machine for both woodworking and metalworking—combining wood dust with metal filings creates a fire hazard. It's a good idea to have one of each dedicated to woodwork and metalwork.

General information

The general information presented here applies to all shop equipment, not just the ones mentioned in this lesson. Refer to AFOSH Standard 91–501, *Air Force Consolidated Occupational Safety Standard* for more information.

Training

All personnel must be trained by the supervisor or designated trainer on all machinery or equipment that they are required to use. That means that only trained personnel or those that are undergoing supervised on-the-job training are to operate shop equipment or machinery. The following are some training items required prior tooperate machinery or equipment.

- Proper operation, safety procedures, cleaning, hazard recognition, and emergency shutdown procedures for each machine or piece of equipment that they use.
- Machine or equipment maintenance or repairs that they are allowed to perform.
- Lockout and tagout procedures.

Safe operations

Supervisors have a vital role in the safe operations of all machines and equipment items. They must do the following three actions:

1. Maintain manufacturer's manuals for all machinery or equipment under their control. If they do not have these, they must develop local operating instructions (OI), to include job safety, maintenance, lubrication, and inspection. The OIs must also identify operator and maintenance technician responsibilities.
2. Ensure that only authorized personnel operate and maintain shop equipment.
3. Periodically evaluate machinery or equipment operators to ensure they are following proper and safe operating procedures.

Inspection and maintenance

For periodic inspection requirements, follow the guidelines set forth in Technical Order 34–1–3, *Inspection and Maintenance of Machinery and Shop Equipment*.

Sanding machines

There are many sanding machines available. The sanding machines we most often find in Air Force structural shops are the disc, belt, and spindle types.

A disc sander is primarily a revolving, circular metal plate to which a sheet of abrasive paper is glued or clamped. Stationary disc sanders are equipped with an adjustable table to support the work. You can tilt the table upward or downward for sanding beveled edges, angles, or tapers.

A belt sander uses an abrasive belt that rotates on the machine. It is also equipped with an adjustable table to support the work.

The spindle sander is a small, revolving drum. It usually projects through a hole in the center of a worktable and moves up and down as it revolves. It is designed for sanding inside curves and is available in various spindle sizes. A worktable can usually be tilted to sand bevels or curves.

Sanding machines are relatively simple to use; however, here are some safety precautions that you must follow:

- *DO NOT* sand or polish magnesium—it may catch on fire.
- Aluminum dust creates a fire hazard when combined with metal dust.
- Maintain a maximum $^{1}/_{16}$-inch clearance between the table and the abrasive disc or belt.
- Always sand in accordance with the directional arrows. When using the disc sander, feed the workpiece against the downward rotation side.
- Do not sand small pieces that are not easy to control.

Sanding aluminum and other nonferrous metals

You can use sanding machines to sand nonferrous metals; however, the belts and discs load up with waste when you dry sand. This happens more with aluminum, but to a varying degree with other nonferrous metals like soft brass and bronze. To help prevent loading, you can use a grease stick on the belt or disc. You can also use the grease stick when sanding steel and some kinds of plastic to prevent overheating the material.

Maintenance

These machines have several adjustments that need to be made at specified intervals. As with all machines, always refer to the manufacturer’s instructions for specific maintenance actions. Here is a list of the most common instructions:

- Adjust the tension and tracking of the sanding belt.
- Adjust the tables to the proper location (ensure $^{1}/_{16}$ inch maximum clearance between table and disc or belt).
- Replace belts, discs, and spindle pads periodically.
- Clean all dust and filings from the machine.

Drill press

The drill press is a precision machine that we use for drilling holes that require a high degree of accuracy. It’s an accurate way to locate and maintain the direction of a hole that is to be drilled and gives the operator a feed control lever to regulate drilling pressure into the material. It is more precise and easier to control than any handheld portable drill. A variety of drill presses are available, but the most common type is the upright drill press, shown in figure 4–53.

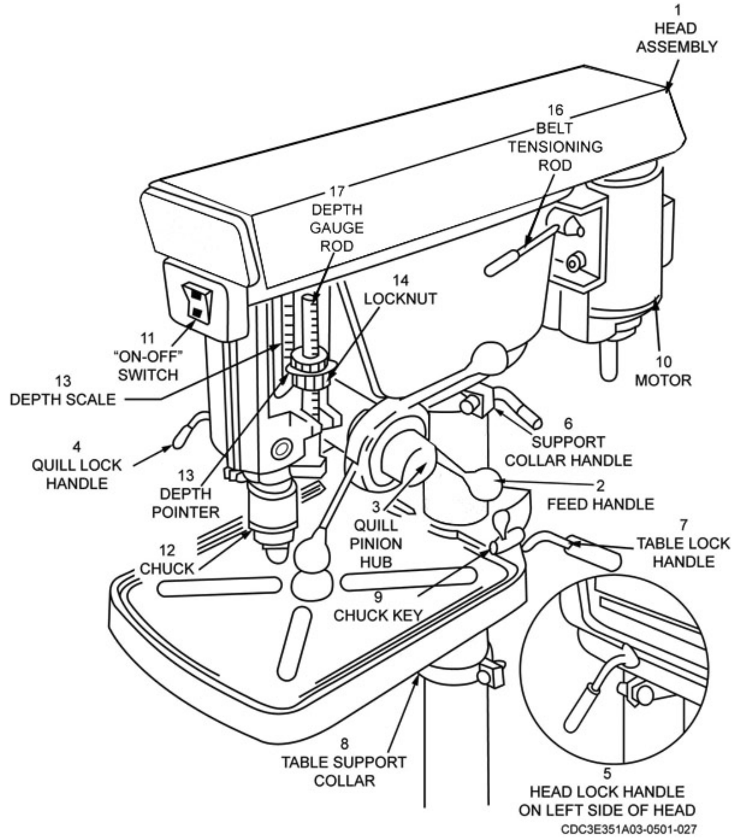


Figure 4–53. Drill press.

Installing bits

To install the drill bits perform the following three actions.

1. Insert the drill bit into the chuck as far as it will go, and then back it back out $^1/_{16}$ inch. If you are using small bits, back those up to the flutes.
2. Center the bit in the chuck and tighten the chuck with the chuck key—be sure to tighten all three chuck jaws (fig. 4–54) so the bit does not slip.
3. Remove the chuck key.

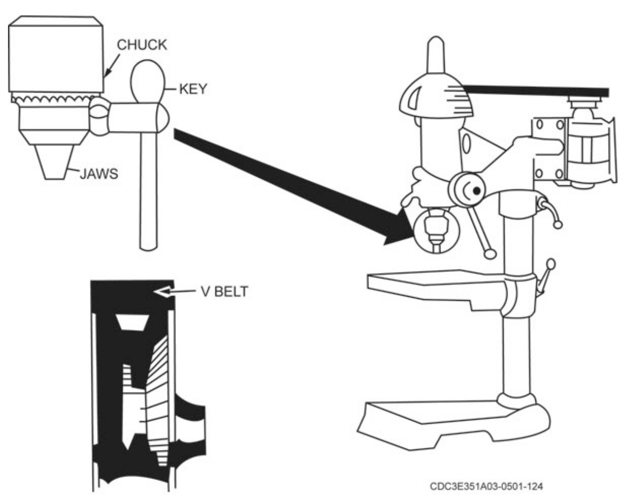


Figure 4–54. Drill press chuck.

Boring in wood

Here are three suggested steps for boring holes in wood.

1. Adjust the height of the working table to accommodate the height and thickness of the part to be drilled. Be sure the bit is lined up with the center hole on the table.
2. When boring through long pieces of wood, position the wood on the table with one end against the left side of the column. This prevents the wood from catching and spinning with the bit. If this is not possible, fasten the wood to the table with clamps or a vise.
3. Turn on the drill and feed the bit through the wood slowly. To reduce the chance of the wood splintering on the backside, reduce pressure as the bit breaks through and/or use a scrap piece of wood under the work.

Drilling in metal

Here are three suggested steps for drilling holes in metal.

1. Adjust the height of the working table to accommodate the height and thickness of the part to be drilled. Be sure the bit is lined up with the center hole on the table.
2. Clamp the material to the drill-press table firmly so that the center punch mark is directly in line with the twist drill. Material or parts that aren't clamped properly may bind in the drill and start spinning—possibly causing the loss of fingers or hands, or causing serious cuts to the operator's arms or body.
3. Turn on the drill and feed the bit through slowly. Use a lubricant, such as cutting oil, on the drill tip. This not only helps keep the bit cool, but it increases drilling action and prolongs the life of the bit.

NOTE: For any drilling operations, you must wear goggles, safety glasses, or a face shield in accordance with your shop's safety policy.

Miscellaneous operations

There are certain attachments that you can use with the drill press for intricate carpentry work. One attachment is the standard router bits we use for inlay or routing work. Another is a shaper head we use for light shaping operations. When you use the drill press for light routing or shaping, adjust it to maximum spindle speed.

A more complex attachment is the hollow-chisel mortiser. It has a yoke assembly that you attach to the drill press's head. Insert the hollow chisel into the yoke. Place the bit into the hollow chisel and into the chuck. When using a drill press for mortising, use the minimum spindle speed. The last attachment is the twist drill bit that we often use for drilling holes for dowel pins.

NOTE: Never use an auger bit in a drill press because it bites quickly into the wood and can bind, break, or cause a serious accident.

Spindle speed

Most drill presses have gears or multi-step pulleys to increase or decrease the speed of the spindle. The drill press in figure 4–54 is shown with the belt guard removed. It can be adjusted for different spindle speeds by changing the V-belt to different steps on the motor and spindle pulleys. You obtain the highest speed when the belt is on the largest step of the motor pulley and the smallest step of the spindle pulley. Be sure to stop the motor before moving the belt from one step to another, and don't forget to check the belt adjustment before operating the drill press.

On most new machines, you don't need to manually adjust the belts—there is a variable speed control handle and/or a speed range control lever. Follow the manufacturer's instructions for adjusting the speed. For most machines, the motor must be running before you adjust the handle and lever.

Installing V-belts on manually adjusted drill presses

To get adequate power, V-belts must be the right size for the pulleys and must be adjusted and installed properly. Most V-belts are installed using the following method.

1. Loosen the hand knob to allow you to push the motor and motor plate in towards the drill press head as far as it will go.
2. Tighten the hand knob to keep the motor in that position.
3. Install belt, loosen hand knob, and push the motor back until you get the desired amount of tension on the belt. As a general rule, allow ½-inch of sag for each foot of distance between pulley centers when you apply thumb pressure to the belt.

General information

Always check the manufacturer's handbook or the technical manual for information concerning the feed and speed recommended for various drilling. When you drill hard metal or steels, use cutting oil to cool the twist drill and keep it sharp. With proper feed and speed, the twist drill usually produces a spiraled shaving, but granular cuttings are produced in drilling cast iron or other porous materials. To prevent binding or breakage, always reduce feed or pressure just before the drill bit goes through the metal.

Maintenance

Preventive maintenance for a drill press consists mainly of keeping it clean, lubricated, and adjusted. Like other shop equipment, a drill press should have a maintenance record folder that specifies the items to be inspected and serviced, the intervals of inspection, and a place to record and initial the maintenance. A drill press like the one in figure 4–54 has sealed bearings and doesn't require oiling, but the spindle and the depth adjustment feed handle have oil cups for lubrication. Follow the manufacturer's instructions of your particular drill press.

Bandsaw

We usually use the bandsaw to make either curved or straight freehand cuts. We often use it when other saws cannot make the cut or where using a different saw would not be safe. The bandsaw uses a continuous narrow saw blade or band that turns between an upper (idler) and lower (driver) wheel. The saw is powered by an electric motor connected to the lower wheel.

Two saw blade guides keep the blade on track. One fixed blade guide is set below the table and one is set above the table. The blade tensioning adjustment is usually located just behind the upper (idler) wheel. The wheel diameter determines the bandsaw size. Some bandsaws are portable but most are shop installed. Common shop installed sizes range in even numbers from 14 through 48 inches. All the saws are much alike in maintenance, operation, and adjustment.

General information

The upright bandsaw is one of the most versatile machines your shop could have (fig. 4–55). You can use this machine to cut all types of material. It can cut irregularly shaped objects from sheet metal, various extrusions, and blocks of metal, as well as most nonmetallic materials, such as wood and plastics. The quality and precision of the work produced depends almost entirely on the skill and knowledge of the operator. If the saw is set up properly for a particular job and the work is guided and fed into the blade properly, it's easy to get a high degree of accuracy.

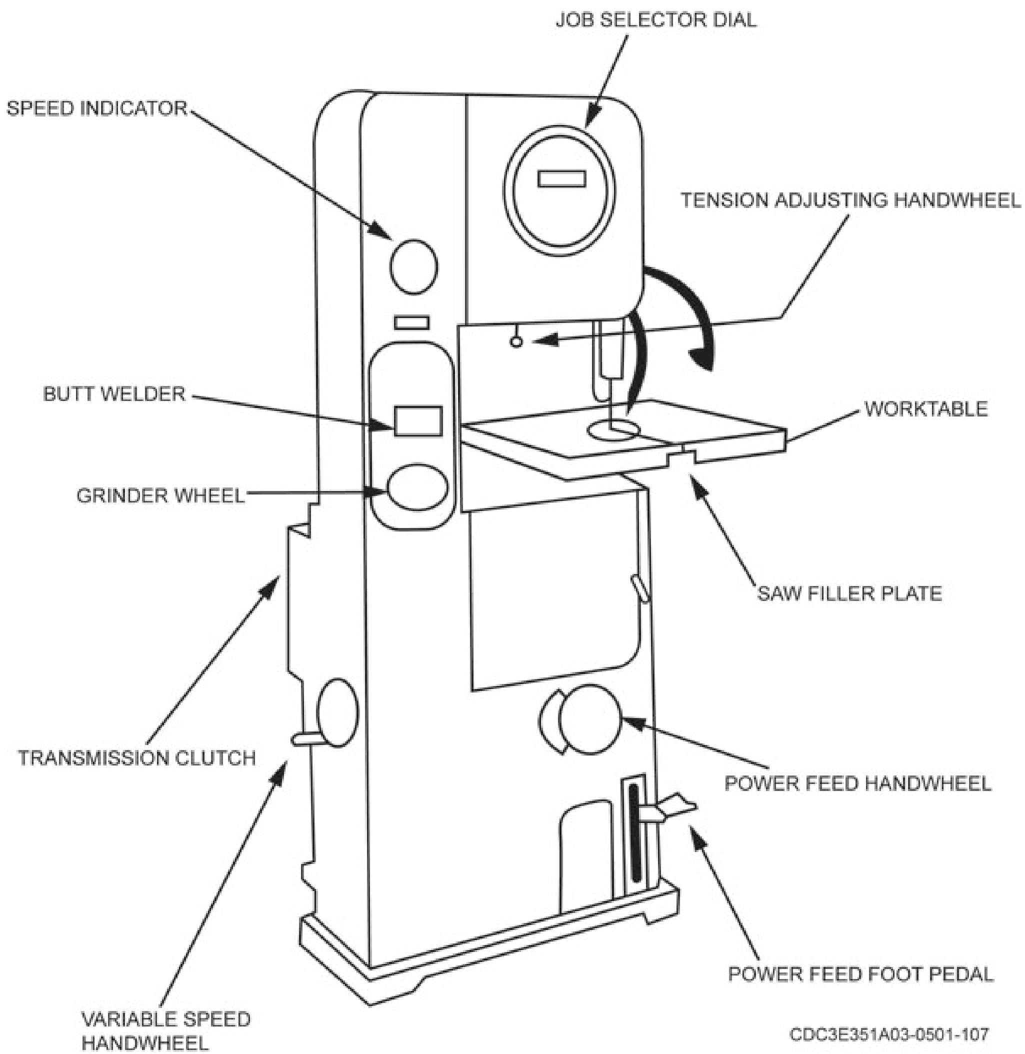


Figure 4–55. Upright bandsaw.

Before operating the bandsaw, you need to understand its operating features. Make sure that you're familiar with all the controls and their functions. Complete knowledge of the machine is required to avoid damaging it or injuring yourself. For personal safety, ensure that you are thoroughly trained on the machine you are using.

Operating controls and adjustments

Due to the wide variety of bandsaws available today, the information presented here is general in nature.

Blade brake

Each bandsaw should be equipped with a blade brake. After you turn off the saw, always depress the brake (which is usually a foot pedal) to stop the blade.

Adjusting blade tension

Turn the blade tension handwheel to add tension to the blade. Most new bandsaws are equipped with a pointer and tension scale. The tension scale is usually marked in increments of the blade width. Align the pointer with the corresponding blade width on the scale (i.e., ½ inch).

Tracking the blade

The blade must be centered on the upper wheel if you want to produce accurate cuts and extend the life of your blade. Before you can make any tracking adjustments, move both the upper and lower blade guides and the blade support bearings away from the sides and back of the blade. (**NOTE:** This information is general and does not apply to some of the older machines.)

1. Disconnect *all* power from the saw.
2. Rotate the upper wheel forward with your hand while turning the tracking adjustment hand knob until the blade travels in the center of the upper wheel.
3. Connect the power source and jog the power switch on and off.

NOTE: Only turn the tracking knob a fraction of a turn at a time. Make tracking adjustments every time you install a new blade.

4. Make all final adjustments at regular operating speed.

Blade guide assembly

The blade guide raises and lowers to adjust for the thickness of the material being cut. You must always adjust it as close as possible to the top of the surface of the material being cut—no more than ⅛ inch above the surface.

Upper and lower blade guides and blade support bearings

Once the blade is tensioned and tracked properly, adjust the upper blade guides and blade support bearing. The following is one method to accomplish the adjustment:

1. Disconnect power source.
2. Adjust the blade guides as close as possible (without touching) to the sides of the blade.
3. Adjust the blade guides so that the front edge of the guides are positioned just to the rear of the *gullets* (the concave cut) of the saw teeth.
4. Adjust the blade support bearing as close as possible (without touching) to the back of the blade. The support bearing's function is to prevent the blade from being pushed too far to the rear. The only time the blade will contact the support bearing is during the cutting operation.

Changing blades

Each bandsaw has a standard blade length. The basic procedures are listed in the following five steps.

1. Disconnect power from the machine and open the upper and lower doors.
2. Remove the upper and lower blade guards.
3. Release tension from the blade.
4. Remove the blade from both the upper and lower wheels and guide it out from the slot in the table.
5. Reinstall the new blade in reverse order (make sure the teeth point down towards the table), adjust blade tension, track the blade, and adjust the upper and lower blade guides and blade support bearings.

Operation

As the saw band passes down past the worktable, the teeth are pointing down and, as the material to be cut is pressed against the teeth, the teeth cut into the material. To use the bandsaw, ensure you wear your PPE. You can either make freehand cuts or use the fence to rip material.

Fence adjustments

If your bandsaw is equipped with a fence, you can move the fence along the guide rail to the desired position. Just be sure to lock the fence and feed the material into the blade without using too much pressure.

Freehand cuts

You can easily make freehand cuts with a bandsaw. Never try to make curve cuts that are too narrow for the blade. Make relief cuts to keep the blade from binding.

General safety note

Sometimes small pieces of material may become jammed between the table and the blade. Never attempt to remove those pieces until the blade comes to a complete stop.

Maintenance

Besides cleaning this machine after each use, you have to lubricate the upper and lower blade guides and blade support bearings periodically. Depending on the machine, you may have to use a pressurized oil gun.

Stationary grinders

Electrically driven grinders (fig. 4–56) may be attached to workbenches or mounted on pedestal floor stands. They should have eye-shields, wheel guards, work rests, grounded power cord, and good abrasive wheels. They normally have medium and fine abrasive wheels—medium for heavy cuts and fine for finish work. Bench grinders are usually equipped for grinding twist drills, chisels, and other small jobs. Fill the cooling tank with water to cool the object you're grinding.

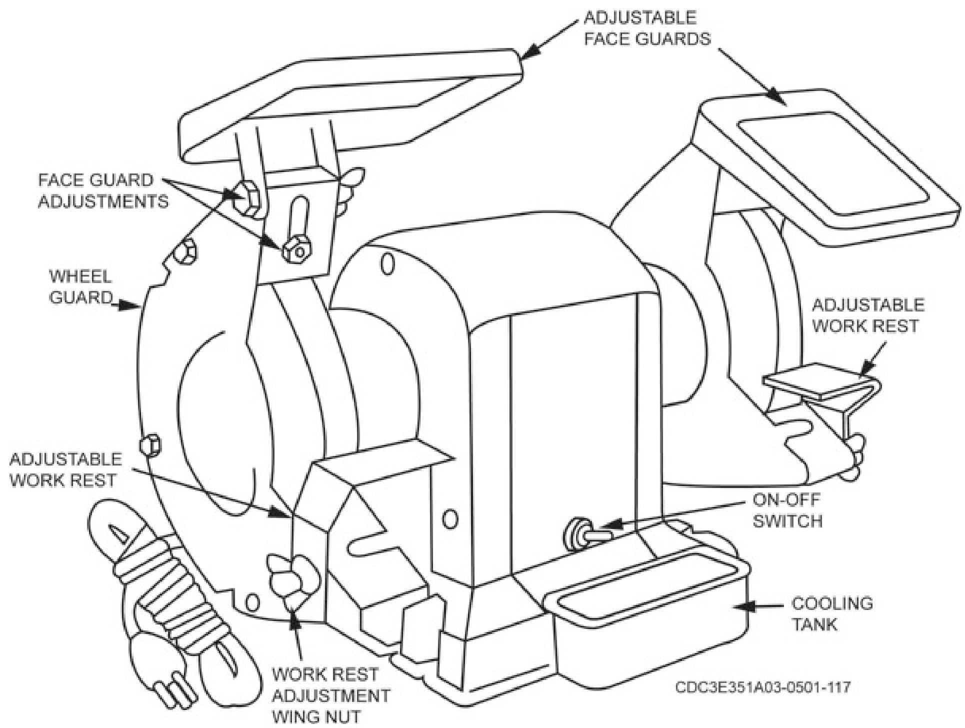


Figure 4–56. Bench grinder.

General safety precautions

To operate the grinder safely you must be familiar with the grinder you're using, additionally here are 12 common safe operating principles that you must also follow.

1. Use only grinding wheels that are for your particular grinder. Some grinders may exceed the RPMs (rotations per minute) of certain grinding wheels.
2. Never use a wheel that is chipped or cracked. Always inspect each wheel before you mount it onto the grinder.

3. Always ensure that the tool rest is within ⅛ inch of the grinding wheel just below the center of the wheel at all times. You'll have to adjust the tool rest as the wheel gets smaller.
4. Always let the grinder run for one minute before using—never grind on a cold wheel.
5. Never grind on the side of a wheel—grind on the face only.
6. Never apply coolant directly to a grinding wheel—dip the workpiece in water instead.
7. Always stand to one side of the wheel when you first turn it on and never have the workpiece against the wheel during startup.
8. Never use a wheel that vibrates.
9. Always keep guards in place whenever you are using a wire brush or buffing wheel.
10. Never grind aluminum, brass, copper, or other soft metals unless the wheel is specifically designed for that purpose. Use soft metal wheels *only* to grind soft metals.
11. Never hold metal with tongs while you are grinding.
12. Do not wear gloves while using an abrasive wheel.

It is very important for you to protect your face and eyes with a face shield even though the grinder may have a small flat shield attached to it. When you're grinding, use only enough pressure to cut the material. Too much pressure causes wear to the wheel and unnecessary heating of the material being ground.

Dressing a grinding wheel

Always keep the grinding wheels properly dressed to maintain good balance and for best results. You can dress a grinding wheel with a wheel dresser wrench or a silicone carbide stick dresser. The wheel dresser wrench (fig. 4–57) consists essentially of a number of circular metal cutters mounted on a spindle in a holder. Before using the wheel dresser, position the tool rest so that you can hook the legs of the dresser over it, as shown in figure 4–57. When you turn on a grinder, always stand aside until it attains operating speed. If there is a defect in a wheel, it will disintegrate. To dress a wheel, hold the dresser firmly against the rest and raise the dresser handle to contact the high point on the face of the wheel. Move it in a steady motion back and forth across the face of the wheel. Keep moving it back and forth until the grinding wheel is clean and the corners are square.

NOTE: Too much pressure causes excessive sparking and rapid cutter wear.

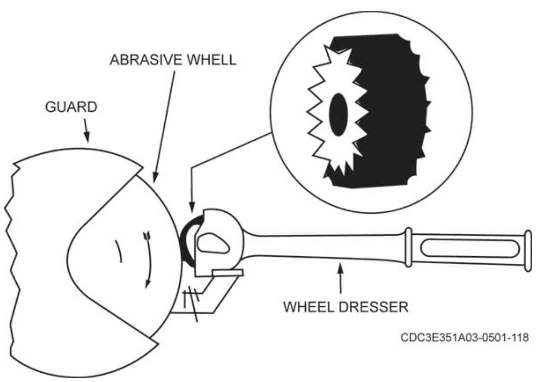


Figure 4–57. Wheel dresser.

Changing a grinding wheel

To change a grinding wheel, disconnect the power source from the machine. Remove the side cover and place a wedge between the grinding wheel and the tool rest. To loosen the arbor nuts, face the grinder and turn the arbor nut clockwise for the left wheel; turn the nut counterclockwise to loosen the right wheel. Remove the wheel and replace with a new wheel in reverse order. Be very careful not to overtighten the arbor nuts.

224. Using woodworking equipment

Most structural shops have shop-installed equipment that we use to cut, shape, plane, and sand wood. This lesson covers the most common types the Air Force uses. Within this lesson we discuss the table and radial arm saws, the types of blades used on them, and other types of woodworking equipment. Just remember to follow your workcenter's instructions for safe operating procedures—the information presented here is general in nature.

Table saw

We also refer to a table saw (fig. 4–58) as a *tilt arbor saw* because when you tilt the circular blade for cutting bevels, you only tilt the arbor (the table remains level). On earlier table saws, the blade and arbor remained in a fixed position and the table was tilted. A tilted table is dangerous in many ways, especially when you must push heavy stock across it, so most of these older models have been replaced with the tilt-arbor type.

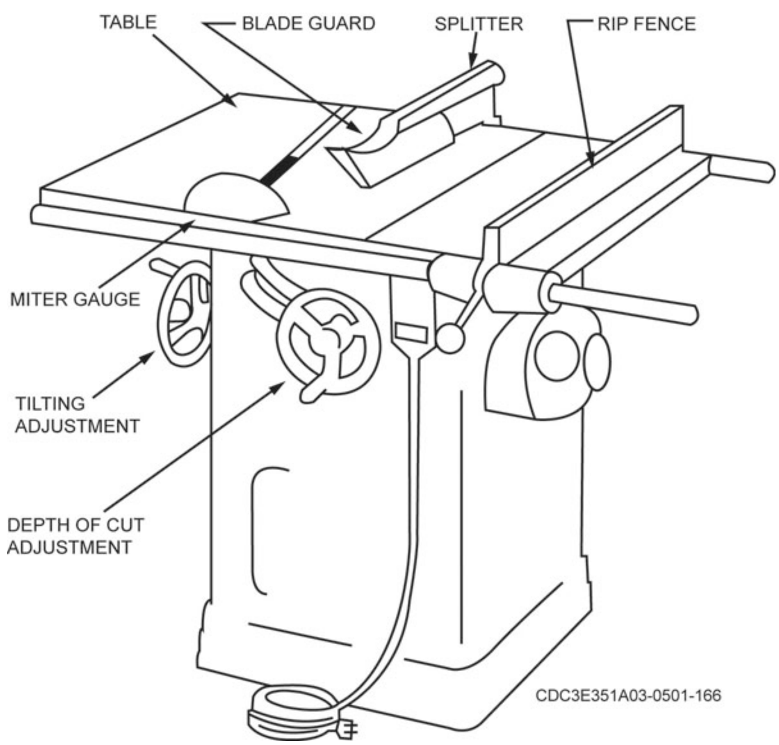


Figure 4–58. Table saw.

We use a table saw for various woodcutting operations. To cut dadoes, grooves, and rabbets, we use special blades as a set to increase the cut width. For ordinary ripping or crosscutting, raise the saw blade ⅛ to ¼ inch above the material to be cut. You control the blade's vertical position with the depth-of-cut handwheel. The tilt handwheel adjusts the blade's angle.

A good safety practice is to keep to the left of the saw blade while cutting to avoid being struck by an object (kickback). The term kickback identifies a cutting situation where the wood is picked up by the spinning circular saw blade and thrown backward (kicked back) through the air with enough force to cause a fatal injury. Never allow yourself or others to be in a saw's kickback area.

Crosscutting

To safely perform crosscutting, use the miter gauge to position and guide the work. The following five steps explain how to properly perform crosscutting.

1. Insert the miter gauge into the slot on the table (usually the left slot) and place the work against it.
2. Set the blade height to where it is ⅛ to ¼ inch above the board to be cut.
3. With PPE in place, turn on the motor and start the cut slowly.
4. Use one hand to hold the work against the miter gauge and the table and use the other hand to push the miter gauge forward. *DO NOT* hold the piece of the work that is going to be cut off.
5. Continue the cut until the work is completely cut. Then pull back the miter gauge and the work to the original starting position. Be sure to shift the work sidewise a little before pulling it back—this keeps it from hitting the blade.

NOTE: Never reach for any short piece of work on the table while the saw is running, and *never* use the fence as a guide while crosscutting.

Ripping

As you learned earlier, ripping is the process of making a lengthwise cut. In this case, you use the rip fence to guide and position the work. Since one edge of the work rides along the fence, that edge must be straight and make solid contact with the table. All good table saws are equipped with saw guards that you must use. These saw guards have anti-kickback fingers that grab into the work to prevent kickback, and they have a little splitter to prevent the saw kerf from closing behind the blade.

The following are six recommended steps to rip a piece of board lumber.

1. Measure from the rip fence to a saw tooth that is set closest to the fence.
2. Set the blade height to where it is ⅛ to ¼ inch above the board to be cut.
3. With PPE on and the board clear of the blade, start the motor.

NOTE: Never stand in line with the saw blade while ripping, but to the left of it.

4. Push the board towards the blade with your right hand. Ensure that you firmly hold it against the table and the rip fence with your left hand.
5. As you approach the end of the board, remove your left hand and continue pushing with your right hand.
6. Continue to feed the board through the blade until it is completely through.

NOTE: If the ripped work is too narrow, you must use a push stick to complete the cut—never place your hands close to the blade. Most craftsmen recommend using a push stick when the work is less than 5 inches wide; however, always follow your workcenter’s safety policy.

NOTE: Use a work support or have someone help you when ripping boards over 36 inches in length to keep the board from falling off the saw table.

Maintenance

Periodically blow out all air passages (wear safety glasses). Clean all plastic parts with a soft damp cloth—never use solvents.

Remove saw blade

To remove the saw blade on most table saws, ensure the power is disconnected. Next, remove the table insert around the blade and place a block of wood against the front of the saw blade. Use the arbor wrench supplied with the saw to turn the arbor nut clockwise. Follow the procedures in reverse to reinstall the blade.

Replacing belts

To replace belts on most table saws, ensure the power is disconnected then complete the following four steps.

1. Remove the access cover to the motor. There should be an area below the arbor for you to place a block of wood. Lower the arbor until the motor comes in contact with the wood.
2. Loosen the bolt on the motor and continue to lower the arbor until there is no more belt tension, then resecure the bolt.
3. Now you can raise the arbor slightly, remove the block of wood, lower the arbor again and remove one belt at a time from the motor pulley, then the arbor pulley.
4. Installation is in reverse order. Place the belts onto the arbor pulley and then the motor pulley. Follow the same procedures with the wood block to put tension on the belts.

Most table saws require approximately 1 inch of deflection in the center span of the pulleys when you press the belt with light finger pressure.

NOTE: An authorized repair technician should accomplish all other maintenance and repair actions.

Radial arm saw

The radial arm saw (fig. 4–59) uses a circular blade mounted into an arbor. A yoke assembly allows you to turn it in any direction. A swivel lock holds the saw motor in the desired position. The yoke slides back and forth along the carriage on the arm of the radial arm saw. You can swing the carriage in any direction and there is an adjustment by which you can set the cut depth. These features make the radial arm saw adaptable to cut many angles.

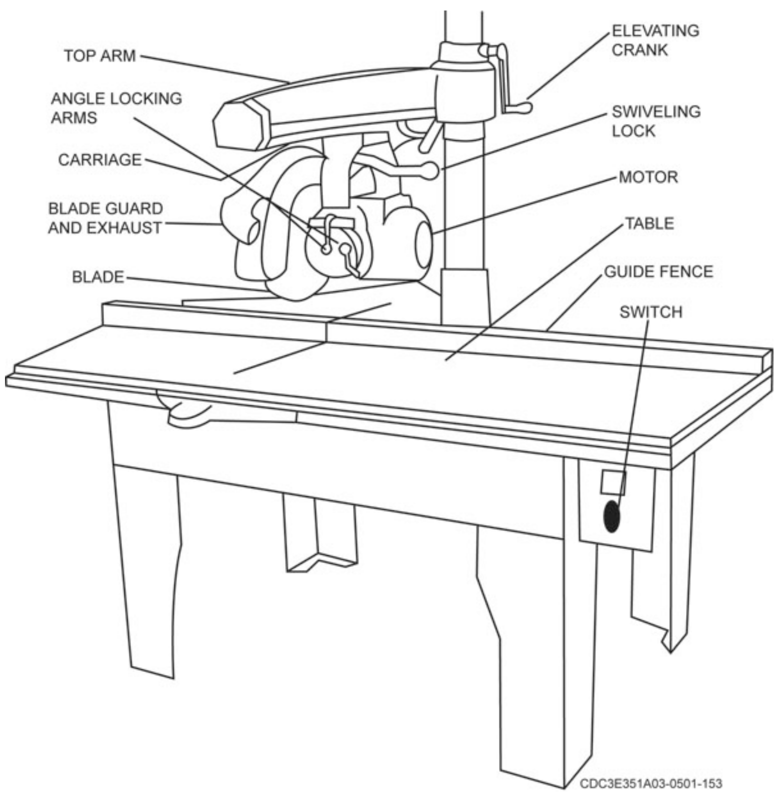


Figure 4–59. Radial arm saw.

Crosscutting

Primarily, we use the radial arm saw for crosscutting. We suggest that you follow these procedures to safely perfom crosscutting.

1. Adjust the arm to a 90° angle to the fence.
2. Adjust the cut depth so that the blade is about $^{1}/_{16}$ inch below the table's surface.

3. Make sure the arm is all the way back with the all guards in place.
4. Measure and mark a cut line.
5. Check blade alignment with your wood cut line.
6. Turn on the radial arm saw (ensure you wear PPE).
7. Hold the wood firmly against the table fence.
8. Pull back on the radial arm handle and the blade will make the cut.
9. Turn off the radial arm saw.

Ripping

Although you can use the radial arm saw for ripping, we recommend that you use a table saw instead. If you must use a radial arm saw for ripping, we list these suggested 10 steps to follow.

1. Adjust and lock the arm so that it is parallel to the fence.
2. Rotate the motor to the in-rip or out-rip position.
3. Measure and set the rip distance from the fence to the blade.
4. Lock the saw carriage with the rip lock at the desired rip distance.
5. Adjust the cut depth so that the blade is about $^1/_{16}$ inch below the table's surface.
6. Adjust the safety guards to allow the in-feed end to just about touch the wood to be ripped.
7. Adjust the kickback assembly to allow its fingers to be located about ⅛ inch below the wood being ripped.
8. Turn on the radial arm saw (ensure you wear PPE).
9. Use the fence to guide the wood and steadily push the wood between the fence and the blade. Make sure that you push the wood through against the blade rotation.

> **CAUTION**: Never push the wood through with the blade rotation (kickback side). If you do, you could be pulled into the saw blade or the wood could be pulled from your hands and be propelled with enough force to cause a fatal injury.

10. Turn off the radial arm saw.

Maintenance

Refer to the manufacturer's instructions or your supervisor for specific guidance. There are a lot of adjustments on this machine that need to be checked over time to make sure everything is in alignment. Here is a list of some of the common adjustments to follow.

- Taking the side motion out of the over-arm.
- Tightening the yoke against the bearing carriage.
- Adjusting the ball bearings against the track rods and adjust the track rods.
- Adjusting the blade guard.
- Adjusting the blade square with the tabletop and the saw travel square with the fence.
- Adjusting the bevel clamp handle, track arm clamp handle and the crosscut stop.
- Removing the "heeling" in the saw cut.

As you can see, the list is long. Some other common maintenance actions include cleaning off dust, lubricating moving parts, and conditioning saw blades so that they stay in good shape. Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Wood shaving power tools

Wood shaving power tools (also called power-planing tools) use cutting knives or have knife-type cutting edges, as opposed to cutting teeth. These tools include jointers, surface planers, and shapers. Let's look at three large shop installed wood shaving power tools, their uses and operating principles.

Jointer

The jointer (fig. 4–60) power planes wood stock's faces, edges, and ends. A revolving cutterhead, equipped with two or more knives, does the cutting. Setscrews in the cutterhead force the throat piece against the blades and hold the blades in position. Loosening the setscrews releases the blades for removal. The cutterhead width (in inches) determines the jointer size. Although wide jointers are available, most Air Force structural shops use the 6-inch size.

CAUTION: Always check the blade guard before using the jointer. The exposed high-speed cutterhead can quickly remove any material it comes in contact with—including fingers.

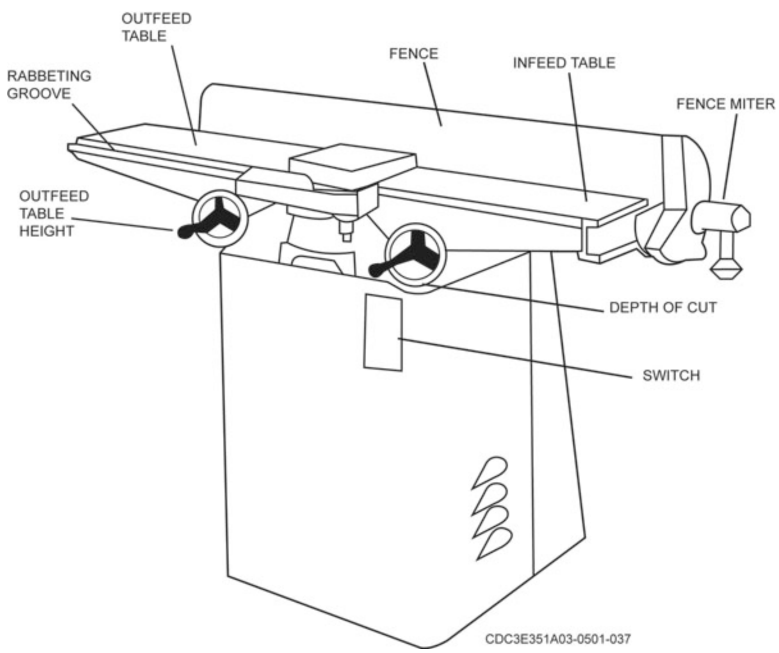


Figure 4–60. Jointer.

Edge jointing

This is the process we use to square an edge of a workpiece. A typical edge jointing operation requires you to do the following:

- Set the guide fence square with the table.
- Set the cut depth (maximum depth is ⅛ inch in one pass if the workpiece is 1-½ inches or less. Cut no more than $^{1}/_{16}$ inch for widths over 1-½ inch).
- Set the outfeed table to match the highest point reached by the blade (fig. 4-61). (**NOTE:** The clearance between the edge of the outfeed table and the cutterhead must not be more than ⅛ inch.)
- Check the knives' and guard's condition.
- Turn on the jointer (ensure you wear PPE).

- Place the material on edge and steadily feed it through from the infeed table across the cutter head and on until it clears onto the outfeed table. (**NOTE:** Use power feeders, holddown push blocks, jigs, or special fixtures.)
- Check the edge after the first pass. If the cut is progressively shallower toward the end, lower the outfeed table. If the cut shows where the edge has dropped down at the last inch or so (deeper cut), raise the outfeed table.
- Check each pass to make sure the cut is correct.
- Turn off the jointer.

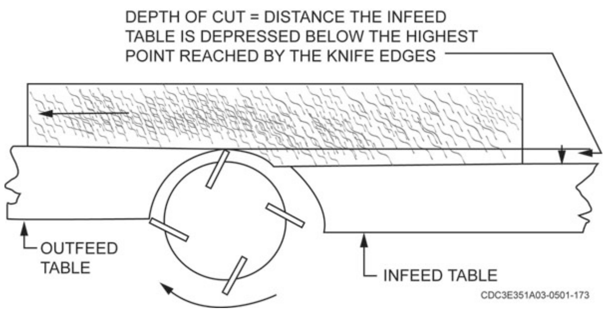


Figure 4–61. Jointer cut depth.

NOTE: Do not try to perform jointing on short material. Refer to your workcenter's safety policy for length requirement. Most manufacturers only recommend jointing material that is 10 inches or longer, ¾ inch or wider and ½ inch or thicker.

Other operations

You can use this machine to perform surfacing, beveling, cutting rabbets and surfacing warped pieces. Refer to the manufacturer's instructions for the machine you are using for safe operating procedures to perform these cuts.

NOTE: Regardless of the cutting operation being performed, ensure that you feed all work into the jointer with the grain. Never feed any lumber into the jointer against the grain. Doing so will result in chipped and splintered edges.

Maintenance

Typical maintenance for the jointer includes cleaning off dust, lubricating moving parts, and conditioning cutterheads (i.e., whetting knives) so that they stay in good shape. Clean all plastic parts with a soft damp cloth—never use solvents. All other maintenance and repair actions should only be accomplished by an authorized service center.

Power planer

A power planer reduces lumber thickness by planing its surface area; we often call it a *surface plane* (fig. 4–62). There are two types available. The first is the single-surface planer. It surfaces one side per pass. The second is the double surface planer. It can surface one or both surfaces in one pass. Most Air Force structural shops use the single-surface planer.

The main power planer parts include the table, rollers, and cutter assembly. The table has three parts: an infeed table, a center table, and an outfeed table. It also has an upper and lower infeed-roller set and an upper and lower outfeed roller set. The upper roller in each set is power-driven through a gear system. The upper outfeed roller is smooth-surfaced and pulls the material through the machine.

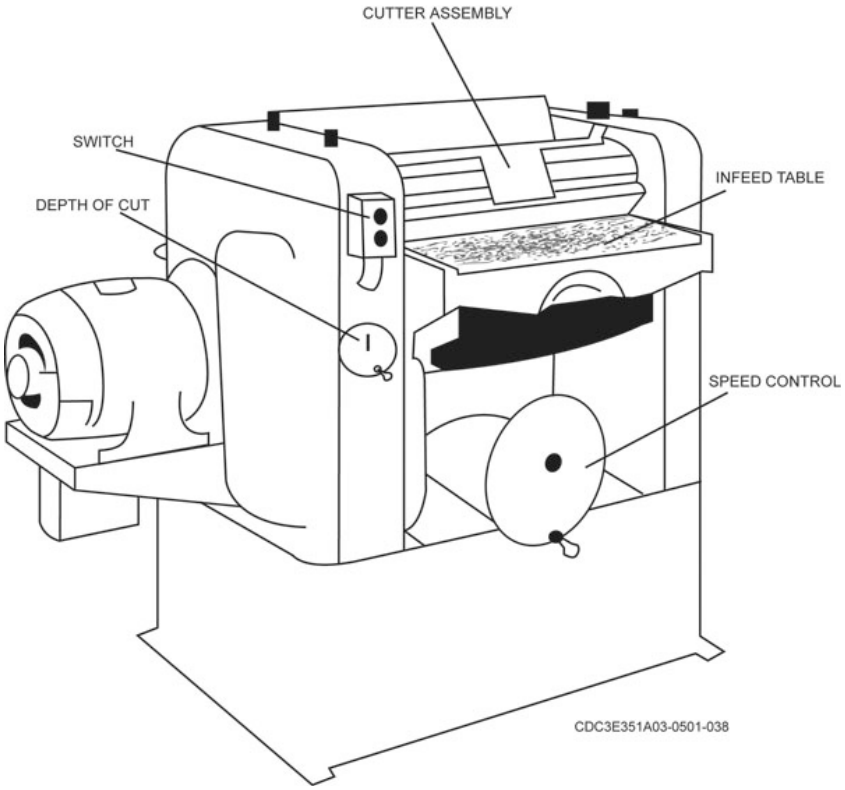


Figure 4–62. Surface planer.

All rollers are geared to the same speed for smooth and continuous board movement. The lower infeed roller is positioned between the infeed and center table. The lower outfeed roller is located between the center table and the outfeed table. The top-rolling surface of each lower roller is slightly above the table surfaces to allow the material to move across the tables without binding or creating excess drag friction. The cutter head is located in an assembly directly above the center table.

The surface planer, alone, cannot remove warp from lumber. The pressure exerted by the rollers temporarily straightens out the warp as it passes through the machine. If you feed warped lumber into the planer, it will come out still warped. If you desire a true plane surface, you must true one face of the warped lumber on the jointer before you feed it through the surface planer. If the lumber has a true surface when it enters the surface planer, it will exit the same way.

Use

The following five steps are one suggested sequence for operating the planner.

1. Set the infeed table to the correct height. Do not plane off more than ⅛ inch at a time.
2. Adjust the feed roll speeds. Use a faster speed for general planing and a slower speed for a finer, smoother cut. Slower speed allows for more cuts per inch of stock.
3. Check the lumber for any loose knots, defects, or any other obstructions before planing.
4. Turn on planer (ensure you wear PPE) and allow the cutterhead to reach full speed. Never start the planer with the lumber in contact with the cutterhead.
5. Keep your hands away from the table and insert the board, being sure to keep it straight. When planing bowed lumber, always turn the concave side toward the table and be sure to cut with the grain.

NOTE: Do not perform any planing on short lumber. The exact size you can plane varies depending on the planer model. Most models do not allow planing on lumber that is 12–14 inches or less.

Maintenance

Refer to the manufacturer's instructions or your supervisor for specific guidance. There are a lot of items on this machine that you must check at specified intervals. Here is a list of some of the common maintenance actions that need checking.

- Check and adjust the table roll height, drive belt tension, and feed roll belt tension.
- Adjust the chipbreakers, pressure bar, outfeed roll, infeed roll, table height scale, and table gibs.
- Inspect the anti-kickback fingers to ensure that they are pitch and gum free.
- Check, reset, and replace knives.
- Level the table.

As you can see, the list is long. Be sure to clean this machine daily to remove sawdust and wood shavings. All other maintenance and repair actions should only be accomplished by an authorized service center.

Shaper

The shaper (fig. 4–63) is a woodworking power tool we primarily use for cutting decorative edges on wood, usually for molding and trim. We also use it to make rabbets, grooves, flutes, and beads. The main parts are a table with a removable throat for the spindle, collars, and cutter knives. It also has a supporting floor base, adjustable guards, and an infeed and outfeed fence (fig. 4–64). The spindle projects vertically through the throat and is usually belt-driven. The speed on floor model shapers is quite high, varying from 5,000 to 10,000 revolutions per minute (rpm) on medium machines. This speed can cause a fatal accident if the operator (you) does not follow proper procedures. Always follow them and use all safety devices and procedures.

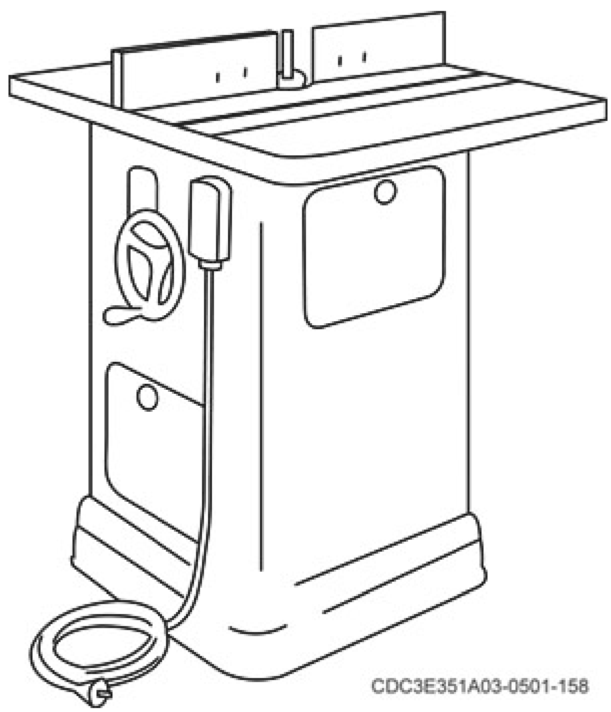


Figure 4–63. Shaper.

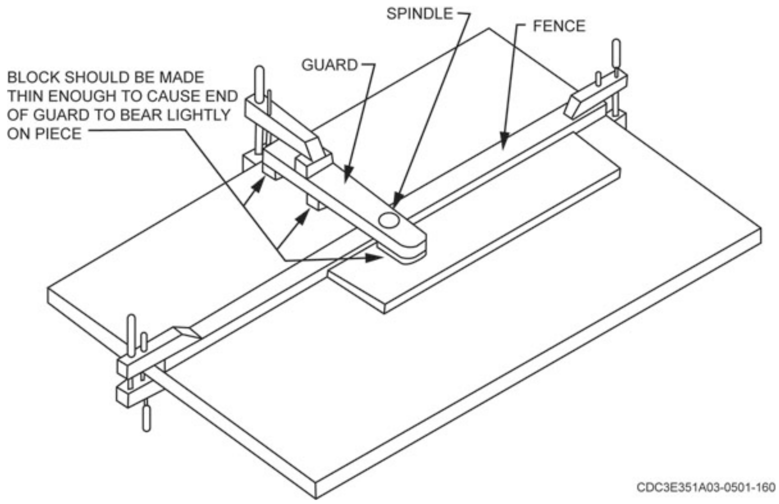


Figure 4–64. Shaper table and fence.

You can install two basic cutter types onto the spindle. One is a three-wing, solid-collar type that fits as one unit. The other is a flat-knife, grooved-collar assembly that is installed in matched pairs (fig. 4–65).

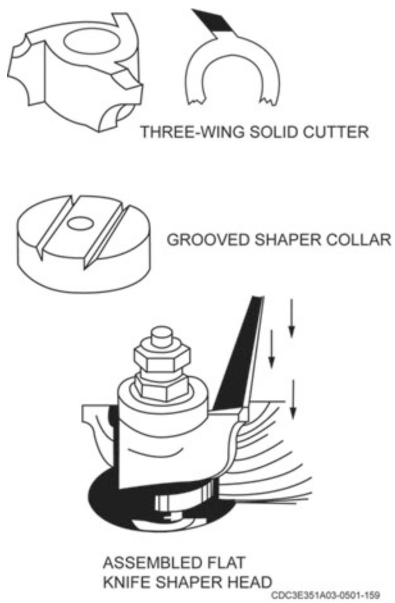


Figure 4–65. Shaper knives.

A hexagonal spindle nut holds the cutters in place on the spindle. A second nut is tightened against the spindle nut and serves as a safety lock. Keep all cutters and knives sharp to ensure quality work. Be very careful when you are placing knives in the grooved collars to avoid unequal pressures or projection of the cutting edges.

If the collars exert more pressure on one knife than on the other, the knives can work loose when the machine is started or running. If one knife extends even slightly farther beyond the other, the assembly will be unbalanced and will vibrate. As with the other machines discussed, you must wear your PPE when operating this tool.

Edge shaping

Here is one method of accomplishing edge shaping.

1. Install the selected cutters on the grooved collar.

2. Adjust the shaper to match the desired cut. Most have an adjustable fence. Others use a wooden straight edge that is clamped to the table.
3. Use a guard over the spindle, if possible.
4. Check all adjustments and any guard, push bar, hold down, or jig that you use.
5. Turn on the shaper.
6. Firmly place the wood against the infeed fence with the wood grain towards the spindle.
7. Steadily feed the wood past the center-mounted spindle and onto the outfeed fence.
8. Turn off the shaper.

End shaping

You must maintain sufficient support of the wood during all shaping operations. It's a good idea to use a miter gauge when end shaping wood that is too short to be supported halfway through the cut. To use the miter gauge when end shaping follow the three steps below:

1. Set the infeed fence parallel to the miter slot and set the outfeed fence so that the wood will not contact it after it has been cut.
2. Place the wood firmly against the miter gauge and the infeed fence.
3. Push the miter gauge to feed the wood into the cutter.

Cross grain shaping

Any time you shape across the grain, the wood usually splinters at the ends of the cut. The slower you feed the wood through the cutter, the less splintering you will have. Be sure to do all cross grain shaping first. Then, shaping with the grain usually removes the splintered ends.

225. Using metalworking equipment

This lesson covers some of the most common types of shop equipment used for metalworking. Other types, such as folding, forming and seaming equipment, we address in future volumes.

Power-operated squaring shears

Power-operated squaring shears (fig. 4–66) provide a convenient means of cutting and squaring sheet metal. Using this tool saves time and increases production.

This machine consists of a lower blade that's stationary on the bed of the shear, an upper blade that's attached to the crosshead, and hold-down clamps (fig. 4–66, A) to hold the metal securely during cutting. The hold-down clamp lets you get your hands out of the way during cutting. The bed of the power shears has extension arms (fig. 4–66, B) to support long sheets of metal. At the left end of the bed is a guide (side gauge, fig. 4–66, C) that is graduated in sixteenths of an inch. This guide can be used as a measuring scale for cutting short lengths of metal. It also keeps the metal square with the blade. The on-off switch (fig. 4–66, D) is mounted on the control box.

The back gauge is not shown in figure 4–66, but is a very useful part of the shear. The back gauge is adjustable forward and backward, depending on the length of metal required. There is no need to measure between the back gauge and the fixed horizontal blade because you can read all measurements on the back gauge, which is graduated in sixty-fourths on an inch. Newer shears have a computerized back gauge with a digital display that makes adjustments easier.

Before turning the power shears on, check the machine to make sure it is clear of material and people. The machines you use have guards for your protection; *never* remove them, except when the machine is being repaired. The blade safety guard isn't visible in figure 4–66, F because it's between the hold-down and cutting blade. The blade guard is designed to keep your hands and fingers away from the cutting blades as you operate the machine. Wheel and belt guards are there to protect people and to keep foreign objects from being caught in the moving parts.

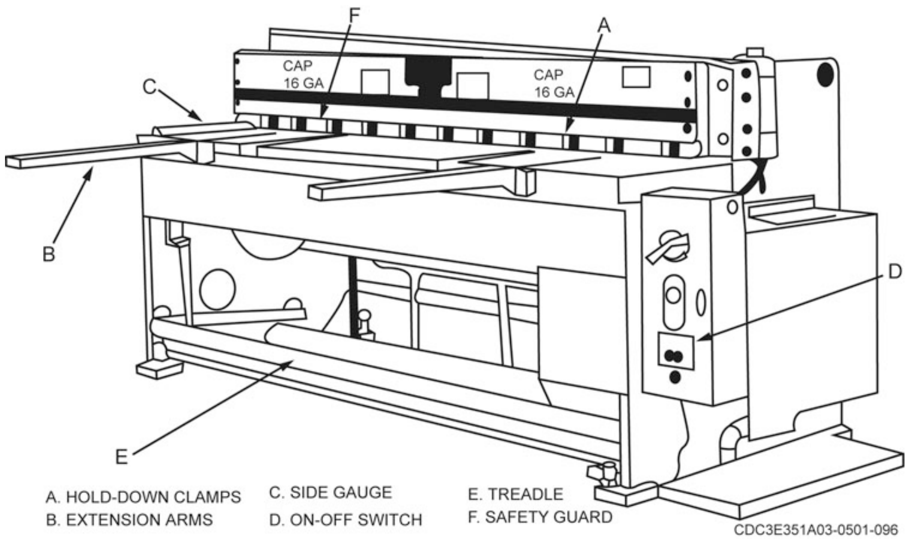


Figure 4–66. Power-operated squaring shear.

Use

Here are four suggested steps to cut sheet metal.

1. Make certain the cutting blades are clear, start the motor by depressing the on switch and set the back gauge.
2. Then place the metal to be cut in the shear.
3. Make sure the motor reaches full speed before you step on the treadle to cut the metal (fig. 4–66, E). Depressing the treadle engages an automatic clutch that sets the shearing blade in action. When set for single, the shear goes through only one cycle of action each time you depress and release the treadle. For continuous operation, move the clutch shift crank to multicut and simply continue holding the treadle in the down position. Once the treadle is released, the machine stops when it completes the cycle of operation.
4. Be sure to turn off the shear after you make all cuts and remove the material that you just cut.

Manually operated squaring shears

These shears are similar to power-operated squaring shears except that your foot supplies the action and power to operate the cutting blade. In addition, the back gauge and hold-down handles are manually operated. There are quite a variety of foot-operated shears, but basically they’re all made the same. If you can operate one successfully, you can operate the others.

The shear in figure 4–67 has a large spring at each end of the housing to raise the blade when pressure is removed from the treadle. A scale, which is graduated in fractions of an inch, is scribed on the bed as a guide for cutting correct lengths. At each end of the bed is a side gauge to help keep the metal square with the blades. If you notice that after several cuts that the cut is not square, the error could be yours or the side gauge. If it’s the side gauge, report it to your supervisor to get it readjusted. If you need to cut long sheets of metal that you must push from the backside, use the extension arms in conjunction with the front gauge. The sheet metal limit for manually operated shears is usually 16-gauge mild steel. Check the manufacturer’s data plate attached to the shear for the exact capacity. To check the thickness of the metal that you are about to cut, use a sheet metal gauge tool like the one illustrated in figure 4–68.

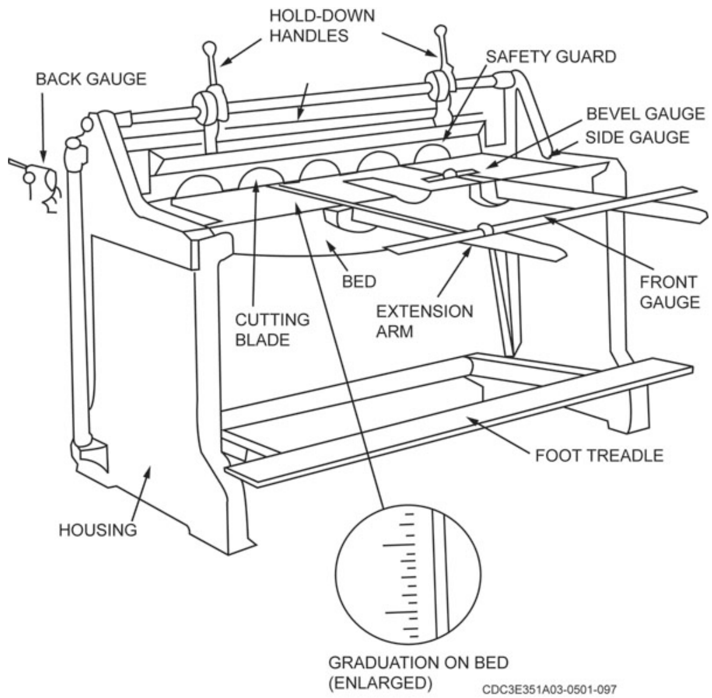


Figure 4–67. Manually operated squaring shear.

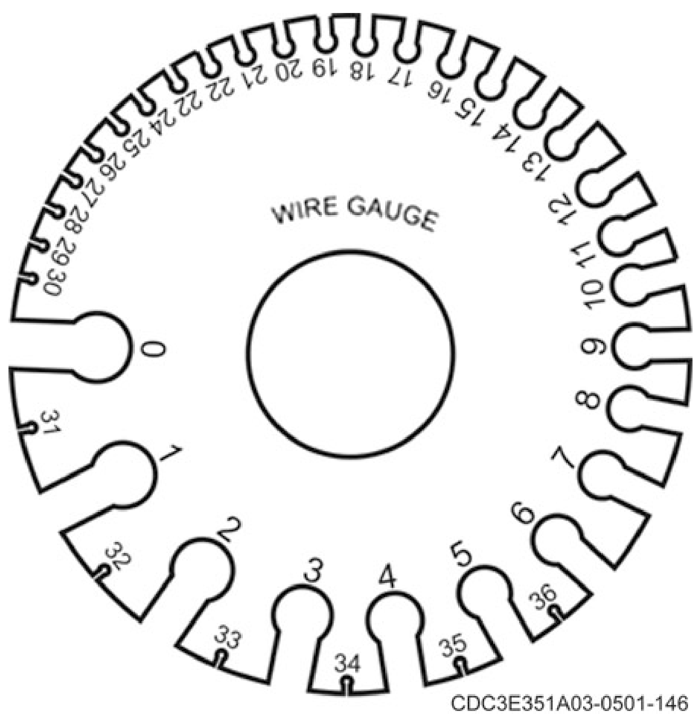


Figure 4–68. Sheet metal gauge tool.

The hold-down attachment on foot-operated shears can be either spring actuated or manually controlled. The squaring shears do many necessary jobs that save a great deal of work—jobs such as cutting to a line, squaring, and multiple cutting to a specific size.

Use

To cut to a line follow the next four steps.

1. Place the sheet on the bed of the shear in front of the cutting blade.

2. Place the cutting line even with the cutting edge of the bed.
3. Pull the hold-down handles forward to lock the metal in place.
4. Then cut the material by stepping on the treadle to start the cutting cycle.

Squaring a piece of metal takes a couple steps.

1. Trim one edge by inserting the metal between the shear blades and cutting off about a quarter of an inch of metal.
2. Then, hold each trimmed edge against the side gauge to make the remaining cuts, one edge at a time, until all edges are square.

When you cut several pieces of metal to the same dimensions, use the back gauge (production gauge). It consists of two support rods that are graduated in fractions of an inch and a squaring fence that can be set at any point on the support rods. To use the gauge follow the next three steps.

1. Set the squaring fence at the desired distance from the cutting blade by loosening the locking knobs and turning the adjusting knobs.
2. Lock the fence in position after you make all adjustments and insert the metal between the blades of the shear until the edge of the metal contacts the squaring fence.
3. To ensure accuracy of the cut, be sure that the edge of the metal is flush all along the fence. When you do this, pull the hold-down handles to clamp the metal. Successful use of this gauge depends on a few predetermined adjustments. Once you make the gauge adjustments, you can cut many pieces of metal to the same dimension without additional measuring.

Safety precautions

Safety precautions for using manually operated squaring shears are practically the same as those for power operated squaring shears. One exception is that when you push down on the foot treadle (which requires considerable force), be sure your other foot is clear of the foot treadle.

Gap squaring shears

The gap squaring shears illustrated in figure 4–69 resemble manual squaring shears except the frame is built to accommodate any width or length of sheet metal for slitting. The front opening, or gap, is usually about 18 inches deep for shears with a capacity of 16-gauge mild steel. Because of its construction, the gap-squaring shear is larger than a squaring shear of the same capacity.

Use

Constructed as they are, you can use these shears to cut one piece or several pieces from a sheet of metal that is longer than the machine itself. You can do this by following the four steps beow.

1. Adjusting the front gauge to the desired width, making sure that the gap is deep enough to allow easy passage of the metal.
2. Move the metal between the cutting blades from left to right, set the hold-down levers and make cuts about three-quarters the length of the blade.
3. Release the hold-down levers and move the sheet to the right so that the edge of the metal rides against the guide.
4. Repeat this step until you complete the cut.

Most cutting jobs that you can do on a squaring shear you can do on a gap-squaring shear, but the gap-squaring shear makes more types of cuts than the squaring shear. Safety precautions for operating gap-squaring shears are like those precautions for manually operated squaring shears.

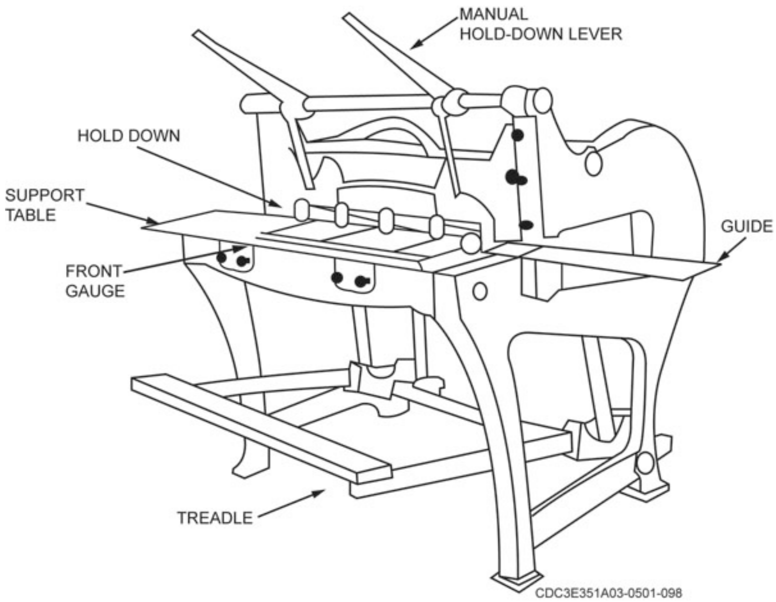


Figure 4–69. Gap squaring shear.

Circle shears

Circle shears, which we illustrate in figure 4–70, are used to greatest advantage in cutting circular blanks for such items as buckets, cans, and the usual run of cylindrical objects. They are also used for slitting sheets and have a guide for that purpose. Circle shears are best suited for cutting discs from mild steel, copper, and aluminum.

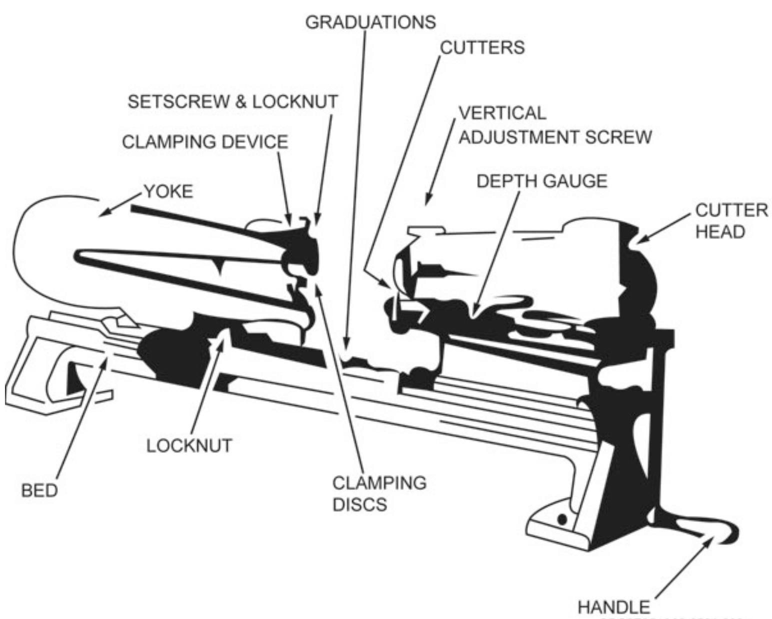


Figure 4–70. Circle shears.

The principal parts of the circle shears are the bed, yoke, and rotary cutters. The bed, since it must absorb and withstand the majority of the load and shock, is made of a strong steel plate. On the top of this bed are graduations every sixteenth of an inch to indicate the approximate diameter of the circle you are cutting. The yoke, or sliding circle arm, centers and holds the sheet. The position of the yoke is governed by the diameter of the cut.

To adjust the yoke, loosen the locknut (usually at the base of the yoke) and slide it along the bed. Attached to the yoke is the clamping device, which you operate with a clamping handle. Setscrews and locking nuts adjust the pressure on the clamping devices, and a hardened center pin in the lower disc helps you center blanks of center-punched metal.

You can adjust the upper rotary cutter on this machine vertically; it should overlap enough to cut through the metal in one cut. Usually the adjusting screw is directly above the upper cutter. You can adjust the bottom cutter the same way, but laterally. For light-gauge metal, the cutters should just touch and operate freely. To cut heavy material, the cutters should be separated slightly, but no more than 10 percent of the metal thickness.

Use

When you cut circular blanks with circle shears complete the following four steps.

1. Cut the metal to rough size.
2. Place the blank between the clamping discs and adjust the yoke so the distance from the center of the clamping discs to the cutting wheels is half the diameter of the blank desired.
3. Adjust the upper cutting blade with the vertical adjustment screw.
4. Stand to the side of the shears with the cutting head to your left when you operate the machine handle, so that the sheet metal feeds away from you.

Don’t try to cut inside circles with this machine and always start the cut from the edge of the sheet. Safety precautions for using circle shears include such things as keeping fingers from the cutters, gears, and burrs.

Ring and circle shears

The basic construction of ring and circle shears (fig. 4–71) is like that of rotary circle shears. The main difference lies in the lower cutting head, which is set at an angle to the upper cutter. This permits cutting inside circles as well as discs and shallow concave curves. Lateral adjustment between the cutters is the same as for circle shears. Turn the adjustment handle left or right to get proper clearance between the cutters. Before you cut outside discs with ring and circle shears, be sure to read the operational procedure for the circle shears.

Cutting inside circles

To cut an inside circle or hole in a sheet of metal complete the following three steps.

1. Adjust the yoke of the ring and circle shears so the distance from the center of the sheet to the cutter wheels is half the diameter of the desired circle.
2. Place the metal between the clamping discs and secure it by lowering the clamping handle.
3. Slowly turn the upper cutter adjustment handle clockwise. When you cut with the ring and circle shears, turn the operating handles clockwise so that the material is fed away from you.

NOTE: Don’t lower the upper cutter any farther than is necessary to cut through the metal. Set the locknuts on the upper cutter adjustment handle so that the upper cutter produces a clean cut.

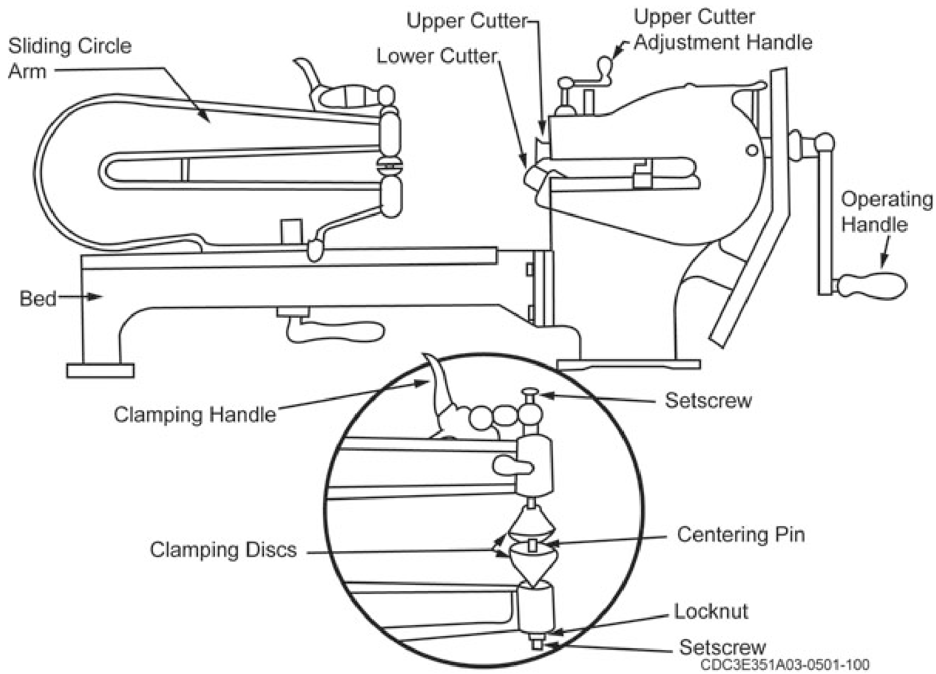


Figure 4–71. Ring and circle shears.

Safety precautions

Safety precautions for ring and circle shears are like those for circle shears, but power-operated ring and circle shears require the following additional safety precautions.

- Keep clear of the sheet metal as it revolves during the cutting process. Move the foot switch away from the machine to help you stay clear.
- Take precautions to not accidentally depress the foot switch. If the switch is accidentally actuated, the power-operated ring and circle shears may damage the material and endanger the operator.
- Do not wear loose clothing.

Power cutoff saw

The cutoff band saw in figure 4–72 is a shop-installed machine we use to cut angle iron, bar stock, and heavy plate. There are various models with different operating procedures.

Use

The following stps are the four basic steps to make a cut.

1. Raise the blade above the material that you intend to cut.
2. Secure the material between the vise jaws to prevent the blade from binding or breaking during cutting (fig. 4–72, B, C). To apply pressure to the vise jaws, you must turn the vise handwheel.
3. Start the saw and adjust the raise-and-lower handle to bring the blade down slowly until it starts to cut.
4. Adjust the feed pressure control if necessary for the best cutting speed for the job.

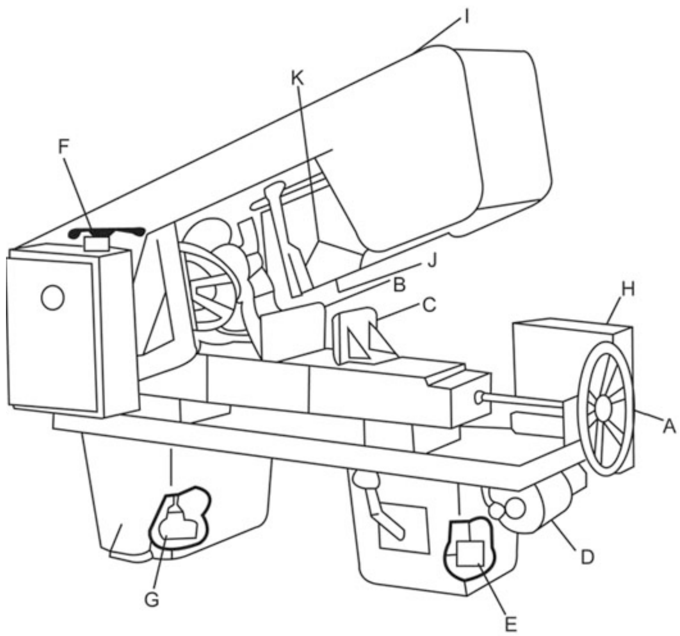


Figure 4–72. Power cutoff saw.

You can make angle cuts by changing the position of the vise jaws. This kind of saw is operated by hydraulic pressure supplied by the motor and pump assembly (fig. 4–72, D). The hydraulic pressure powers the hydraulic cylinder to raise and lower the cutting blade and apply feed pressure. When the cut is complete, the limit switch turns the machine off automatically. Remove the cut material from the saw and clean the saw and area. Be sure to follow the manufacturer's recommendation for saw blade coolant fluid. To save time when making multiple cuts, use the adjustable stop.

Ironworkers

These machines are used to shear thick steel plate, punch holes in heavy stock, cut pipe and angle, and notch all types of ferrous and nonferrous metals. Many ironworkers also have stations for notching flat stock or angle iron, and stations for bending flat stock and pipe or tubing.

Use

The following information is general in nature. Refer to the manufacturer's instructions for the machine in your shop. (**NOTE:** Never attempt to punch or shear hard or high-tempered materials.)

Punching

Always refer to punching and notching specifications in the manufacturer's instructions to determine the maximum size hole that you can punch in various sheets of metal. Keep in mind that stainless steel has approximately 40 to 50 percent greater shear strength than mild steel. This greatly reduces the punching capacity of your machine.

There is a ratio between the thickness of metal being punched and the punch size. For mild steel, the punch diameter must be equal to or more than the thickness of the metal being punched. As the shear strength increases or decreases, the ratio changes. (**NOTE:** Using a wrong-sized punch may cause it to explode, resulting in serious injury or death.)

The die size must be larger than the punch by approximately 10 percent the thickness of material being punched. Thus a ½-inch-thick plate (0.5 inch) would require a die 0.05 inches larger than the punch. Using a too large die will leave burrs around the holes.

After installing the punch and die, you must check for proper alignment. Keep adjusting (i.e., rotating) the punch 90° until it has proper alignment.

Shear bar

When using the shear bar, you must be sure that all shields and guards are in place. When you shear flat or angle bars, adjust the hold down screws to allow for a close slip fit. This way there is not any undue looseness, but the material can still be fed (i.e., slipped) through.

Maintenance

General maintenance procedures include the following:

- Ensuring all shields are cleaned and installed properly.
- Lubricate the machine in accordance with manufacturer's instructions.
- Keep punches sharp and lubricated.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

223. Using dual purpose shop equipment

1. What type of training must you receive on all machinery or equipment that you are required to use?

2. What must supervisors do in order to ensure safe operations of all machines and equipment under their control?

3. What could result if you sand or polish magnesium on a sanding machine?

4. How much clearance should be maintained between the table and abrasive disc on a sanding machine?

5. What are the procedures you use to install a drill bit into a drill press?

6. What is the suggested method for boring through long pieces of wood using the drill press?

7. Which type of bit do you *never* use on a drill press?

8. As a general rule, how much tension is placed on the V-belt of a drill press?

9. How do you stop a band saw blade after you turn the bandsaw off?

10. When using a bandsaw, the blade guide should be at what distance above the material being cut?

11. What do you do to keep from binding the blade when making freehand curve cuts on a band saw?

12. What distance must the tool rest be away from the grinding wheel on a stationary grinder?

13. What do you do during the initial startup of a stationary grinder?

14. What results when you exert too much pressure when dressing a grinding wheel?

224. Using woodworking equipment

1. How do you use the fence when performing crosscutting on the table saw?

2. When performing normal ripping operations on the table saw, at what height do you adjust the blade?

3. Where do you stand when operating the table saw?

4. What precautions must you take when ripping boards over 36 inches in length with a table saw?

5. When performing crosscutting operations with the radial arm saw, to what height do you set the blade?

6. When ripping lumber on the radial arm saw, how do you adjust the kickback assembly?

7. When ripping lumber on the radial arm saw, what could result if you push the wood through with the blade rotation?

8. When edge joining lumber over 1 ½ inches wide on the joiner, how do you set the cut depth?

9. When using the joiner, what action do you take if you notice the cut is progressively shallower toward the end?

10. In what direction must you feed work into the jointer?

11. When using the surface planer, how much material can you shave off at a time?

12. When using the surface planer, what speed produces a finer cut? Why?

13. What do you use when you must end shape lumber that is too short to be supported halfway through the cut?

14. In what sequence do you shape lumber to avoid splintering when both the cross grain and with grain edges are to be shaped?

225. Using metalworking equipment

1. What is the first step that you take before turning on the power shears?

2. What parts of the shear are safety items that you must not remove?

3. What must you depress to begin the cutting action of the power shear?

4. What is the last step in a power shear cutting operation?

5. On a manual squaring shear, what is the purpose of the large springs mounted on each end of the blade?

6. On a manual squaring shear, what is usually the maximum capacity sheet metal that can be cut?

7. What item on a manually operated squaring shear do you use when cutting several pieces of metal to the same dimensions?

8. When cutting metal that is longer than a gap-squaring machine, how much material can you cut at a time in relation to the size of the blade?

9. When cutting circular banks on a circle shear, at what distance do you adjust the yoke?

10. When cutting with the ring and circle shears, how do you turn the operating handles?

11. When you use the power operated cutoff band saw, what must you do to keep the material from binding and breaking the blade?

12. What do you turn to apply pressure to the vise jaws?

13. How do you control cutting speed of a power cutoff saw?

14. When using the ironworker, what size punch is needed to pierce mild steel?

15. On an ironworker, what size die do you use in relation to the punch?

4–4. Safety

Accidents are costly. Money spent on materials and manpower for recovering from accidents is a waste and not redeemable—even if no personal injury is involved, materials damaged by unsafe acts are costly to the Air Force. Injury and material loss are only two of the many factors involved when an accident happens. Other factors involved are the efficiency of the organization, morale, and, if enough accidents occur, the good relations between an organization and other units.

226. Occupational safety and health

A standard dictionary defines the word "accident" as "an event that takes place without foresight or expectation." This definition indicates that adequate foresight prevents most accidents. In this lesson, you will learn about workplace safety and the occupational safety and health program.

Causes of accidents

Natural phenomena such as lightning cause only two percent of all accidents, physical hazards such as falling down stairs account for 10 percent, and unsafe acts of people account for 88 percent of the accidents. Many times, such unsafe acts include horseplay and improper work procedures.

People involved in unsafe acts or who allow unsafe conditions to exist cause accidents. The Air Force Occupational Safety and Health (AFOSH) instruction 91-203 covers many rules of safety pertaining to you. Included are major topics such as shop safety and personal protective equipment to name a couple.

Obtain a copy of this instruction and study the portions that apply to you and your work. This effort will be valuable to you throughout your career and even into your retirement. SAFETY IS IMPORTANT! Learn the rules and apply them to your daily work.

Accident prevention methods

There are three principal methods of accident prevention (1) physical modification, (2) education and training, and (3) enforcement of safety standards.

Remember, accidents are *preventable*. They do not happen without cause. If you identify and eliminate the cause, you eliminate the accident.

Physical modification

For example, suppose a utilities system journeyman is operating a water processing plant and he cuts a 3-foot by 8-foot hole in the floor for a plastic drainpipe. He needs two days to complete the job. At the end of the days, he leaves the hole without covering it or erecting a safety barrier (i.e., physical modification). More than likely, someone will fall in and get hurt. Other examples of physical modification include using machine guards, handrails, and walk boards.

Education and training

A second method of preventing accidents is education and training. This is an effective means of preventing individuals' unsafe acts. Through adequate instruction, personnel gain useful knowledge and develop safe attitudes. You can educate people by placing safety suggestions on the bulletin board, passing safety literature to each plant worker on a frequent basis, presenting training in a group situation, using movies and slides in a classroom, and assigning self-study using Air Force and commercial publications. Training to develop skills on specific machines supplements and broadens safety consciousness developed through education. Training develops habits of safe practice and operation.

Enforcement of safety standards

The third method of preventing accidents is the strict enforcement of safety standards. Some people are a hazard to themselves and others because they consistently fail to comply with accepted safety standards. For these persons, strict enforcement of safety practices is necessary. The person who drives 100 mph when traffic laws call for 65 mph is bound for trouble. Eventually, excessive tickets for speeding cause licenses to be revoked. Worse yet, a traffic accident damages vehicles and can injure or kill people.

Each supervisor is responsible for enforcing safety standards and regulations in the work area. When supervising Structural personnel, ***you*** are responsible for the safe conduct of those workers. If you do not enforce safety directives, you condone conduct that leads to accidents and are as much to blame for the accident as those involved.

Occupational Safety and Health Administration

On December 29, 1970, the Occupational Safety and Health Act (OSHA) of 1970 established the Occupational Safety and Health Administration to ensure the safe and healthful working conditions for working men and women.

Air Force Occupational Safety and Health

The Air Force fulfills OSHA requirements through its AFOSH standards. This allows the Air Force to regulate its safety program in much the same way a state implementation plan (SIP) allows a state to regulate an environmental program.

Supervisory responsibility

All supervisors must recognize potential mishap factors in the workplace. Supervisors shall not require personnel to work in environments and conditions that are hazardous to their safety or health without first providing adequate engineering and administrative controls or personal protective equipment (PPE). Supervisors must do the following:

- Ensure safe working conditions.
- Provide necessary protective equipment.
- Ensure required guards and protective equipment are provided, used, and properly maintained.
- Ensure tools and equipment are properly maintained and used.
- Plan the workload and assign employees only to jobs they are qualified to perform.
- Ensure the employees understand the work to be done, the hazards that may be encountered, and the proper procedure for doing the work safely.
- Take immediate action to correct any violation of safety rules observed or reported to them.
- Ensure workers exposed or potentially exposed to hazardous chemicals or materials are trained on the hazards of those chemicals and materials.
- Conduct Job Safety Analysis (JSA) of job tasks whenever required to ensure a safe work environment.

NOTE: You accomplish a JSA when you install new equipment, relocate equipment, or implement new procedures in critical or hazardous operations.

Safety education

Education and training help prevent accidents. The goals are to instill safe attitudes and teach workers to handle tools, equipment, and chemicals safely. Conducting safety meetings, posting safety suggestions on the bulletin board, and distributing safety literature through the organization are components of a good safety education program.

An ongoing requirement of any good safety program is regular safety briefings. Supervisors should give *new* workers a safety briefing every day and the *entire* shop should be briefed weekly.

If a worker does *not* seem to understand procedures given by the supervisor, the supervisor should have the worker state the procedures—especially if the job involves any special hazards. Safety is a two-way street. The supervisor briefs new workers, but new workers must ask questions when they don’t understand.

227. Safe work practices

Although much of the work we do as Structural Journeymen entails some degree of risk, we must be especially concerned with safety on the job and while in the field, and recognize its inherent hazards. To protect yourself as much as possible, use protective equipment when it is prescribed and keep your tools in good working order. You must also ensure that you follow prescribed safety standards. In this lesson, you will learn about hazard abatement and AFS specific safety.

Hazard Abatement

A hazard is any existing or potential condition, act, or procedure that results in a mishap. There are three areas to hazard abatement—identifying, reporting and correcting.

Identifying

There are hazards involved with every job and with every tool. It's your supervisor's responsibility to determine where people may be injured or equipment damaged prior to starting any new task or training. They do this by conducting a job safety analysis (JSA). The supervisor *must* use a JSA to evaluate each work task *not* governed by a technical order (TO) or other definitive guidance and when a new work task or process is introduced into the workplace. The JSA can be used to evaluate both industrial and nonindustrial operations and processes. There are many different methods used to conduct a JSA; however, the installation ground safety staff can provide guidance in getting a JSA started.

After performing the analysis, your supervisor knows what hazards are present in the workplace and can determine appropriate measures to ensure work center personnel and equipment safety, as well as focus on mission success. If unsafe and unhealthful working conditions exist, your supervisor *must* eliminate or control them through engineering, substitution, isolation, administrative controls, revised procedures, special training, or the use of PPE. Using the information gathered during the JSA, your supervisor is then ready to create a job safety training plan that will be used to educate you and your coworkers.

Reporting

Each supervisor and individual is required to report unsafe conditions and actions that violate standards and pose a risk to operations. You are highly encouraged to use the chain of command, but your right to a safe work environment allows reports to be sent directly to the safety, fire, or health management office that supports your installation or site. The official method to report a hazard is to submit AF IMT 457, USAF Hazard Report. If you eliminate a hazard on the spot, there is no need to report it. However, when the hazard cannot be eliminated (or abated) immediately, the program provides an avenue for investigation, validation, monitoring, and follow-up until corrective action is complete. All units set up procedures for reporting mishaps to the safety staff. Learn these procedures so that if you witness or are involved in a mishap, you can report it promptly and properly.

Correcting

To abate (correct) a hazard is to control or eliminate its existence. Air Force safety engineers review specifications and drawings to control and eliminate unsafe conditions during the design phase. However, every member of the Air Force team has a vital, continuing role to identify and eliminate unsafe acts and conditions. Supervisors, commanders, and functional managers are responsible for controlling or eliminating identified hazards to prevent mishaps. If a mission-essential task must be accomplished before a hazardous condition is permanently corrected, interim controls can be approved until final corrective actions are completed.

The interim controls must effectively minimize the hazard for the length of the task. A supervisor's role is to track abatement (corrective) actions and implement interim control measures as appropriate. Installation fire, safety, and health officials are required to assign a risk assessment code (RAC) to each occupational hazard based on mishap severity and probability of occurrence. Functional managers should use RACs to prioritize corrective actions on a worst first basis.

Operating power tools and equipment

Equipment with exposed moving parts, such as belts, chains, flywheels, moving arms, and so forth, can be a serious safety hazard.

Machine guarding

All parts such as flywheels, pulleys, belts, chains, clutches, and so forth that are less than 8 feet off the floor must have a guard to cover them. The guards are designed to give maximum operator protection without interfering with normal equipment operation. To permit easy access, machine guards should be designed with hinged or removable sections. While you're working around moving parts that have guards, you must still stay alert.

Power tools

The power tools you will be working with are electrical, pneumatic, or hydraulic. Follow these safety rules for all power tools.

- Never operate any power tool, unless you're trained on its use and are *completely* familiar with it.
- Inspect all power tools before you use them. They should be clean and in good condition.
- Make sure the work area is well lit. *Don't* operate power tools if you can't see clearly.
- Make sure the tool is turned *off* before you connect it to a power source.
- When you use a power tool, give the tool your full and undivided attention.

NOTE: Do *not* distract or disturb another worker who's operating a power tool.

- Always disconnect a power tool from the power source before cleaning or adjusting the tool.
- Before plugging an electric power tool into a power source, make sure the power source is the right voltage and current for the tool.
- Make sure the power source for a hydraulic or pneumatic tool is the right pressure for the tool.
- Never use a tool that has a damaged cord or hose.
- Do *not* let power cords or hoses contact sharp objects, hot surfaces, oil, grease, or chemicals, and *don't* let them become kinked.
- Check electrical cords frequently for overheating; use *only* approved extension cords.
- Place cords and hoses so that they *won't* become tripping hazards.
- Do *not* use electric tools in areas where water is present.

Safety precautions

Use common sense as you work near moving equipment. Do *not* wear rings, jewelry, gloves, neckties, or loose clothing (i.e., particularly large loose sleeves) around moving machinery. Visualize what happens if you catch your sleeve in a drive belt or chain—you may be injured or killed. Do any adjustment, cleaning, lubrication, or repair of moving machinery with the power turned *off* (lockout/tag out).

Performing lockout/tagout procedures

Lockout is the process of blocking the flow of energy from a power source to a piece of equipment, and keeping it blocked out. You accomplish lockout by installing a lockout device at the power source so that equipment powered by that source is *not* operable. A lockout device is a lock, block, or chain that keeps a valve or lever in the off position.

You accomplish tagout by placing a tag on the power source. The tag acts as a *warning* not to restore energy—it is *not* a physical restraint. Tags must clearly state "*Do Not Operate"* and *must* be applied by hand.

If the switches are in another room or area, padlock and tag the switch box (lockout/tagout) to prevent unintended operation. This keeps the equipment from energizing until all workers on the job are finished. To be sure you're following the right procedures, talk to your supervisor or the squadron safety NCO.

NOTE: Each specialist working on a piece of equipment that has electrical power supplied is required to follow their unit's specific lockout/tag out procedures *before* work begins.

Only authorized personnel shall perform lockout and tagout procedures.

NOTE: The information presented here is *not* intended to replace the procedures used in your unit.

The following is the sequence of the lockout or tagout procedure.

1. Notify all personnel that a lockout or tagout system is going to be used and the reason.
2. Ensure the individual knows the type and magnitude of energy that the machine or equipment uses and understands the hazards it presents.
3. If the machine or equipment is operating, shut it down using the normal stopping procedure. If the machine only has a simple wall plug as the power source, it must be unplugged and tagged with an AF Form 979, Danger Tag, or AF Form 982, Danger Tag: Do Not Start.
4. Operate the switch, valve, or other energy isolating devices so the equipment is isolated from its energy sources. Dissipate or restrain stored energy by methods such as repositioning, blocking, and bleeding down to name a few.
5. Lockout or tagout the energy isolating devices with assigned individual locks or tags.
6. After ensuring that no personnel are exposed, operate the push button or other normal operating controls to make certain the equipment will not operate and to relieve any stored or residual energy as a check on having disconnected the energy sources.

   CAUTION: Return operating controls to "neutral" or "off" position after the test.
7. The equipment is now locked out or tagged out.

Using hand tools

You will encounter many different types of hand tools during your Air Force career. Here we will discuss basic safety precautions you need to be familiar with; review the following list.

- Keep each tool in its proper storage place. A tool is useless if you cannot find it. If you return each tool to its proper place, you will know where it is when you need it.
- Keep your tools in good condition.
- Keep them free of rust, nicks, burrs, and breaks.
- Keep your tool set complete. If you are issued a toolbox, place each tool in it when not in use. If possible, lock and store the box in a designated area. Keep an inventory list in the box and check it after each job. This will help you to keep track of your tools.

Use each tool only on the job for which it was designed. If you use the wrong tool to make an adjustment, the result will probably be unsatisfactory. For example, if you use a socket wrench that is too big, you will round off the corners of the wrench or nut. If this rounded wrench or nut is not replaced immediately, the safety of your equipment may be endangered in an emergency.

Be sure that you keep your tools within easy reach and where they cannot fall on the floor or on any machinery. Avoid placing tools anywhere above machinery or electrical apparatus. Serious damage may result if the tool falls into the machinery after the equipment is turned on or running.

NOTE: Return broken tools *immediately* to your tool equipment custodian. Never use damaged tools. Notify your supervisor of broken or damaged tools.

Remember, a worker's efficiency is often a direct result of the condition of the tools being used. Workers are often judged by the manner in which they handle and care for their tools. You should care for hand tools the same way you care for personal property. Always keep hand tools clean and free from dirt, grease, and foreign matter. After use, return tools promptly to their proper places in the toolbox. Improve your own efficiency by organizing your tools so that those you use most frequently are easily reachable without sorting through the entire contents of the box. Avoid accumulating unnecessary items.

Working from heights

Structures personnel work on all varying building components throughout the base. Anytime you work on an area where the potential to fall at least 6 feet or more, you must ensure fall protection is used. Fall protection encompasses many different items—guardrails on ladders and scaffolds, personal fall arrest systems, safety nets and warning lines. You'll learn about ladder and scaffold safety in a later lesson, so we'll just focus briefly on the other types. For more specific information, refer to AFOSH Standard 91–203, *Air Force Consolidated Occupational Safety Instruction.*

Personal fall arrest systems

You need to ensure that lifelines, safety harnesses, and lanyards are only used as a safeguard to keep from falling. Obviously, you'll want to make sure that all parts of the system are in good repair and inspected IAW AFOSH Standard 91–203. The service life of fall protection equipment manufactured of synthetic fiber shall be five years or sooner if determined unserviceable.

Safety nets

Safety nets are used when workplaces are more than 25 feet above the ground or other surfaces where the uses of ladders, scaffolds, catch platforms, temporary floors, or personal fall arrest systems are impractical. If a safety net is required, it must be able to catch an object that weighs 400 pounds. You must test the net before work begins. A couple requirements are that the net shall extend 8 feet beyond work area edges and shall *not* be greater than 25 feet below the work surface.

Warning lines

Warning lines are typically used in low-slope roof operations. They are posts (stanchions) with rope, wire, or chain strung between them. They must be flagged every 6 feet and have a 500 pound breaking strength. The posts must not tip over unless more than 16 pounds of pressure pulls or pushes them. You want to be sure that the lines are at least 34 to 39 inches from the roof's surface and placed 6 feet from the roof edges or 10 feet from the edges in the direction of travel if using mechanical equipment.

Lifting manually

Workers often hurt themselves while picking up heavy equipment and supply boxes. If a box is too heavy to carry comfortably, divide the supplies into two or more boxes that are easier to handle. Use common sense in moving objects. If an object is too heavy or cumbersome to lift, ask someone to help you. If you decide you can lift a heavy load, use the proper lifting technique to do it.

To prevent a serious back injury *use your legs—not your back* to lift a heavy or bulky object from the floor. An injured back heals very slowly and keeps you from participating in many work and athletic activities. If you take the following precautions in lifting, you can greatly reduce your chances for an injury (fig. 4-73).

1. Consider the size, weight, and shape of the object you want to carry.
2. Never carry a load that you cannot see over or around. Make sure the path of travel is clear.
3. Do not lift more than you can handle comfortably, if necessary get help.

4. Set your feet solidly, with one foot slightly ahead of the other for increased stability. Place your feet far enough apart to assure good balance.
5. Get as close to the load as possible. Crouch and bend your legs at the knees.
6. Keep your back as straight as possible. It does not have to be vertical, but do not arch it. Bend at the hips, *not* the middle of the back.
7. Grip the object firmly. Maintain your grip while lifting and carrying the object to the desired location.
8. Straighten your legs to lift the object and bring your back to a vertical position at the same time.
9. To set an object down, reverse the procedures used to pick it up.

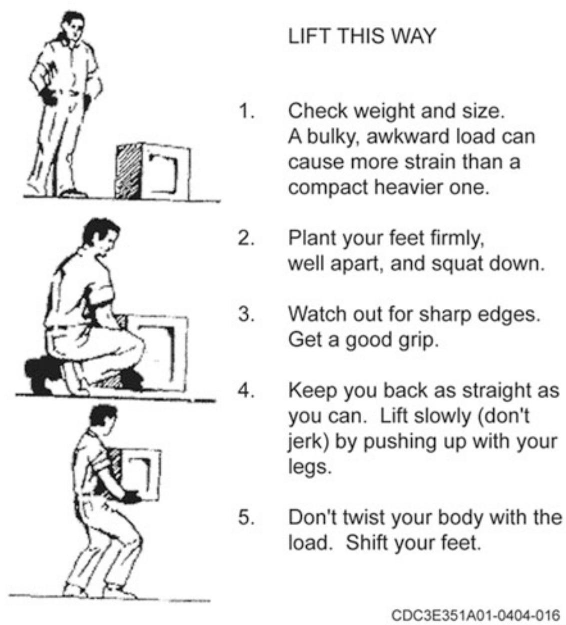


Figure 4-73. Proper lifting procedures.

Handling compressed gas containers

Each compressed-gas cylinder carries markings indicating compliance with Interstate Commerce Commission requirements. When the cylinders are at your work site, they become your responsibility. The following list identifies several things you *must* remember when handling and storing compressed-gas cylinders.

- Never alter or fix the safety devices on a cylinder—it is illegal. The only personnel permitted to work on cylinder safety devices are the cylinder owners and suppliers.
- Never store cylinders near a heat source or in direct sunlight. Heat causes the gas inside a cylinder to expand. This could result in cylinder failure or fire.
- Never store cylinders in a closed or unventilated space. If one of the cylinders were to leak, it could cause an explosion or asphyxiate someone entering the space. You must always store cylinders in protected, well-ventilated, and dry spaces. Protect the cylinder valves and safety devices from ice and snow. A safety device may not work if it is frozen.
- Never store fuel cylinders and oxidizers within the same space. Oxidizers must be stored at least 50 feet from fuel cylinders. Use fire-resistant partitions between cylinder storage areas.
- Never mix empty cylinders with full cylinders. Do not mix cylinders that contain different gases.

- Always replace the cylinder cap and mark the cylinder “Empty” or “MT.” Store the cylinders in a cool, dry place ready for pickup by the supplier. Even in storage, chain the cylinders when they are stored in the upright position.

When it comes time to move a cylinder, be sure that you *never* drag it. When available, use a cylinder hand truck. If possible, leave the cylinders on the hand truck and operate them from there; otherwise, tilt the cylinder slightly and roll it on the bottom edge. ***Always*** install the cylinder cap before moving the cylinder. Never use slings or magnets to carry cylinders. If a cylinder is dropped and the valve breaks, it could launch the cylinder like a rocket. When cylinders have been stored outside in freezing weather, they sometimes become frozen to the ground or to each other. To free the cylinders, you can pour warm water (not boiling) over the frozen or icy areas.

Handling corrosive materials

Corrosive materials can come as liquids, solids, or gases. Corrosive liquids present the *most* common types of injury, especially where external injury is involved. The skin and the eyes are the primary areas that are affected by liquids. Corrosive solids are the *least* hazardous of the corrosive substances. The effects of corrosive solids are largely depends on how easily they become soluble and how long you are in contact with them. Corrosive gases are the *most* serious hazard. Gases are easily absorbed into the body by skin absorption and inhalation. Some common examples are ammonia, hydrogen chloride, hydrogen fluoride, and formaldehyde.

Personal protective equipment (PPE)

When working with corrosive material, you need to be familiar with the material safety data sheet (MSDS) for that product and be sure to wear the PPE required. The following are some of the most common PPE items.

PPE	Use
Eye protection	Safety glasses *must* be worn at all times when handling corrosive materials. Your safety glasses *must* meet the Practice for Occupational and Educational Eye and Face Protection requirements and *must* be equipped with side shields. If there is chance that the product may splash, you *must* wear other eye protection and/or face protection, such as face shields.
Hand protection	Gloves *must* be worn when handling corrosives. Refer to the MSDS for the specific type required.
Protective clothing	Lab coats, closed toed boots, and long sleeved clothing should be worn, as required by the MSDS. Additional protective clothing may be required if there is a likelihood of skin contact.
Safety shielding	Safety shielding (e.g., full face shield, heavy duty rubber apron and gloves, etc.) is required any time there is a chance that the material may explode, splash, or cause an exothermic (releasing heat) reaction.

Handling procedures

In addition to wearing the PPE listed above, you should follow these safe operating procedures, as well as any additional precautions as specified on the MSDS.

- Use acid bottle carriers when transporting containers of corrosive liquids greater than 500 ml in size.
- DO NOT carry corrosives by the ring on the bottle—the ring is used for pouring only.
- NEVER sniff the material.
- Keep all corrosive containers tightly closed when not in use and be sure *never* to lay stoppers or caps down on the counter top.

When diluting corrosive materials, use great care and combine the materials together *SLOWLY*. Always make sure that you add acid to water—*never* add water to acid. Whenever strong mineral acids are diluted with water, they become highly exothermic (releases heat); the reaction vessels can become hot enough to cause severe burns if touched (e.g., similar to the Meals Ready to Eat [MRE] heat pouch).

Confined space

While most of your jobs will be in well-ventilated areas, there remains a chance that you may get a requirement to work in a confined space. A confined space is a space that is large enough and configured so that a worker can bodily enter and perform work. It also has limited or restricted means for entry or exit (e.g., tanks, vessels, missile silos, storage bins, hoppers, vaults, manholes, and pits are spaces that may have limited means of entry) and is not designed for continuous human occupancy. These spaces are generally life threatening and require specialized training before entering.

Construction workers are routinely exposed to these areas. Most people think of these spaces as being equivalent to a manhole and are easily identified. This is not always the case. Confined spaces are created daily at on-going construction/job sites. Be extremely careful when working around old and newly constructed confined spaces and do not hesitate to point out a suspected space to your supervisor.

More than 60 percent of confined space fatalities occur among would-be rescuers, who are overcome by the same hazardous condition as the victim. If you hear someone calling for help from a manhole or areas you suspect as a confined space do not enter the space. Phone the fire department immediately for emergency rescue.

Classification of confined spaces

Confined spaces are classified by the level of danger they present to people working in them. “Permit Required” spaces may present a situation of immediate danger to life or health or has the potential for or contains a hazardous atmosphere as defined in AFOSH STD 91-25, *Confined Spaces*.

A “Non-Permit Required” confined space does not contain a hazardous atmosphere with no credible potential for a hazardous atmosphere, engulfment, or entrapment; however, workers must *not* perform any work that could cause a hazardous atmosphere. Permits and signs are not required.

When working in any confined space, always take precautions to protect yourself and others workers. If you have any questions about the safety of an area, ask your supervisor or unit safety representative before you work in the area.

NOTE: Always follow your installation’s confined space program for specific guidance.

Permit required

Entry supervisors must ensure that workers ONLY enter a permit required confined space after an AF Form 1024, Confined Spaces Entry Permit, or an approved entry permit has been obtained. The permit is an authorization and approval in writing that specifies the location and type of work to be done. It also certifies an evaluation of all existing hazards and the necessary protective measures have been taken to ensure the safety of each worker.

Non-permit required

You may enter a non-permit required confined space without an entry permit and attendant.

Housekeeping

Another important aspect of safety is good housekeeping. Some important points to remember when working in the shop are the following:

- Wet and cluttered floors cause terrible accidents. Oil and fuel spills are especially dangerous and should be cleaned up immediately.

- Keep the work area well ventilated to prevent a buildup of toxic fumes.
- Replace burned-out light bulbs to keep the workplace well lit. You cannot work safely with poor lighting.
- Put tools and equipment away when you finish with them. They last longer and are not in your way while you do other jobs.
- Keep tools and equipment in top condition by performing recurring maintenance on them.
- Put waste materials into suitable containers. Mark each container with the material it holds. Be especially careful when disposing of waste with sharp edges such as scrap metal.
- Finally, keep water fountains, lunch areas, and clothing lockers clean. Illnesses caused by contaminated water and food are more serious than many accidents.

228. Ladders, scaffolds, and mobile work platforms

In your job, you must often work above ground level on ladders, scaffolds, and mobile work platforms. To be able to work safely, you must know the safety procedures for working at heights.

Ladders

Ladders are simple tools comprised of two rails, rungs, and some basic hardware to hold it all together. Unfortunately, hundreds of deaths and thousands of injuries result every year from people using ladders. The following is some important information you need to know about ladders.

Classification

There is a wide variety of ladders on the market today, each designed for different jobs. The three most common materials used for portable ladders are aluminum, wood, and fiberglass. You can purchase straight, extension, trestle, or self-supporting stepladders.

Inspection

Before using any type ladder, you must inspect the ladder for loose, broken, or missing rungs, steps, cleats, or side rails. Also, check for any missing safety shoes (feet), frayed ropes, or other defective parts. You want to make sure there are not any slippery materials on the rungs, steps, or side rails. In addition, you need to be sure that any moving parts are operating correctly.

Use

Using a ladder is relatively easy. You just need to follow some simple guidelines. The following guidelines concern ladder placement.

- Never place a ladder in a horizontal position.
- Never place ladder in front of any doors, windows, or openings, unless the area has been properly secured (lock the door or block it off and route people to another area).
- Never place a ladder around a high traffic area, unless the area has been roped off, the ladder fastened securely, and a safety monitor positioned at the base.

Support

Now that you know how not to place a ladder, we’ll discuss ladder support. The following guidelines concern footing support.

- Place ladder on a level base (never on blocks or boxes), ensuring that both rails are on a solid footing.
- Secure the ladder or ensure that slip resistant feet are used when working on slippery surfaces.

Safety

The following are general safety precautions that apply to *all* types of ladders:

- Make sure the ladder side rails have safety shoes.
- As you ascend or descend, face the ladder and hold onto each side rail.
- Never leave a ladder unattended for any length of time while it is erected—take it down and lay it on the ground.
- When you work from any ladder, stand no higher than the third rung from the top.
- If you need help to do the work, have your helper get another ladder. Do *not* allow anyone on the ladder with you.
- Never climb a ladder while using both hands to hold material; you *must* use at least one hand to climb or descend a ladder.
- Never use metal ladders where they might contact electric current.
- Never paint a wooden ladder. If a protective coating is required, it *must* be *clear* so any cracks in the wood are visible.

Observe the following safety precautions when you use a stepladder.

- Never use stepladders as substitutes for work stands.
- Before climbing a stepladder, be sure it is fully open and locked and that all four legs are on solid footing.
- Don't leave tools on the top of a stepladder unless it has a special holder.

Observe the following safety precautions when you use an extension ladder.

- Get help when erecting long heavy ladders.
- Always raise ladders so that the upper section overlaps and rests on the bottom section.
- Never place either the top or the bottom of a ladder against an unstable surface.
- When you use a ladder against the side of a building, the bottom of the ladder must be $^1/_4$ of the ladder's total length away from the building, as shown in figure 4-74.
- If you use a ladder to get onto a roof or scaffold, the ladder must extend at least 36- inches above the top edge of the eave, as shown in figure 4-75.

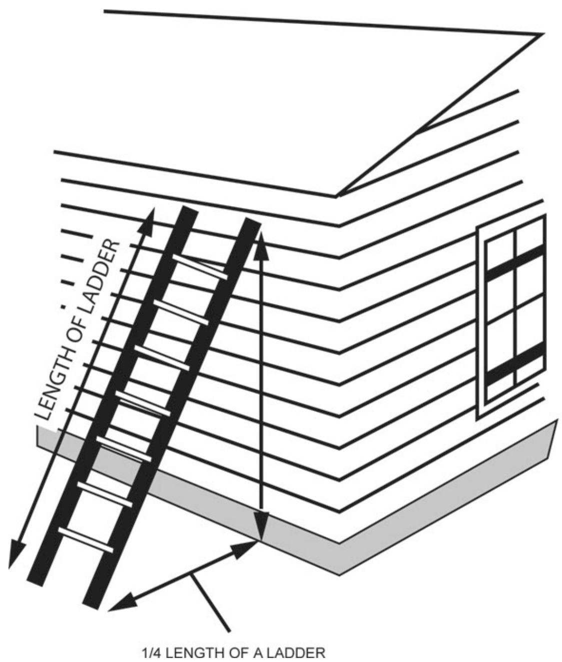


Figure 4-74. Placing a short ladder.

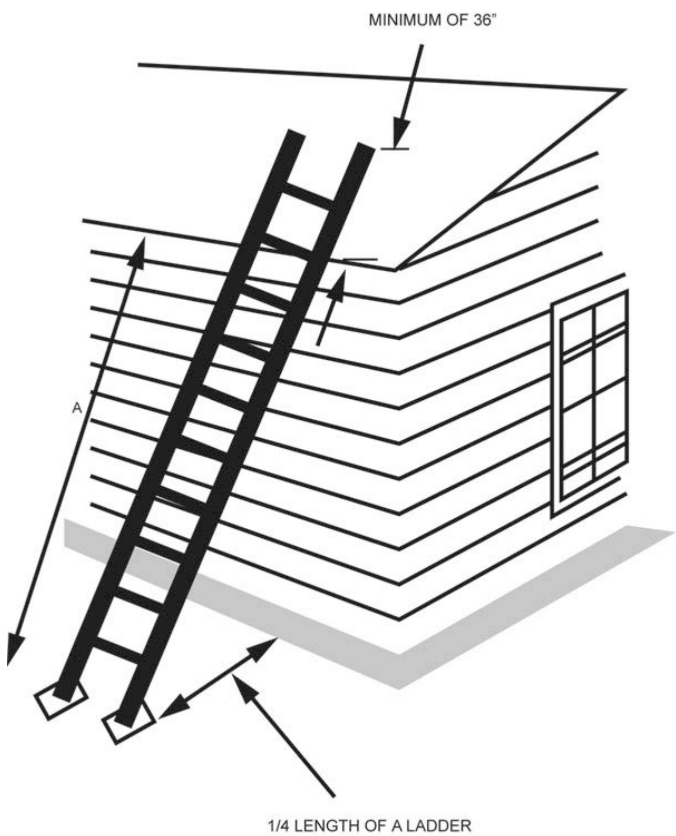


Figure 4-75. Placing a long ladder.

Scaffold safety

Scaffolds are an essential part of construction. They allow you to work from various elevations; however, they also create a dangerous working environment. The Occupational Safety and Health Administration (OSHA) reported that falls are the number one cause of fatal construction accidents, and 40 percent of those injured had less than one-year of experience. In fact, 89 percent of those injured or killed were skilled craftspeople, but lacked scaffold training. It is very important for you to know how to work safely with scaffolds. There are various scaffold types on the market today and numerous manufacturers. The next few paragraphs discuss some general safety precautions for the scaffold horse, sectional scaffolds, and aluminum stairway scaffolds. For specific safety information, always refer to the scaffold owner's manual.

Competent person

OSHA requires that a *competent* person supervise and direct scaffold erection. A competent person's role is to identify existing and predictable hazards and to make any necessary corrections. They must be capable of making decisions regarding fall protection, safe access, scaffold integrity, and be thoroughly familiar with the manufacturer's specifications and instructions for safe use.

Scaffold horses

Even though you're not very high above ground when you work from a scaffold horse (fig. 4-76), you're still in danger. The following are several precautions you can take to prevent serious injury to yourself or others.

- Always inspect the scaffold horses for split boards, loose knots, and loose nails.
- Set the scaffold horses on firm, even footing for each leg.
- Test scaffold boards by setting them on blocks close to the ground and jumping on them.
- Never use a scaffold board under 1 ½- × 9 ½- inches (2- × 10-).
- Place the boards close together on the horses.
- Don't overload the scaffolds.

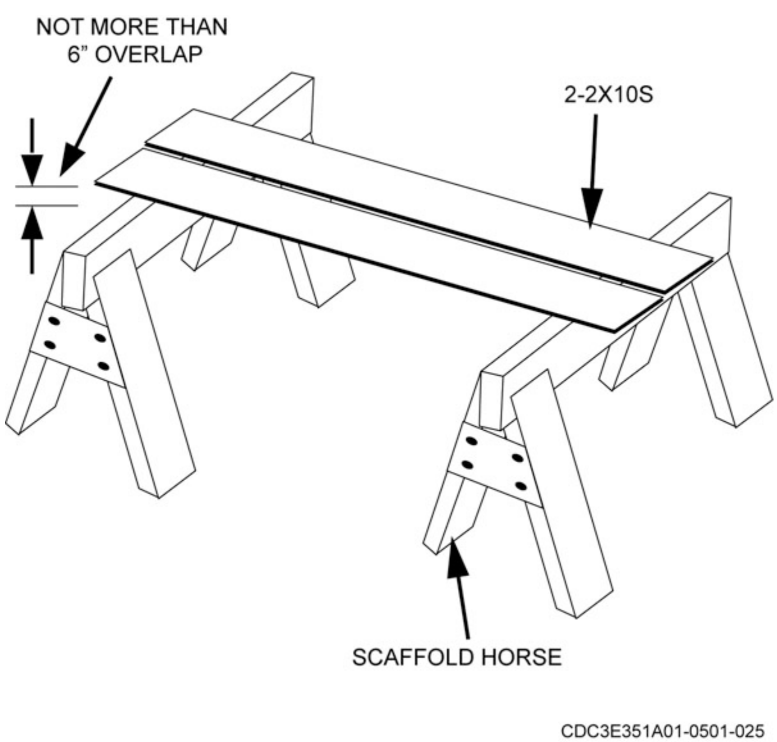


Figure 4-76. Scaffold horse.

Sectional scaffold

Sectional scaffolds are the most common types on the market today. There are different types available, such as fiberglass, aluminum, and steel. The sectional steel, or metal tubular frame, scaffold is the type used to support the heaviest loads. There are several safety precautions for working from this type of scaffold.

Inspection

Inspect all scaffolds before using—*never* use any equipment that's damaged or deteriorated in any way. In fact, inspect the scaffold parts before erection, during erection, during scaffold use, during disassembly, and before storage. Tag and remove any damaged parts that you find. You want to ensure that all equipment is in good repair and avoid using corroded equipment. The following is a list of some basic parts to observe during the inspection process (always refer to the owner's manual for the product you are using).

- Broken or excessively rusted welds.
- Bent, split, cracked, or crushed tubes.
- Warped scaffold parts.
- Excessive rust.
- Damaged brace locks.
- Excessively worn rivets or bolts on the braces.
- Damaged threads on the screw jacks
- Broken casters.

General safety precautions

You must use base plates with mudsills whenever you erect scaffolding on soft or frozen ground. Furthermore, use leveling jacks (fig. 4–77) Are tinstead of blocking to adjust for uneven grade conditions. Plumb and level all scaffolds as the erection proceeds. Don't force braces to fit—level the scaffold until you make a proper fit between the braces and the quick locks as shown in figure 4–78. You need to ensure that the scaffold is plumb and level at all times. Fasten all braces securely and never climb across them.

The scaffold height should *never* exceed four times its minimum base dimension, unless you secure it from tipping. You can use guy wires, bracing, ties, or equivalent means to secure the scaffold. If an outrigger is used, that increases the base area resulting in increased height. Whatever method you choose, you must install the first tie-in at no more than four times the minimum base dimension and then every 26 vertical feet and every 30 horizontal feet.

NOTE: You must brace all scaffold poles, legs, posts, frames, and uprights to prevent swaying.

Platform safety

Lumber used for scaffold planks must never be painted or covered with any coating. All platforms must be stamped to indicate that they meet OSHA and industry requirements for scaffold planks. Scaffold platforms are usually strength rated for the intended load—light duty (25 pounds per square foot (psf)), medium duty (50 psf), and heavy duty (75 psf). The platforms *must* be at least 18 inches wide, except for walkways used during erection or disassembly. The platform's working edge cannot be more than 14- inches from the work area (certain exceptions may apply). You must ensure that the platforms extend at least 6- inches over the end supports, but no more than 18 inches unless they are cleated or restrained by hooks, nails, or 9-gauge wire. If a platform must be overlapped, ensure that it is supported and overlapped at least 12- inches.

NOTE: Never work on a scaffold that is covered in ice or snow.

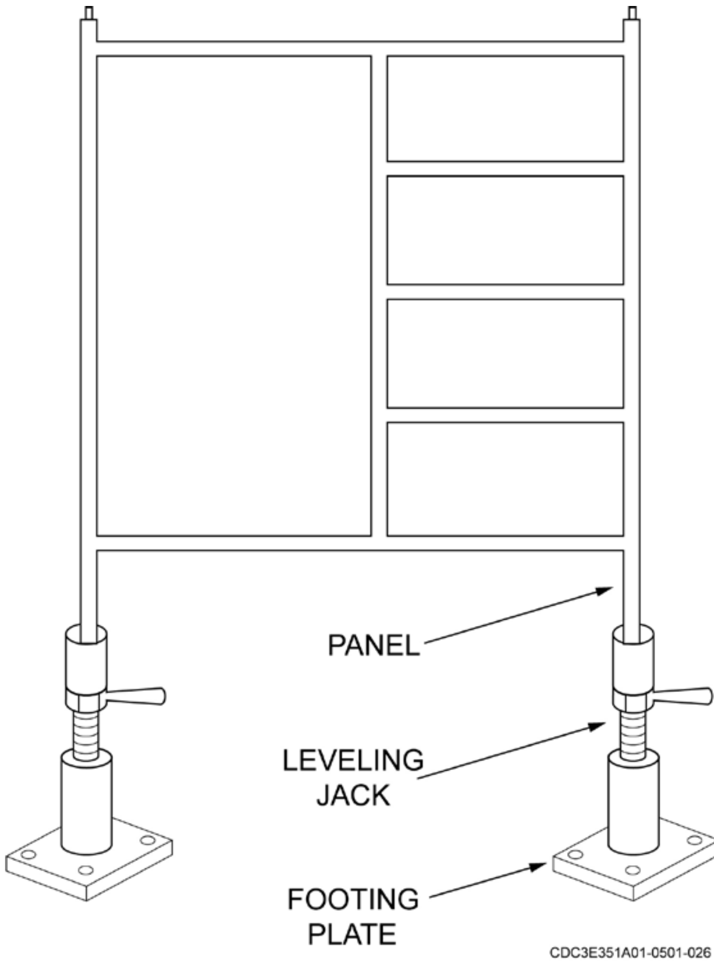


Figure 4-77. Installing leveling jacks

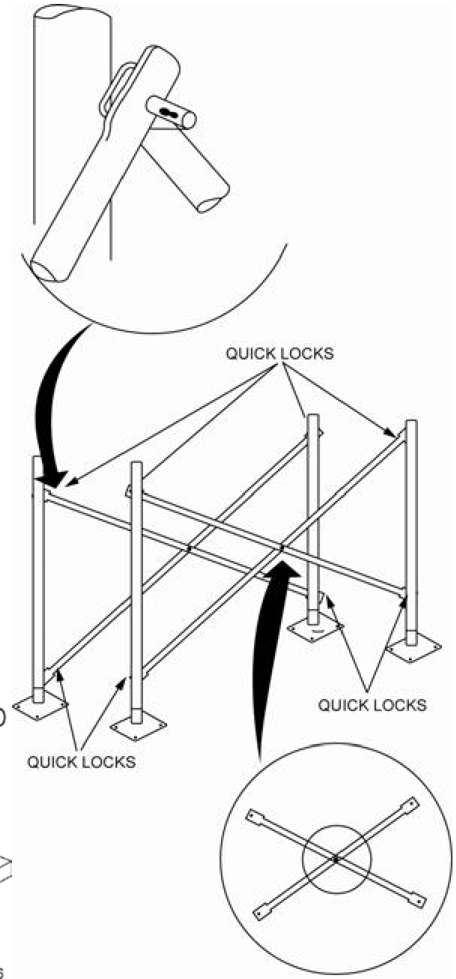


Figure 4-78. Installing braces

Guardrail system

A guardrail system is a vertical fall protection barrier that is comprised of toprails, midrails, toeboards, and posts. As you learned in the previous lesson, fall protection is required when working from heights 6 feet or more. The toprail must be able to withstand 200 pounds horizontally or downward pressure and be placed between 38– 45- inches above the work platform. The midrail must be installed between the toprail and platform surface and be capable of withstanding 150 pounds of horizontal or downward pressure. One by four-inch minimum toeboards must be installed under the midrail as an overhead protection for lower-level workers, not to mention all workers must wear hard hats.

Safe work practices

Never ride a rolling scaffold; remove all material and equipment from the platform before moving the scaffold. Apply the caster brakes whenever the scaffold is not being moved. Casters with plain stems must be attached to the panel or adjustment screw by pins or other suitable means. Don’t try to move a rolling scaffold without enough help. Watch out for holes in the floor and for overhead obstructions. Always consider the likelihood of overturning before you move a rolling scaffold. Don’t extend the adjusting screws on a rolling scaffold more than 12- inches and *never* use the adjusting screws to increase the height (only use the adjusting screws to level the scaffold).

NOTE: Ensure a 10-foot minimum safe distance is maintained between all energized lines and scaffold assemblies.

Never use the cross bracing to gain access; ladders, frames with built-in ladders, or stairways must be used. Access ladders must extend at least 3 feet above the working platforms and be secured at the top and bottom. You can use special hook-on and attachable ladders if they are designed for the type scaffolding they will be used on. The only time a worker can climb up on the end frame is when the end frame is specifically designed and constructed for use as ladder rungs.

NOTE: Never work on a scaffold during storms or high winds above 40 miles per hour.

Aluminum stairway scaffold

In addition to the safety requirements mentioned above for sectional scaffold, the next few paragraphs cover safety procedures when using the aluminum stairway scaffold.

Adjusting the height

When you adjust a leg on the scaffold, make sure you push the locking collar completely over the expanding nut and below the safety locks. Never adjust the legs when anyone is on the scaffold. Do *not* try to "stretch" the platform height with the adjustable legs. When additional height is required, add more scaffold sections. Save the leg adjustment for leveling the scaffold. Do *not* lean a ladder against a stairway scaffold or place a ladder on the platform of a scaffold.

Braces

Make sure all locking hooks are firmly in position at each end of the separate horizontal and diagonal braces and at the lower end of stairways. Before using a scaffold with folding braces, be sure that the latches of all locking hinges are locked. Do *not* climb or stand on diagonal braces for any reason. Do your work with your feet being supported by a work platform.

Interlock clips

The columns of each scaffold section have interlock clips positioned in the lower pair of holes at the upper ends. When you insert an upper section, move the interlock clips of the section below to the upper section bushings; this interlocks the two sections. Never erect a scaffold without interlocking the sections this way. If the interlock clips are damaged or lost, replace them immediately.

Safe work practices

Never work from stairways; they are for people to walk up and down between platforms. Most stairways are designed to take the weight of a 200-pound person. They are *not* designed to take excessive loads or abuse. Never climb up the outside of a stairway scaffold. Always use the stairway for access. The platform of the stairway scaffold must be on the floor and braced by four locating pins. Outdoors or wherever the scaffold is exposed to wind of updrafts, tie down the platform and secure the scaffold to the building. The platform of the stairway scaffold is designed to carry a maximum load of 750 pounds; don't exceed this limit. When you erect or take down an upper section of the scaffold, stand in the center of the platform below and keep a firm hold on the section.

Mobile work platform safety

Anyone that works from a mobile work platform (lift) is considered an operator and must be trained in operation and inspection of the platform. This includes hands-on training prior to actual on-the-job training tasks (document training in individual's training records).

Inspection and safety

Mobile work platforms must be inspected daily, before use. Items to be inspected include brakes, jacks, wheel locks, securing cables, locking pins, hydraulic systems, anchor connections and overall equipment condition. Don't exceed the weight and height limits prescribed by the platform manufacturer. Workers on the platform must secure themselves to the work platform with safety harnesses. If they fasten their safety harnesses to other surfaces and the platform is moved, they may be crushed or pulled off the platform being injured or killed.

Operation

For each type of lift, you must have the manufacturer's operating manual and it must be readily available (stored in a weather resistant compartment provided by the manufacturer) for use by the operators.

Power-operated platforms must have controls on the platform and at ground level. The ground controls must be able to override the platform controls. When workers are on the platform, only operate the ground controls with the permission of the workers on the platform or in case of an emergency.

NOTE: Whenever a worker is in or on an elevated platform, there *must* be at least one person qualified to operate the equipment stationed near the lower level control panel.

Do not ride on platforms that are being moved unless they are specifically designed to be driven and the operator is driving. Finally, don't tow platforms that aren't equipped with tow bars.

Clearances

You *must* be careful when operating these lifts around electric power lines. For lines rated 50 kilovolts (kV) or less, you *must* maintain at least a 10-foot clearance between the lines and any part of the lift. For lines rated in excess of 50 kV, you *must* have at least 10 feet plus 4 inches for each kV over 50 kV.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

226. Occupational safety and health

1. What is the major cause of accidents?

2. Which Air Force publications cover safety precautions?

3. List the three principal methods used in the prevention of accidents.

4. Give some examples of physical modification.

5. How does education and training help prevent accidents?

6. Who is responsible for enforcing safety standards?

227. Safe work practices

1. What must your supervisor do when a new task is introduced into the workplace and the task is not governed by a technical order or other definitive guidance?

2. What form (IMT) do you use to report hazards that you cannot eliminate yourself?

3. At what height must all parts such as flywheels, pulleys, and belts be covered?

4. What must you do before cleaning or adjustments a power tool?

5. What safety precautions must you follow when working around moving machinery?

6. Who must lockout/tag out a piece of equipment that is being worked on?

7. What should you do with a broken tool?

8. At what height must fall protection be used?

9. List three types of fall protection.

10. Arrange the steps in the proper numerical sequence for lifting a heavy load.

____a. Keep your back straight.
____b. Crouch.
____c. Check weight and size.
____d. Plant your feet well apart.
____e. Lift slowly by pushing with your legs.

11. What must you always do before moving a gas cylinder?

12. List four common types of personal protective equipment (PPE) used when handling corrosive materials.

13. How is acid mixed with water safely?

14. What is a confined space?

228. Ladders, scaffolds, and mobile work platforms

1. What must you do before using any ladder?

2. List at least two simple guidelines to follow when using a ladder.

3. When you work from any ladder, what is the highest rung that you are allowed to stand on?

4. Which type of ladder is never used around electrical current?

5. How far above the roof eave must a ladder extend if you are going onto the roof?

6. Who does OSHA require to supervise and direct scaffold erection?

7. When are scaffolds inspected?

8. What is the height requirement when erecting scaffolds to prevent tipping without being secured?

9. List the three scaffold platform ratings, and how many pounds per square foot they can support?

10. List the guardrail system requirements for the top rail.

11. When are you allowed to ride on a rolling scaffold?

12. You never should work on a scaffold when the wind speed is at or greater than what speed?

13. What weight is the aluminum stairway scaffold designed to support?

14. What is the maximum load that can be placed on aluminum stairway scaffold platforms?

15. Where are safety harnesses connected when using mobile work platforms?

16. Where must the controls for power-operated work platforms be located?

17. What conditions must be met before you ride a moving platform?

Answers to Self-Test Questions

216

1. b = $^{15}/_{16}$”; d = 2 $^{5}/_{16}$”; e = 3 ⅛”; f = 4 ¼”.
2. Rules.
3. (1) 6-, 12-, and 15-inch rigid or flexible rules.
   (2) Folding rules.
   (3) Circumference rule.
   (4) Steel tapes.
   (5) Power return steel tape.
4. The approximate circumference of any circle within the range of the rule.
5. To account for the thickness of the ring or hook at the end of the tape.
6. (1) Blade.
   (2) Square and miter head.
   (3) Center head.
   (4) Turret protractor head.
7. The turret protractor head.
8. Body, tongue, and heel.
9. The face is graduated in eighths and sixteenths; the back is graduated in tenths, twelfths and sixteenths.
10. To lay out roof rafters and stair members and to layout 45° and 90° angles.
11. (1) e.
    (2) a.
    (3) g.
    (4) d.
    (5) b.

217

1. 1) Boring holes, 2) countersinking, and 3) driving screws.
2. The number stamped on its shank represents its diameter (in $^{1}/_{16}$ inch increments).

3. Forstner bit.
4. Let it cool slowly.
5. On the shank.
6. Concrete, brick, or cinder blocks.
7. To bevel the edges of a hole so that rivets, bolts, or screws with countersunk heads can be inserted flush with the surface of the material of which it is driven.
8. Hand drill, portable drill or drill press.

218

1. (1) a.
   (2) d.
   (3) b.
   (4) c.
2. Jackplane.
3. With the bevel down.
4. By its width.
5. Use a soft-faced hammer or mallet.
6. Rough-cut, bastard-cut, second-cut, and smooth-cut.
7. You place one finger or thumb near the file tip to guide the file. Use your other hand to grip the handle and apply pressure. (Place a file handle on the "tang" or sharp end of the file or rasp before you use it unless the tool is manufactured with rounded ends.) You begin the filing by applying pressure with your hands as you push forward without pulling back on the file. Apply pressure *only* on the forward filing stroke.
8. To prevent vibration.
9. Draw filing is similar to straight filing except that you hold the file or rasp at an angle to the surface being filed. Move the file or rasp back and forth over the length of your work; this produces a finer finish than straight filing.
10. Flat sheets of metal (cutting wire or rods damages the cutting blades).

219

1. Head weight.
2. It damages the wood's surface.
3. Tack hammer.
4. Sledge hammer.
5. Forming grooved seams and wired edges that require a great deal of handwork.

220

1. Starting, drift, and taper punches.
2. Prick punch.
3. Hand lever punch.
4. Too small a punch pierces the hole but dimples the materials.
5. Stiff paper.
6. No. The upper and lower turrets are synchronized.

221

1. Brass or aluminum.
2. So it will be out of the way when it's not in use.
3. To protect the object being held.
4. To protect the object being clamped and spread the pressure evenly over a wide area.
5. Hand-screw clamp.
6. To let you use more pressure when you tighten the clamps.

222

1. The diameter of the blade.
2. ⅛ to ¼ inch below the material you intend to cut.
3. The blade may bind, resulting in a kickback.
4. Center punch the metal.
5. Immediately release the trigger and then remove the bit from the drill. You must then determine the cause. You may, however, use the reversing switch to the back the drill bit out of the hole.
6. To avoid overheating and burning the wood.
7. The harder the metal, the slower the speed must be. The softer the metal, the faster the speed must be.
8. A blade that allows at least three (3) teeth to be in contact with the thickness of the material.
9. Place the wood face-side down since the blade cuts on the upstroke.
10. Ensure you place the lumber on the table with the cut line against the fence.
11. Cross cutting, miter cutting, bevel cutting, and compound miter/bevel cutting.
12. 5 inches or less.
13. None; cast iron should be cut dry.
14. None; let the saw's weight do the cutting.
15. Trained and licensed.
16. Continue to hold it against the work surface for thirty seconds. Then follow the manufacturer's instruction for further guidance. Never try to pry out a live powder load. It could explode in your hands and cause a fatal injury.
17. Never use a laser level unless you have been trained to do so; never stare directly at the laser light; never point the laser beam at others; always try to set up the laser light above or below eye level; always turn off the laser when you don't need it; always consider posting signs to show that a laser light is in use; and avoid exposure to the laser.

223

1. Proper operation, safety procedures, cleaning, hazard recognition, and emergency shutdown procedures for each machine or piece of equipment that they use; machine or equipment maintenance or repairs that they are allowed to perform; and lockout and tagout procedures.
2. (1) Maintain manufacturer's manuals for all machinery or equipment. If they do not have these, they must develop local operating instructions (OIs), to include job safety, maintenance, lubrication, and inspection. The OIs must also identify operator and maintenance technician responsibilities.
   (1) Ensure that only authorized personnel operate and maintain shop equipment.
   (2) Periodically evaluate machinery or equipment operators to ensure they are following proper and safe operating procedures.
3. It may catch fire.
4. $^1/_{16}$-inch maximum clearance.
5. (1) Insert the drill bit into the chuck as far as it will go, and then back it back out $^1/_{16}$ inch. If you are using small bits, back those up to the flutes.
   (2) Center the bit in the chuck and tighten the chuck with the chuck key—be sure to tighten all three chuck jaws, so the bit does not slip.
   (3) Remove the chuck key.
6. Position the wood on the table with one end against the left side of the column to prevent the wood from catching and spinning with the bit. If this is not possible, fasten it to the table with clamps or a vise.
7. An auger bit.
8. ½ inch sag for each foot of distance between pulley centers.
9. Depress the brake pedal.
10. No more than ⅛ inch above the surface of the material being cut.
11. Make relief cuts.

12. Within ⅛ inch of the grinding wheel just below the center of the wheel.
13. Always stand to one side of the wheel when you turn it on and never have the work piece against the wheel during startup.
14. Wear to the wheel and unnecessary heating of the material being ground..

224

1. Never use the fence.
2. ⅛ to ¼ inch above the board being cut.
3. To the left of the blade; *never* stand in line with the blade.
4. Use a work support or have someone help you to keep the boards from falling off the saw table.
5. About $^{1}/_{16}$ inch below the table's surface.
6. Adjust it to allow its fingers to extend about ⅛ below the wood being ripped.
7. You could be pulled into the saw blade or the wood could be pulled from your hands and propelled with enough force to cause fatal injury.
8. No more than $^{1}/_{16}$ inch.
9. Lower the outfeed table.
10. With the grain.
11. No more than ⅛ inch at a time.
12. Slower speed because it allows for more cuts per inch of stock.
13. Use a miter gauge.
14. Perform all cross grain shaping first, then shape with the grain to remove the splintered ends.

225

1. Check the machine to make sure it is clear of material and people.
2. Wheel, belt, and blade guards.
3. Treadle.
4. Turn off the shear and remove cut material.
5. To raise the blade when pressure is removed from the treadle.
6. 16-gauge mild steel.
7. The back gauge.
8. About three quarters the length of the blade.
9. Adjust the yoke so that the distance from the center of the clamping discs to the cutting wheels is half the diameter of the blank desired.
10. Clockwise so that the material is fed away from you.
11. Clamp the material in the vise jaws.
12. The vise handwheel.
13. By adjusting the feed pressure control.
14. The punch diameter must be equal to or more than the thickness of the metal being punched.
15. The die size must be larger than the punch by approximately 10 percent the thickness of material being punched.

226

1. Unsafe acts of people.
2. The AFOSH 91 series regulations.
3. Physical modification, education and training, and enforcement of safety standards.
4. Machine guards, handrails, and walk boards.
5. Through adequate instructions, personnel gain useful knowledge and develop safe attitudes.
6. Each supervisor.

227

1. Conduct a job safety analysis.
2. AF IMT 457, USAF Hazard Report.
3. 8 feet or less from the floor.
4. Disconnect the tool from the power source.
5. Do not wear any rings, jewelry, gloves, neckties or loose clothing.
6. Each specialist working on the piece of equipment.
7. Return the tool to the tool equipment custodian.
8. 6 feet or more.
9. 1) Personal fall arrest system; 2) safety nets; 3) warning lines.
10. (a) 4.
    (b) 3.
    (c) 1.
    (d) 2.
    (e) 5.
11. Install the cylinder cap.
12. 1) Eye protection; 2) hand protection; 3) protective clothing; 4) safety shielding.
13. Always add the acid to the water.
14. A space that is large enough and configured so that a worker can bodily enter and perform work. It has limited or restricted means for entry or exit (for example: tanks, vessels, missile silos, storage bins, hoppers, vaults, manholes, and pits are spaces that may have limited means of entry); and is not designed for continuous human occupancy.

228

1. Inspect the ladder for loose, broken, or missing rungs, steps, cleats or side rails. Also check for any missing safety shoes (feet), frayed ropes or other defective parts. Make sure that there aren't any slippery materials on the rungs, steps, or side rails and that all moving parts are operating correctly.
2. 1) Never place a ladder in a horizontal position; 2) Never place ladder in front of any doors, windows, or openings, unless the area has been properly secured; 3) Never place a ladder around a high traffic area, unless the area has been roped off, the ladder fastened securely, and a safety monitor positioned at the base.
3. Third rung from the top.
4. Metal.
5. 36 inches.
6. A competent person.
7. Before and during erection, during use and disassembly, and before storage.
8. The height will never exceed four times the minimum base dimension unless the scaffold is secured.
9. Light, medium, and heavy duty; 25, 50, and 75 pounds per square foot, respectively.
10. The toprail must be able to withstand 200 pounds horizontally or downward pressure and be placed between 38 – 45 inches above the work platform.
11. Never.
12. 40 miles per hour.
13. 200 pounds.
14. 750 pounds.
15. Only to the platform.
16. On the platform and at ground level.
17. The platform must be one that is designed to be driven by the operator.

Do the unit exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

51. (216) When performing masonry construction, which measuring device that’s made of wood with brass tips and positive-locking joints do we use to establish the heights of corner leads?
a. Folding rule.
b. Framing square.
c. Power return tape.
d. Combination square.

52. (216) Which blade description holds the blade of a combination set to the various heads?
a. A double groove in the blade and setscrews in the heads.
b. A double groove in the blade and a locknut on the heads.
c. A central groove in the blade and setscrews in the heads.
d. A central groove in the blade and a locknut on the heads.

53. (216) When using the framing square to locate opposite points on a circumference, where do you place the heel of the square?
a. On the center of the circle.
b. On the radius of the circle.
c. At any point outside the circle.
d. At any point on the circumference.

54. (216) When transferring measurements from a steel rule to the job, which tool do you use?
a. Dividers.
b. T-square.
c. Sliding T-bevel.
d. Turret protractor.

55. (217) When using a ratchet brace and auger bit, what number bit do you select to bore a 1-inch hole in wood?
a. 4.
b. 8.
c. 12.
d. 16.

56. (217) If a high-speed drill bit overheats, which actions do you take?
a. Dip it in oil.
b. Cool it in water.
c. Let it cool slowly.
d. Blow fast-moving air over it.

57. (217) The purpose of a countersink is to
a. enlarge holes.
b. elongate holes.
c. create inlayed designs in wood.
d. bevel edges of holes for special rivets, bolts or screws.

58. (218) When using a handsaw where *finish* is important, how do you cut lumber?
a. With the face side up.
b. With the backside up.
c. Do not cut with a handsaw.
d. With the face side up or down.

59. (218) When using a hacksaw to cut thin-wall tubing and light gauge sheet metal, which size blade do you use?
a. 14 teeth per inch.
b. 18 teeth per inch.
c. 24 teeth per inch.
d. 32 teeth per inch.

60. (218) When cutting with a wood chisel held with the bevel side up, what is/are the usual result(s)?
a. You lose control over the cut.
b. The chisel is easier to control.
c. The chisel tends to bite into the wood and is harder to control.
d. The chisel tends to bite into the wood and you have more control over the cut.

61. (218) Which procedure is the *correct* way to straight file hard metal?
a. Apply pressure only on the back filing stroke.
b. Apply pressure only on the forward filing stroke.
c. Hold the file at an angle and move the file back and forth over the work length.
d. Hold the file perpendicular to the piece and move the file back and forth over the work length.

62. (219) Which hammer head face is *best* for rough framing?
a. Flat.
b. Round.
c. Smooth.
d. Serrated.

63. (219) Which procedure is the *correct* way to hold and swing a curved claw hammer?
a. Firmly hold the end of the handle and put only your lower arm in motion.
b. Firmly hold the end of the handle and put your entire arm and shoulder in motion.
c. Loosely hold the end of the handle and put only your lower arm in motion.
d. Loosely hold the end of the handle and put your entire arm and shoulder in motion.

64. (219) Which hammer/mallet do you use to preliminary shape copper, aluminum, and other light-gauge sheet metals to prevent damage?
a. Ball peen hammer or plastic mallet.

b. Wooden or plastic mallet.
c. Claw hammer.
d. Rubber mallet.

65. (220) To establish location points in laying out patterns on sheet metal, which type of *punch* should you use?
a. Pin.
b. Drift.
c. Prick.
d. Starting.

66. (220) To align holes in two pieces of metal before installing screws, bolts, or rivets, which type of *punch* should you use?
a. Pin.
b. Drift.
c. Prick.
d. Starting.

67. (220) Which *punch* do we use to pierce holes in light-gauge metal because it is quicker than using twist drills?
a. Solid.
b. Taper.
c. Center.
d. Hand lever.

68. (220) When using a rotary punch, you align the punch and die accurately by
a. rotating the upper turret body.
b. rotating the lower turret body.
c. aligning the centerline marks on the punch and die.
d. punching through several thicknesses of stiff paper.

69. (220) Which action is the *final* step in performing preventative maintenance on a rotary punch?
a. Wipe off all excess oil.
b. Clean and oil the index pin.
c. Inspect each punch for proper alignment.
d. Make the appropriate entries in the maintenance record folder.

70. (221) How do we determine a C-clamp's size?
a. Bolt diameter.
b. Opening depth.
c. Opening width.
d. Contact diameter.

71. (221) When setting up a bar clamp, which procedure allows you to put more clamping pressure on your project when you tighten the clamps?
a. Return the swivel-head assembly to the rear of the fixed-head assembly.
b. Return the swivel-head assembly to the front of the fixed-head assembly.

c. Back the swivel-head assembly four rotations away from the fixed-head assembly.
d. Back the swivel-head assembly eight rotations away from the fixed-head assembly.

72. (222) Before operating the circular saw, to which depth do you adjust the saw blade?
a. ⅛ - ¼ inch below the material being cut.
b. ¼ - ½ inch below the material being cut.
c. ⅛ - ¼ inch above the material being cut.
d. ¼ - ½ inch above the material being cut.

73. (222) When cutting bowed lumber on the power miter saw, you place the lumber on the table with the
a. cut line away from the fence.
b. cut line against the fence.
c. outward bow to the left of the blade.
d. outward bow to the right of the blade.

74. (222) When crosscutting with the frame and trim saw, how *must* you position the track arm?
a. Indexed to the 0-degree positive stop.
b. Indexed to the 45-degree positive stop.
c. Positioned to the desired angle on the miter scale.
d. Positioned with the cutting head tilted to the desired bevel.

75. (222) Which procedure would you use to cut cast iron with the portable bandsaw?
a. Apply liquid lubricant to the blade.
b. Apply stick wax to the blade.
c. Apply spray wax to the blade.
d. Cut cast iron dry.

76. (223) The *correct* directional feed and *maximum* clearance between the disc and the table when using an abrasive disc-sanding machine is feed with the
a. upward rotation side; $^1/_{16}$ inch clearance.
b. upward rotation side; ¼ inch clearance.
c. downward rotation side; $^1/_{16}$ inch clearance.
d. downward rotation side; ¼ inch clearance.

77. (223) When boring through long pieces of wood on the drill press, the action you take to prevent the wood from catching and spinning with the bit, position the wood
a. close to you on the table and clamp it there.
b. in the center of the press table and clamp it there.
c. against the left side column or fasten it to the table with clamps.
d. against the right side column or fasten it to the table with clamps.

78. (223) When applying tension to a drill press's V-belt, how much sag for each foot of distance between pulley centers do you allow?
a. ½ inch.
b. ¾ inch.
c. 1 inch.

d. 1 ¼ inch.

79. (223) Before using an upright bandsaw, which height *must* you adjust the blade guide assembly above the material being cut?
a. ⅛ inch or less.
b. ⅛ - ¼ inch.
c. ¼ - ⅜ inch.
d. ⅜ - ½ inch.

80. (223) The *correct* operating procedures for using stationary grinders is to adjust the tool rest to within
a. ⅛ inch of the grinding wheel and grind on the wheel face.
b. ⅛ inch of the grinding wheel and grind on the wheel side.
c. ¼ inch of the grinding wheel and grind on the wheel side.
d. ¼ inch of the grinding wheel and grind on the wheel face.

81. (224) Which of the following procedures are used to safely rip lumber on a table saw?
a. Set the blade ¼ to ½ inch above the board to be cut.
b. Set the blade ⅛ to ¼ inch above the board to be cut.
c. Stand to the right of the blade.
d. Stand in line with the blade.

82. (224) Which operating procedure is correct to rip lumber on a radial arm saw?
a. Lock the arm parallel to the fence and feed the wood with the blade rotation.
b. Lock the arm parallel to the fence and feed the wood against the blade rotation.
c. Lock the arm perpendicular to the fence and feed the wood with the blade rotation.
d. Lock the arm perpendicular to the fence and feed the wood against the blade rotation.

83. (224) When edge-jointing lumber that is 1 ½ inch thick or less, at what *maximum* depth do you set the cut depth?
a. ⅛ inch.
b. ¼ inch.
c. ⅜ inch.
d. ½ inch.

84. (225) Before you turn on power-operated squaring shears, you *must*
a. adjust the back gauge.
b. tighten the hold downs.
c. ensure the side gauge is square.
d. ensure the machine is clear of material and people.

85. (225) When using the circle shears to cut heavy metal, which percent of the metal thickness are the cutters separated?
a. 10 percent or less.
b. 10 percent or more.
c. 15 percent or less.
d. 15 percent of more.

86. (225) When cutting inside circles with the ring and circle shears, you adjust the yoke so the distance from the center of the sheet to the cutter wheels is which diameter of the desired circle?
a. ¼.
b. ½.
c. ¾.
d.5/8.

87. (225) When punching mild steel with an ironworker, the ratio between the punch size and the thickness of metal being punched is the punch diameter *must* be
a. equal to or more than the thickness of the metal being punched.
b. at least ½ the thickness of the metal being punched.
c. at least ¼ the thickness of the metal being punched.
d. twice the thickness of the metal being punched.

88. (226) Placing safety suggestions on the bulletin board and passing safety literature to each worker are examples of which type of accident prevention method?
a. Physical modification.
b. Accident investigation.
c. Education and training.
d. Enforcement of safety standards.

89. (226) How often should supervisors give *new* workers a safety briefing?
a. Daily.
b. Weekly.
c. Monthly.
d. Quarterly.

90. (226) If a worker does *not* seem to understand the procedures for an assigned task, what should the supervisor do?
a. Repeat the procedures to the worker.
b. Have the worker state the procedures.
c. Remove the worker from that specific task and assign it to another person.
d. Allow the worker to experiment with the task without further instructions.

91. (227) Which procedure *must* your supervisor follow when a new task is introduced into the workplace and the task is *not* governed by a technical order or other definitive guidance?
a. Conduct a job safety analysis.
b. Request ground safety to analyze the task.
c. Submit an AF Form 457, USAF Hazard Report.
d. Brief the personnel weekly until they are familiar with the task.

92. (227) At which height *must* you install guards on machinery with exposed moving parts, such as flywheels, pulleys, and chains?
a. At all heights.
b. Eight feet or less from floor.
c. Ten feet or more from floor.
d. There are no height requirements.

93. (227) What *must* you do before cleaning or adjusting a power tool?
a. Disconnect it from its power source.
b. Connect it to its power source.
c. Lower the speed setting.
d. Raise the speed setting.

94. (227) When performing lockout/tagout procedures, what *must* you do if the equipment to be locked out is still operating?
a. Allow it to continue running.
b. Reduce the power feed to one-fourth cycle.
c. Shut it down using the normal stopping procedures.
d. Shut it down using the emergency stopping procedures.

95. (227) You *must* use fall protection anytime a fall hazard is greater than
a. 4 feet.
b. 6 feet.
c. 3 feet.
d. 1 feet.

96. (227) The service life of fall protection equipment is
a. 5 years.
b. 10 years.
c. 2 years.
d. 3 years.

97. (228) How many feet above the roof eave *must* a ladder extend before you use it?
a. 1.
b. 2.
c. 3.
d. 4.

98. (228) To prevent tipping when erecting a scaffold, the scaffold should *never* exceed which height without being secured?
a. Three times its minimum base dimension.
b. Four times its minimum base dimension.
c. Three times its largest base dimension.
d. Four times its largest base dimension.

99. (228) You *must* install toprails in a scaffold guardrail system at which height range (minimum – maximum) above the work platform?
a. 32 – 36 inches.
b. 32 – 38 inches.
c. 38 – 45 inches.
d. 38 – 48 inches.

100. (228) When working on a mobile work platform, where *must* workers attach their safety harnesses?

a. Work platform only.
b. Overhead structure only.
c. Work platform or overhead structure.
d. Any structure capable of holding their weight.

Glossary of Terms, Abbreviations, and Acronyms

Terms

alloy—A combination of metal and one or more elements mixed together to create specific properties.

annealing—A heat treatment process that softens a metal by heating it to a certain temperature, then holding it at that temperature, then allowing it to cool at a certain rate.

blemish—A flaw that mars the appearance of lumber but has no effect on the utility value.

defect—Any flaw in lumber that tends to affect the strength, durability, or utility value of the lumber.

ductility—A metal property that lets it be permanently bent, stretched, or formed without breaking.

elongate—To make longer.

equation—A mathematical statement that expresses the equality of two or more quantities.

formula—A special type of equation that expresses a certain fact, law, relation by means of symbols or letters.

geometry—The branch of mathematics that deals with lines, angles, surfaces and solids.

gimlet—The pointed end of a screw.

kerf—The cut produced by a saw blade. The kerf helps guide the saw and assist it with making a straight cut.

malleable—Capable of being shaped or formed by hammering or pressure.

mensuration—The particular branch of geometry that deals with the *measurement* of lines, angles, surfaces and solids.

metal, ferrous—Metal made mainly of iron and iron alloys.

metal, nonferrous—Metal made mainly from some element or elements other than iron.

orthographic projection drawing—a type of drawing that is two-dimensional and shows only one side of an object.

oxidation—The combination of metal with oxygen to form a metal oxide.

pictorial drawing—A drawing that is similar in appearance to a picture.

seasoning—The removing (drying) of moisture from the small and large cells of wood. Wood is considered dry enough for most uses when the moisture content is reduced to around 12 to 15 percent.

Abbreviations and Acronyms

AFCESA	Air Force Civil Engineer Support Agency
AFOSHSTD	Air Force Occupational Safety and Health Standard
AGS	Architectural Graphics Standards
AISI	American Iron and Steel Institute
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
CE	civil engineer
CMU	concrete masonry unit
DOD	Department of Defense
EPS	Engineered Performance Standards
HET	heavy equipment travel
MIL-STD	military standards
MSDS	material safety data sheet
MTM	methods-time measurement
OI	operating instruction
OSB	oriented strand board
PM/RM	preventive maintenance/recurring maintenance
PPE	personal protective equipment
psi	pounds per square inch
RPM	rotations per minute
SPM	strokes per minute
TTS	task time standards
UFGS	unified facilities guide specifications
UL	underwriters laboratories
USACE	U.S. Army Corps of Engineers

Student Notes

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