Working Drawings

Learning Objectives

After studying this chapter, you will be able to:

- Explain the purpose of working drawings.
- List the different types of working drawings and describe the information communicated by each type.
- Identify and explain the common elements used to convey information on working drawings.
- Explain how company and industry standards are incorporated on drawings.
- List the common applications for working drawings in major industries.
- Define functional drafting.

Technical Terms

Assembly drawing
Casting
Detail drawing
Exploded assembly drawing
Fixed characteristics
Freehand sketch
Functional drafting
Layout drawing
Materials block
Operation drawing
Outline assembly drawing
Patent drawing
Piping drawing
Process drawing
Revision block
Structural steel drawing
Subassemblies
Tabulated drawing
Title block
Variable characteristics
Welding drawing
Working drawings

Working drawings provide all the necessary information to manufacture, construct, assemble, or install a machine or structure. Usually, a working drawing is the product of a team effort. Engineers or architects, designers, technicians, and drafters all add their special talents to the solution of production problems. Literally thousands of hours go into the preparation of drawings used in modern industrial production, **Figure 17-1**.

Types of Working Drawings

Working drawings may be divided into a number of subtypes, depending on their use. One type of working drawing is a freehand sketch, which is used for preliminary work. Other drawings can be classified as instrument drawings. These types of drawings serve various purposes in manufacturing and production. Common drawing types are discussed in the following sections.

Figure 17-1. Nearly every manufactured part requires a working drawing. The efforts of many specialists are combined to produce the working drawings essential to manufacturing and construction. (Emerson Electronics)

Freehand Sketches

A ***freehand sketch*** provides basic graphic information about a design idea or part. The engineer or designer will often make a freehand sketch on graph paper that will serve as the working drawing for tooling, for jigs and fixtures, or for test equipment setups, **Figure 17-2**. Such drawings are also sometimes used for prototypes, or for experimental or research parts and assemblies.

Modifications to the drawing may be made during the initial construction by the designer or technician. Because of the nature and use of these sketches, only the basic information for part or assembly fabrication is included. It should be emphasized that such working drawings are for limited use; they are not released for general production.

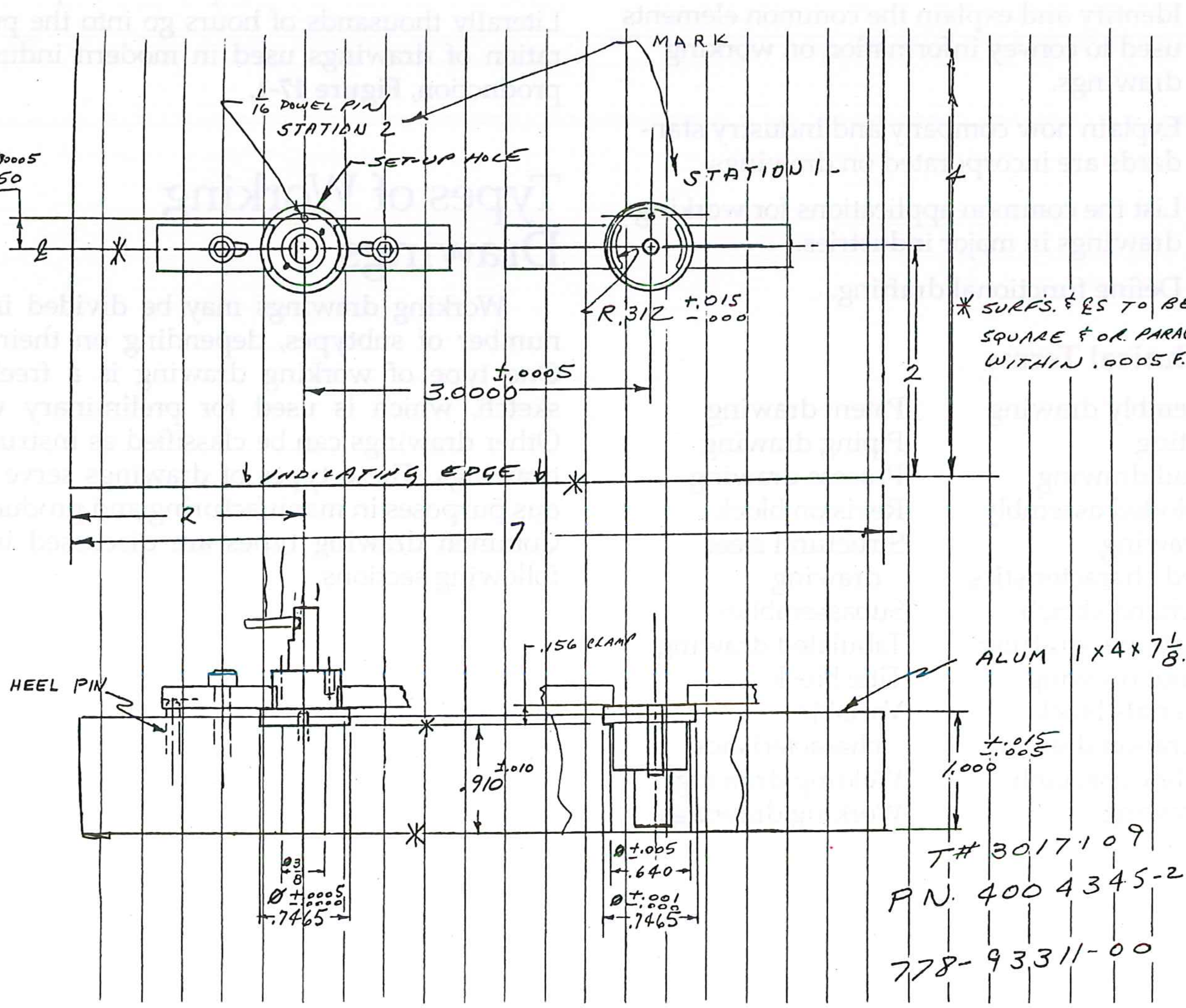


Figure 17-2. A freehand sketch used as a working drawing in the production of a tooling fixture. (Sperry Flight Systems Div.)

Detail Drawings

A *detail drawing* describes a single part that is to be made from one piece of material. Information is provided through views and by notes, dimensions, tolerances, material specifications, and finish specifications. Also included is any other information needed to fabricate, finish, and inspect the part.

Views of the part are usually drawn in orthographic projection as normal views or sections. Pictorial views may be included for clarification when necessary. An example of a detail drawing of a machine part is shown in **Figure 17-3**. When parts are closely related and space permits, some industries permit detailing of several parts on one detail drawing.

Before beginning a detail drawing of a part, the drafter should consider the methods by which the part will be processed before it is finally assembled on a machine or produced. The

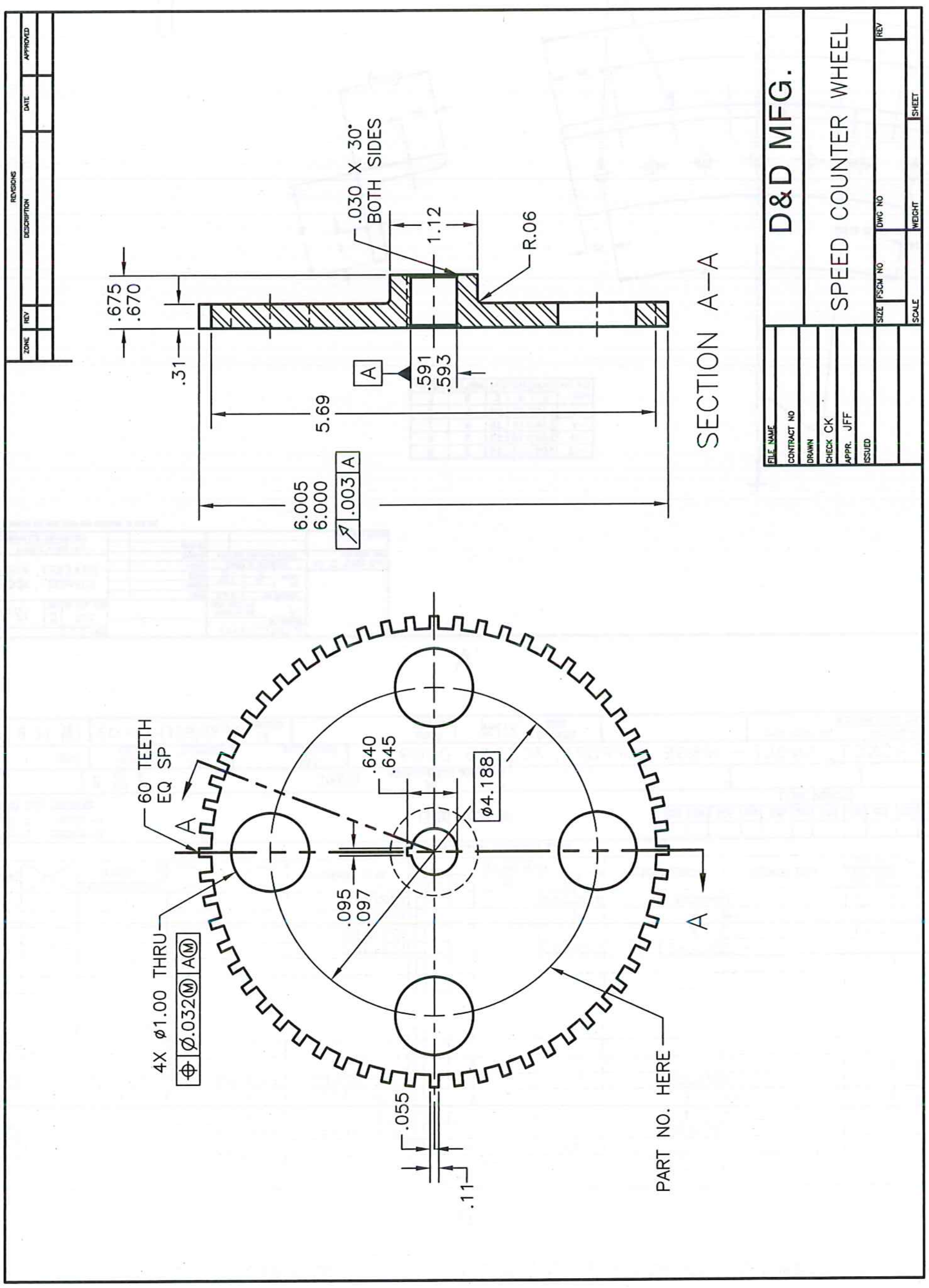
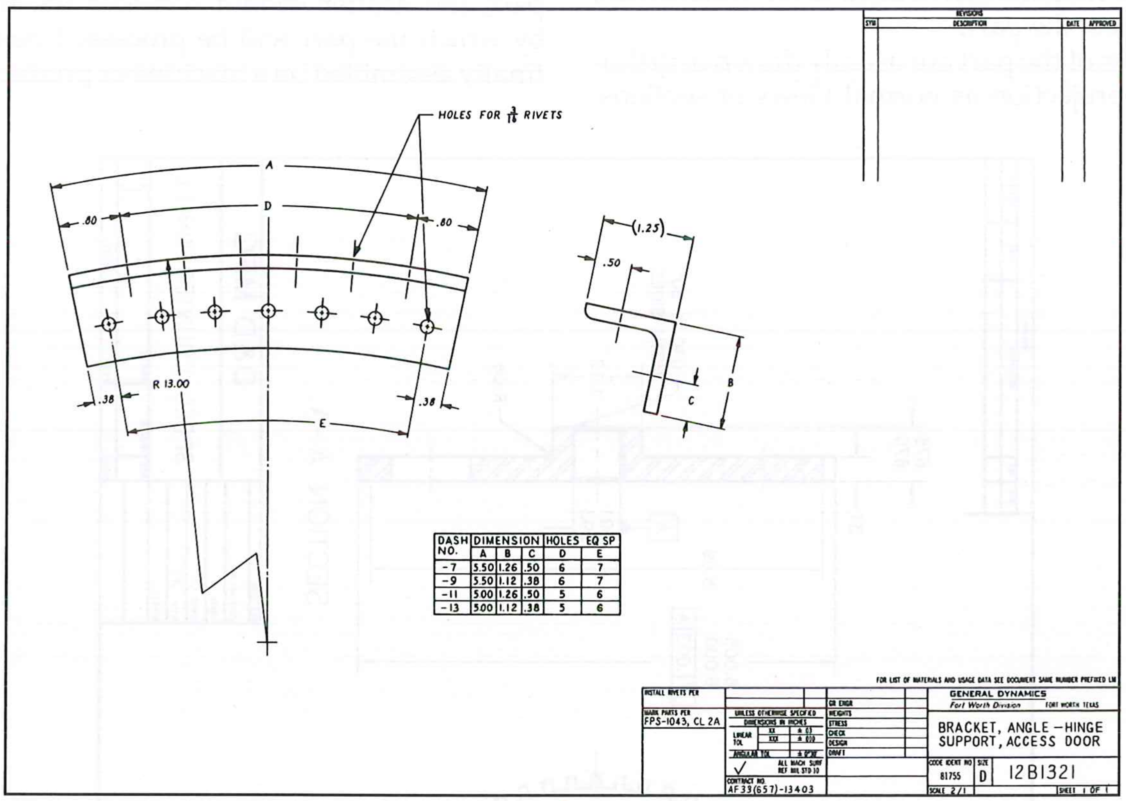


Figure 17-3. A detail drawing provides complete information necessary to fabricate, finish, and inspect the part.

drawing should include information sufficient to purchase or make the part and to design the tools used for its manufacture. The drafter must decide how many views will be necessary, and then locate the views to allow plenty of space for dimensions and notes.

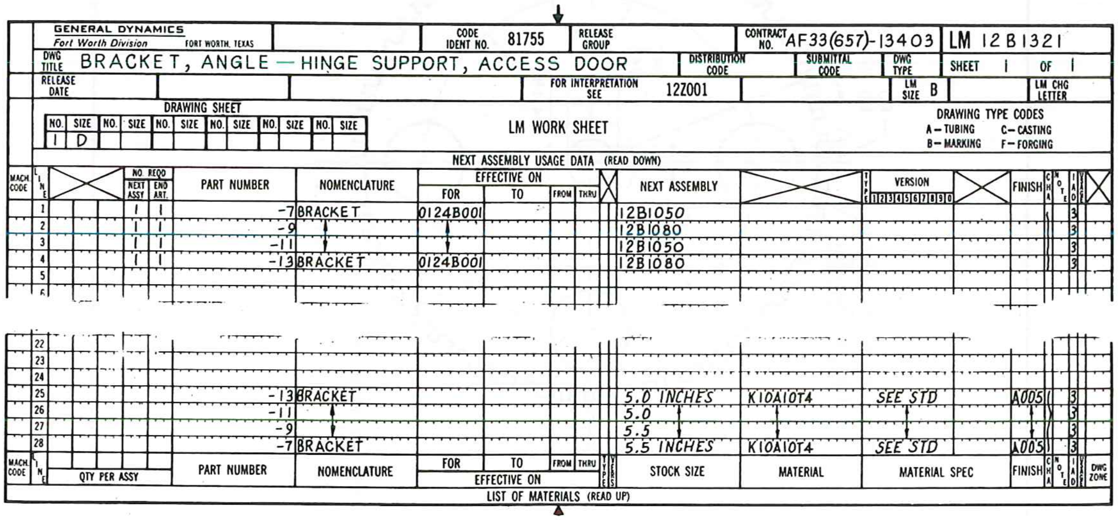
Tabulated Drawings

A ***tabulated drawing*** provides information needed to fabricate two or more items that are basically identical but vary in a few characteristics, **Figure 17-4A**. These variable characteristics typically involve dimensions, material, or finish.



DASH NO.	DIMENSION A	DIMENSION B	DIMENSION C	HOLES EQ SP D	HOLES EQ SP E
-7	5.50	1.26	.50	6	7
-9	5.50	1.12	.38	6	7
-11	5.00	1.26	.50	5	6
-13	5.00	1.12	.38	5	6

A



B

Figure 17-4. A tabulated drawing is used for the fabrication of parts that are nearly identical. A—The drawing includes a tabulation block to show variable dimensions. B—A materials list for the drawing. (Convair Aerospace Div., General Dynamics)

The ***fixed characteristics*** (those that remain the same for all parts involved) should be detailed only once, either on the body of the drawing or in the material block, or in the tabulation block. The ***variable characteristics***, such as dimensions that change from part to part, are expressed on the drawing with letter symbols. The different values for each symbol are given in the tabulation block. Sizes of stock for the parts are given in a materials list, **Figure 17-4B**.

A tabulated drawing eliminates the need to prepare separate drawings of parts that are basically alike.

Assembly Drawings

An ***assembly drawing*** depicts the assembled relationship or positions of two or more detail parts, or of the parts and subassemblies that comprise a unit. As shown in **Figure 17-5**, the views of the object are usually orthographic views. Isometric or other pictorial views are permissible if needed for clarity. Use only the views, sections, and details necessary to adequately describe the assembly. A list of parts is detailed in tabulated form on the drawing, or on a separate sheet, and referenced to the parts in the assembly by numbers.

Assembly drawings should be developed by referring to the detail drawings of the respective parts. This provides an excellent check for fits, clearances, and interferences. Only the operations performed on the assembly in the condition shown should be specified. No detail dimensions should be shown on assembly drawings except to cover operations performed during assembly or to locate detail parts in an adjustable assembly.

A special type of assembly drawing is the ***exploded assembly drawing***, **Figure 17-6**. This type of drawing is most useful when assembling a number of components. Components are usually drawn in pictorial form, with an axis line showing the sequence of assembly.

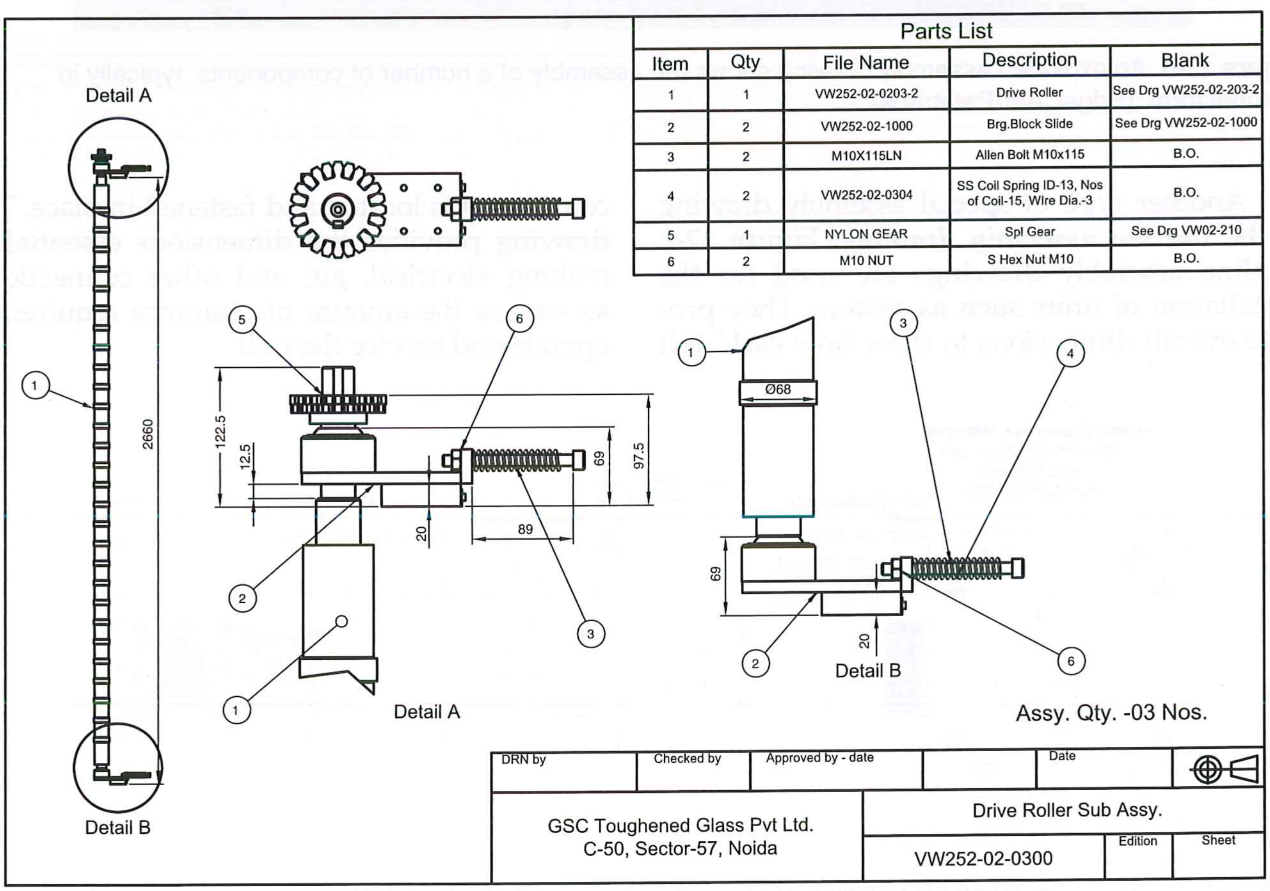


Figure 17-5. An assembly drawing shows the assembly of two or more parts. A parts list is included. (Autodesk, Inc.)

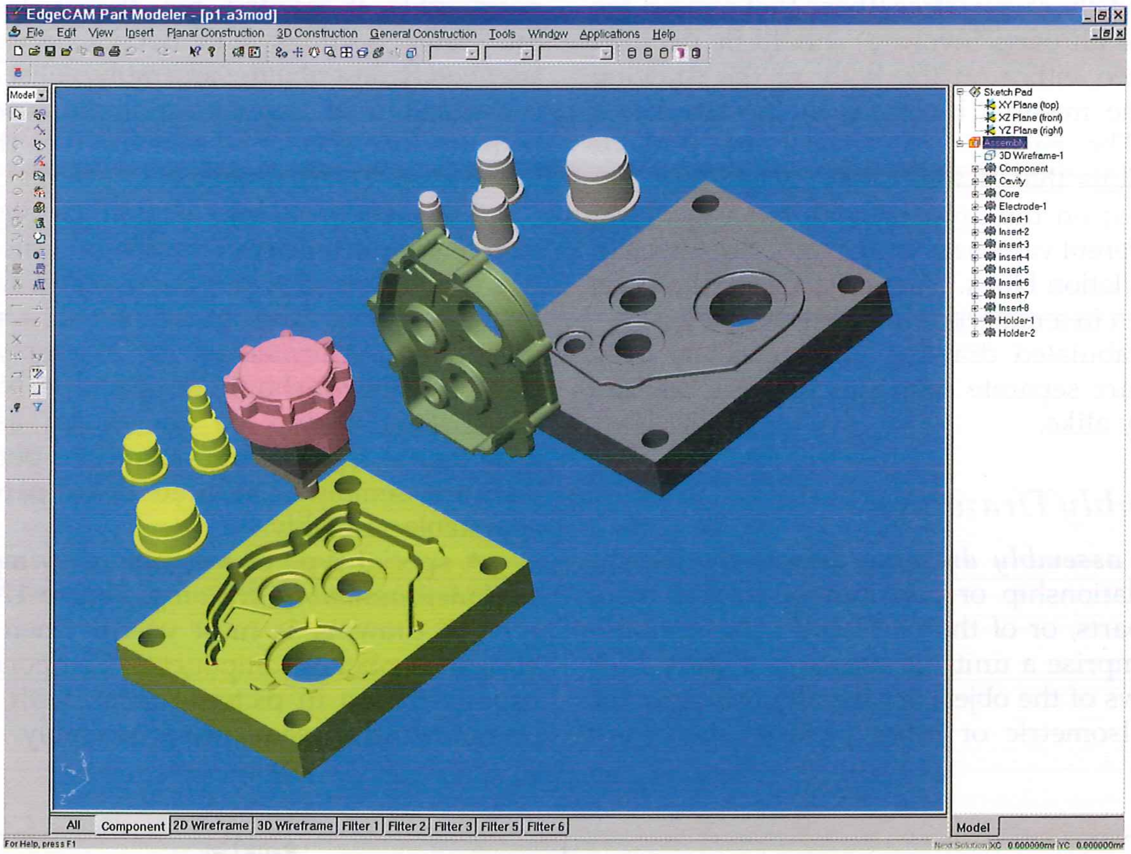


Figure 17-6. An exploded assembly drawing shows the assembly of a number of components, typically in pictorial form. (EdgeCAM/Pathtrace)

Another type of special assembly drawing is the ***outline assembly drawing***, **Figure 17-7**. Outline assembly drawings are used for the installation of units such as motors. They provide overall dimensions to show how each unit component is located and fastened in place. The drawing provides the dimensions essential to making electrical, air, and other connections, as well as the amount of clearance required to operate and service the unit.

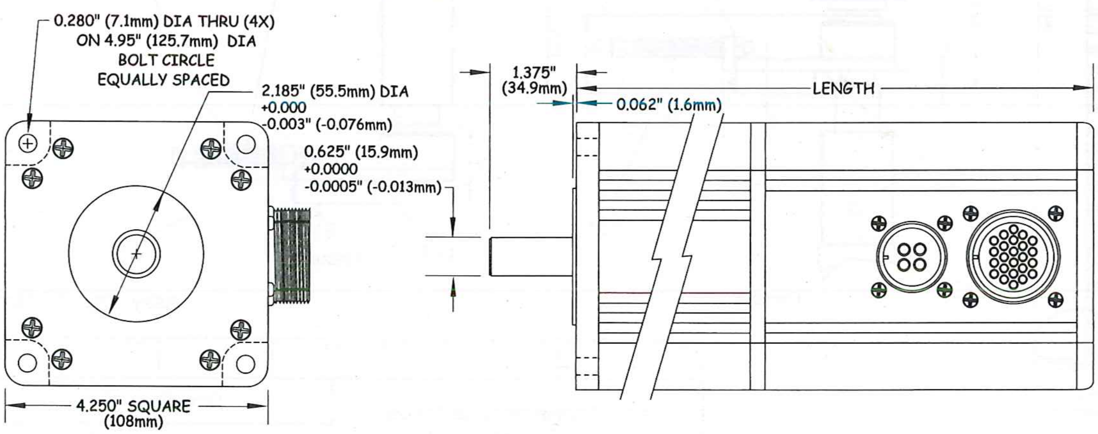


Figure 17-7. An outline assembly drawing provides the necessary dimensions for an installation. This drawing shows the requirements for a servo motor installation. (Animatics Corp.)

Notes may be included to indicate the weight of the unit, the electrical and cooling requirements, and any special notes of caution. Outline assembly drawings are sometimes called *installation drawings.*

Operation Drawings

In addition to the types of working drawings already discussed, there is another type that concerns production methods. An ***operation drawing*** or ***process drawing*** usually provides information for only one step or operation in the making of a part. A CAD-generated operation drawing used in a computer-aided manufacturing (CAM) turning operation is shown in **Figure 17-8**.

This type of drawing is used by a machine operator when making a particular machine setup and performing single operations, such as drilling a hole or milling a slot. Operation drawings usually are accompanied by the machine setup specifications and specific steps for performing the operation in the machine shop. These drawings are usually prepared by a person knowledgeable in drafting and machining operations.

Layout Drawings

A ***layout drawing*** is often the original concept for a machine design or for placement of units. It is not a production drawing, but rather serves to record developing design concepts. It is used to obtain approval of a particular design or to check clearances and relationships of component parts, **Figure 17-9**. Layout drawings are used by experimental shops when constructing models or prototypes, and by design drafters as a reference when preparing detail drawings of various parts.

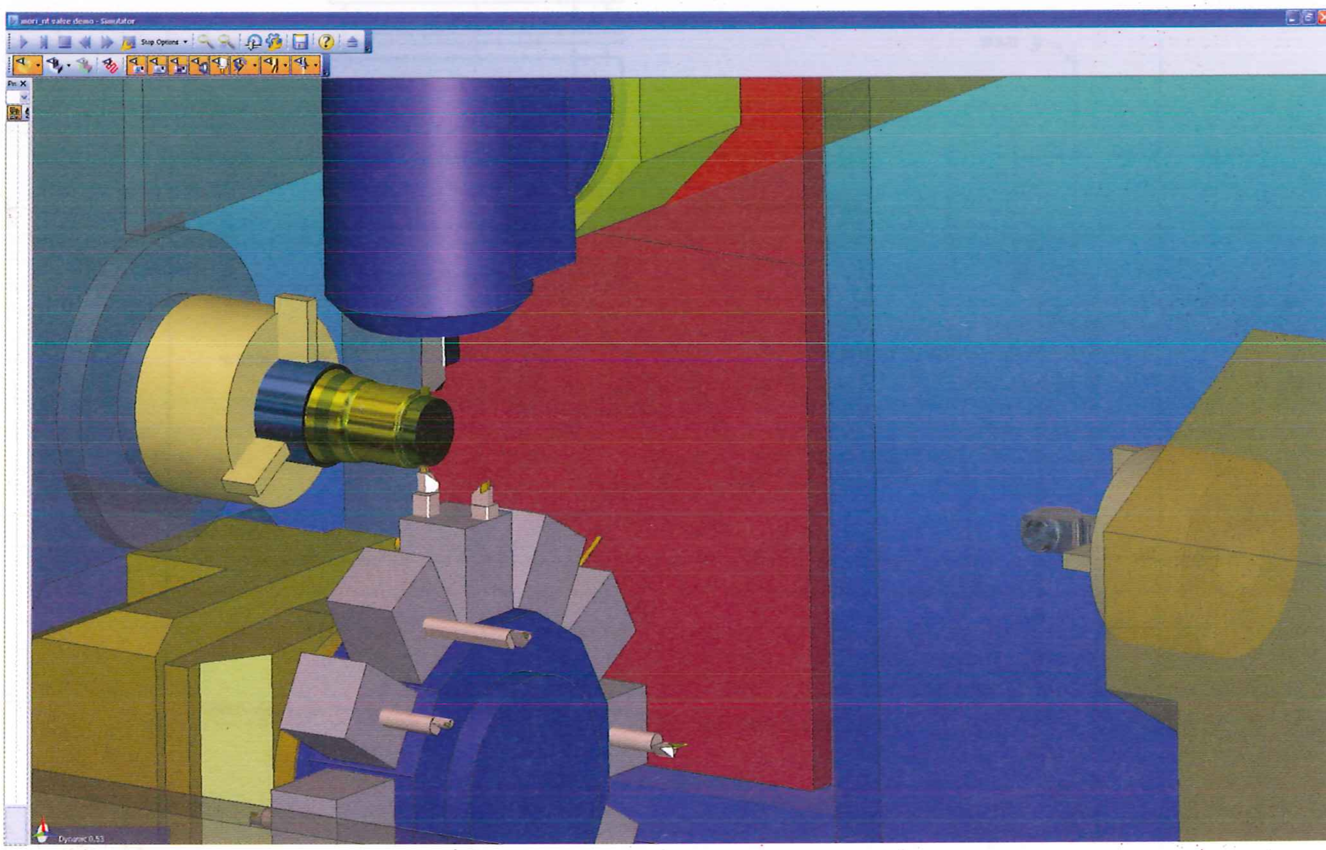


Figure 17-8. A CAD-generated operation drawing showing tooling specifications for a turning operation. (Parametric Technology Corporation)

Although layout drawings may look like assembly drawings, the purposes of the two are entirely different. Layout drawings are used in the early concept and product design stage; assembly drawings are used near the end for fabrication of the product.

Block Formats on Working Drawings

All formal industrial drawings include areas in which essential information is recorded in an organized manner. These areas include the title block, materials block, and revision (or change) block. Certain basic information is common to these blocks in nearly all industries, although the style and location of the block on the drawing may vary. The following sections discuss the information usually recorded in these areas.

In CAD drafting, drawing templates with predrawn title blocks and areas for revisions and materials are typically used as a starting point when beginning a drawing. It is common to have drawing templates for different sheet sizes and drafting disciplines. This saves drafting time and ensures that drawings appear consistent, particularly when a number of drawings are used for a single project.

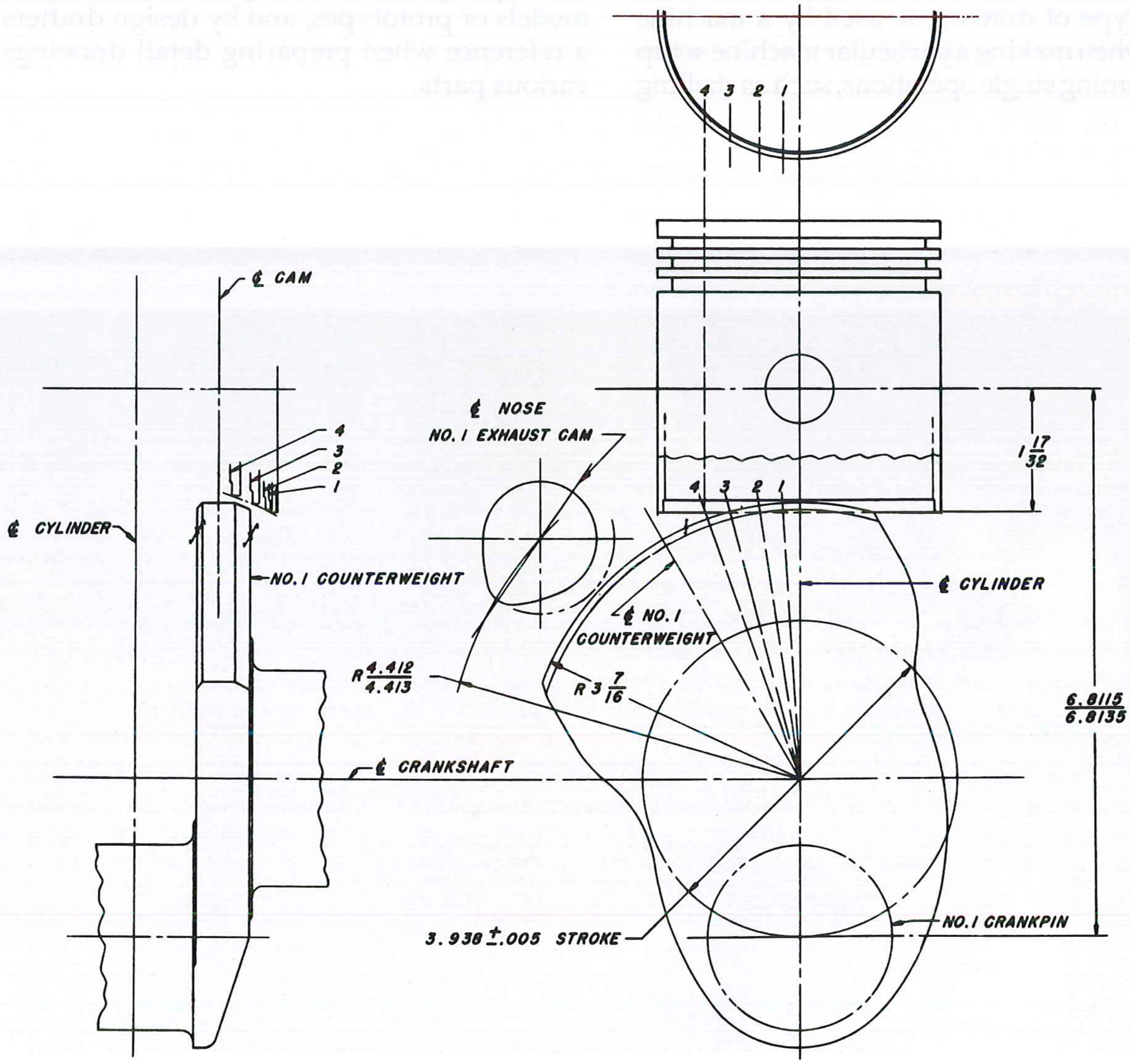


Figure 17-9. A layout drawing used to determine the largest radius crankshaft counterweight that can be used and still maintain clearance between the counterweight and the cam and piston. (General Motors Engineering Standards)

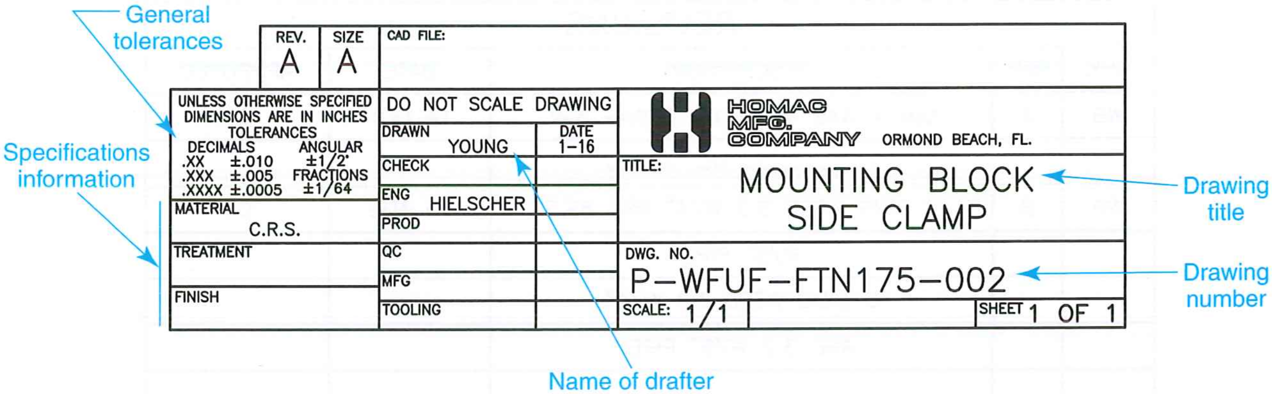


Figure 17-10. Common elements of a drawing title block.

Title Block

The *title block*, **Figure 17-10**, usually is placed in the lower right-hand corner of the drawing. Included in the block are the title or name of the part or assembly, the drawing number (or part number), the names of the drafter and checker, and the signatures of the individuals who are responsible for approvals related to engineering, materials, and production. Other items usually shown in the title block are general tolerances, specifications (material, heat treatment, and finish specifications), and an application block that provides additional information.

Materials Block

The *materials block* is a tabular listing that usually appears immediately above the title block on assembly and installation drawings, **Figure 17-11**. This block may also be identified as a Parts List, List of Materials, Bill of Materials, or Schedule of Parts. It lists the different parts that go into the assembly shown on the drawing, the quantity of each part needed, the name or description of the part, and any material specifications. If the part is to be purchased, the supplier should be identified by name or identification code in the materials block.

Revision Block

After prints of a drawing have been released to production, it is sometimes necessary to make changes for various reasons. These reasons may include design improvement, production problems, or errors found in the drawing. All changes to the original drawing must be approved by the proper authority.

When a change has been approved and made on the drawing, it is recorded in the *revision block*, **Figure 17-12**. The entry typically consists of a brief description of the change, an identifying letter referencing it to the specific location on the drawing, and the date. The initials or signature of the drafter

ITEM	QTY	PART NO.	DESCRIPTION
8	2	P-WFUF-FTN-175-008	Top Plate Clamping Blocks
7	2	P-WFUF-FTN-175-007	Side Clamping Blocks
6	1	P-WFUF-FTN-175-006	Plate Locator for Even Number of Fingers on Casting
5	1	P-WFUF-FTN-175-005	Plate Locator for Odd Number of Fingers on Casting
4	1	P-WFUF-FTN-175-004	Casting Locator & Support
3	1	P-WFUF-FTN-175-003	Casting Support Mounting Bar
2	2	P-WFUF-FTN-175-002	Side Clamp Mounting Blocks
1	1	P-WFUF-FTN-175-001	Upper Frame Weldment
PARTS LIST			

Figure 17-11. A materials block lists all of the parts required to complete the assembly shown on the drawing.

REVISIONS				
CHK	REV	DESCRIPTION	DATE	APPROVED
WB	A	DIM A WAS 46.8, DIM D WAS 3.4;	14 OCT	CK
		PRODUCTION NO. ADDED		
WB	B	B DIMS WERE 8.0 W/4" AND 89.5	10 AUG	CK
		W/5" PIPE		
		D DIMS WERE 3.0 W/4"		
		AND 3.2 W/5" PIPE		

Figure 17-12. The revision block is a record of changes made to the original drawing.

making the change, and those of the person approving the change, are required in most organizations.

The revision block is usually located in the upper right-hand corner of the drawing, and is sometimes titled *Alterations* or *Notice of Change.*

Standards for Drafting

All industrial drawings should conform to the appropriate standard recognized by the given industry. Standards for drafting are prepared by various industrial and professional organizations and are available from the American National Standards Institute (ANSI) or the American Society of Mechanical Engineers (ASME). The ASME Y14 series of drafting standards is recognized throughout industry. Most companies also have their own standards and list them in a drafting manual. Company standards generally conform with industry standards, but they are modified or added to so that they meet the needs of the company or a particular industry.

Today, there is a strong trend toward the adoption of internationally recognized standards and symbols, particularly by companies engaged in multinational manufacturing and trade. Worldwide sourcing, which involves the assembly of a product from components made in several different countries, has become common. This often means that drawings made in one country must be easily read and used to make parts in another.

The Design and Drafting Process

The production of an industrial drawing begins with an expressed need for something to be produced, **Figure 17-13.** This need is given to the design department, where the concept is developed and researched. Original designs of the product are sketched or drawn. The designers give the sketches to drafters for further development of the design ideas in layout drawings, or for preparation of detail and assembly drawings. The original drawings are then carefully checked by experienced design drafters for correctness of all details.

After a drawing is approved by design engineers, cost analysts, production engineers, and management, it is released to production. Tool designers use the documentation to prepare drawings for the jigs and fixtures used with the machines that will produce the product. Once prints of the production drawings are in use, drawing changes may be made only by the design department under authority of the project engineer for the product.

Applications of Working Drawings

The working drawing is the vital link of communication in industry, making it possible to produce individual machine parts in widely

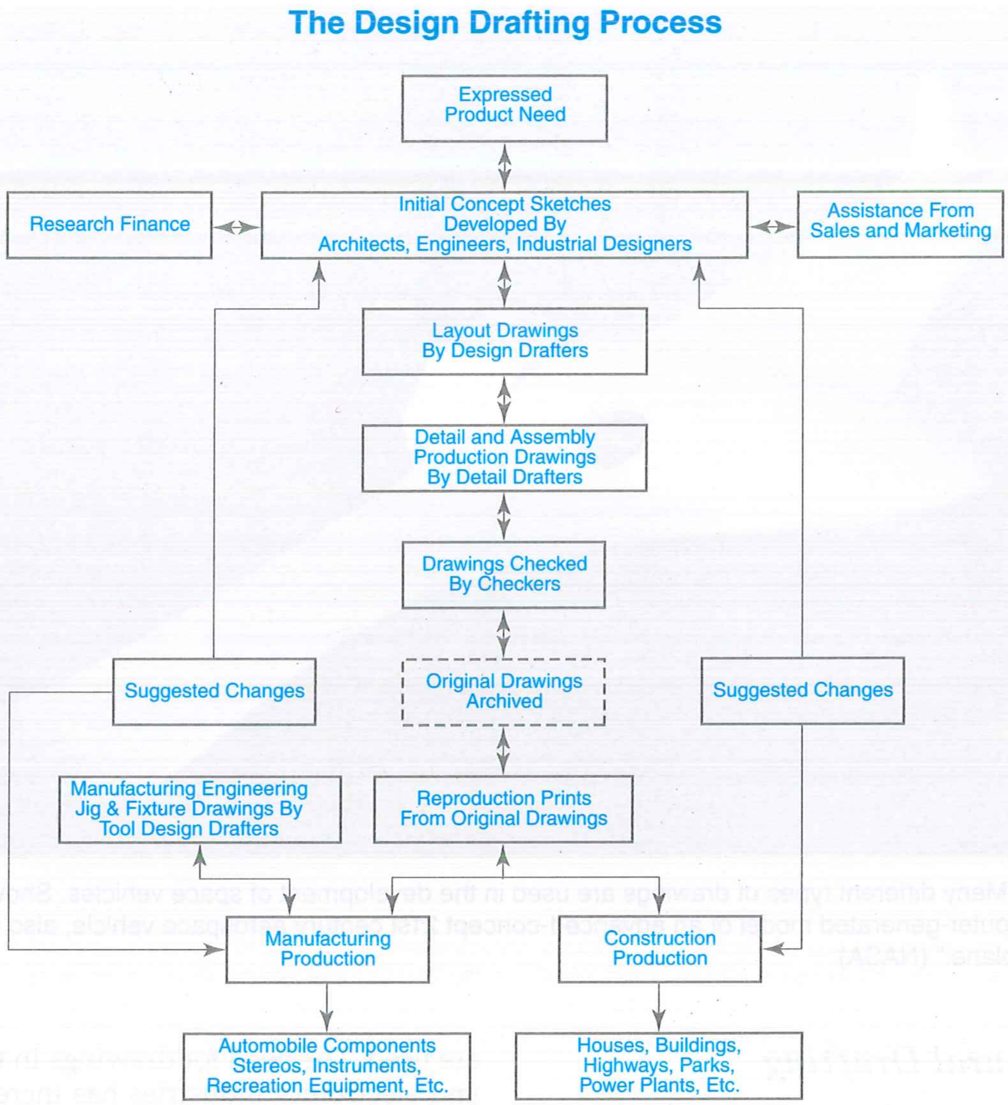


Figure 17-13. The design and drafting process from product conception to production.

separated plants. Some applications of working drawings in major industries are discussed in the following sections.

Aerospace Drafting

Because of the type of product manufactured, aerospace drawings are perhaps the most elaborate of those of any industry. Precision dimensioning, tolerancing, and rigid specifications characterize these drawings, since many of the parts and components are made by subcontractors and brought together for assembly by the primary contractor.

Literally thousands of detail and assembly working drawings are used in the production of one model of an aerospace vehicle or airplane. Every type of drawing is employed in the aerospace industry, **Figure 17-14**.

Automotive Drafting

Automotive manufacturing makes up perhaps the largest sector of industry in the world. It can be argued that more has been done in this industry than any other to perfect the drafting process. Both the automotive and aerospace industries have produced a great number of drafting practices to supplement US and international drafting standards. As in the aerospace industry, every type of drawing is employed in the production of automobiles and trucks.

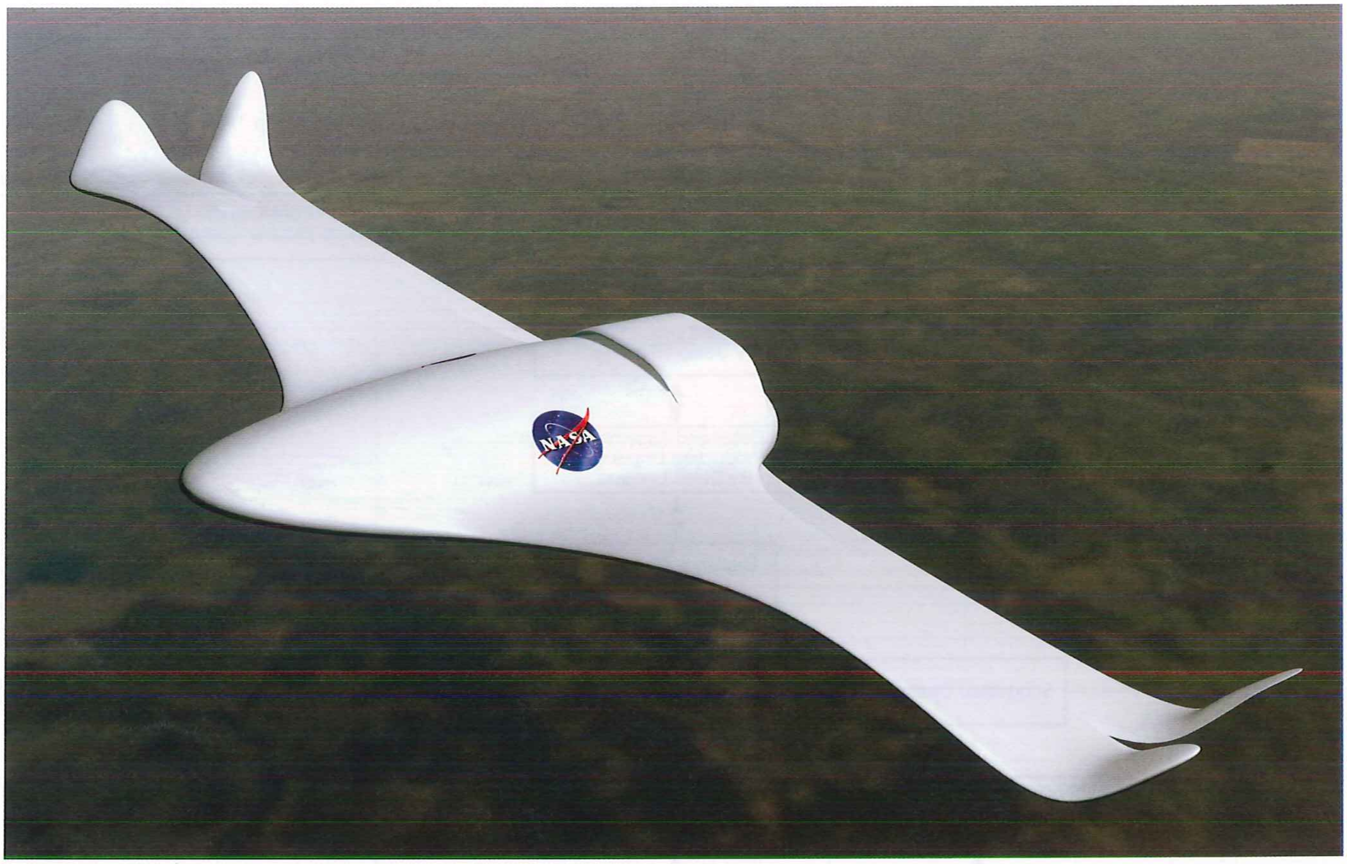


Figure 17-14. Many different types of drawings are used in the development of space vehicles. Shown is a rendered computer-generated model of an advanced-concept 21st century aerospace vehicle, also known as a "morphing airplane." (NASA)

Architectural Drafting

Architects, engineers, technicians, and construction workers rely heavily on working drawings in planning and constructing a residential or commercial building. The nature and types of architectural drawings are discussed in Chapter 22. This is a field in which creative design and individuality are expressed in nearly every project. To achieve the design solution planned by the architect to meet the desires of the owner, carefully developed working drawings and specifications are necessary.

Electrical and Electronics Drafting

Working drawings used in the electrical industry differ from those in other industries, as discussed in Chapter 24. Instead of detail and assembly drawings of machine parts, various diagrams and line drawings with graphic symbols are used. The need for drawings in the electrical and electronics industries has increased due to the more complex circuitry of many household appliances as well as electronics applications such as computers and process controllers.

Casting Drawings

Casting is the process of pouring molten metal into a mold where it hardens into the desired form as it cools. In a casting drawing, the rough and machined versions of the casting should be combined in the same views on one drawing. The material to be removed by machining is shown using phantom lines, **Figure 17-15**. For complex castings, where the combined rough and machined castings in a single view would cause confusion, make separate dimensioned drawings showing the rough casting and machined piece. The two drawings should be placed on one sheet, when possible. A

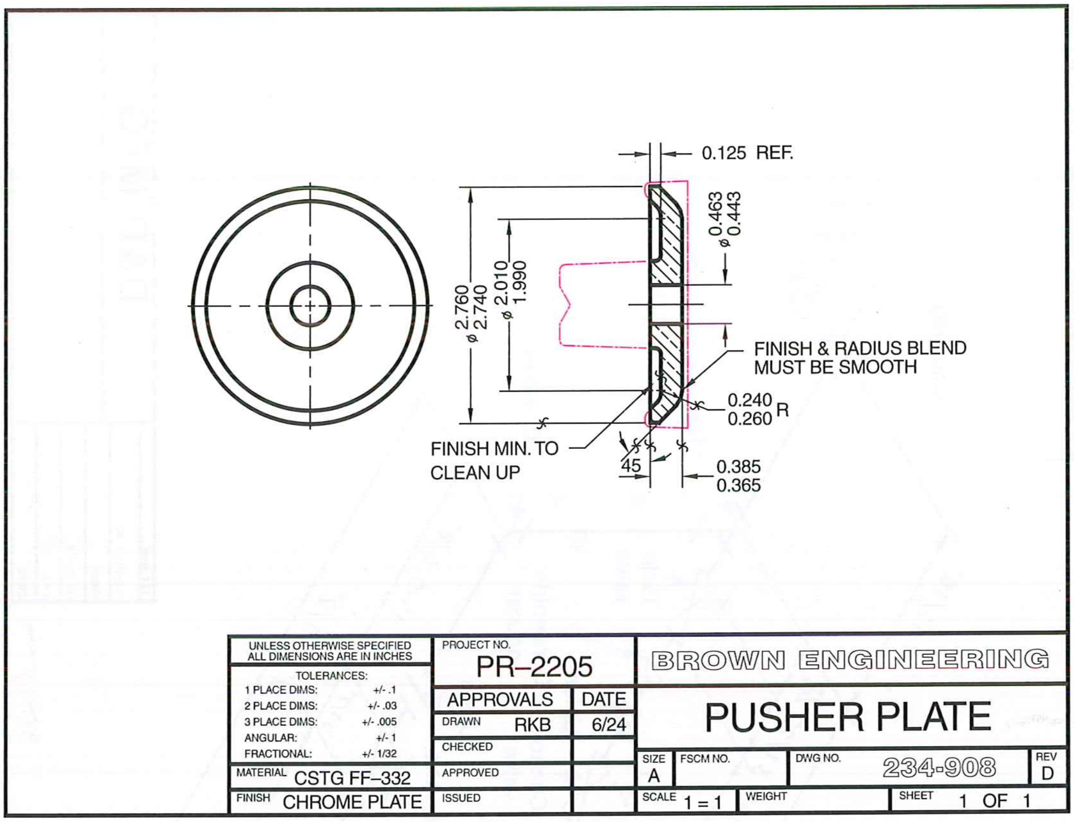


Figure 17-15. A composite casting drawing with finished machining dimensions given.

detail drawing of a casting should give complete information for the following specifications:

- Material specification
- Hardness specification, if required
- Machining allowances
- Kind of finish
- Draft angles
- Limits on draft surfaces that must be controlled
- Locating points for checking the casting
- Parting line
- Part number and trademark

Piping Drawings

A ***piping drawing*** is an assembly drawing that represents a piping layout using symbols and either single lines or double lines. To represent the various fittings, either pictorial or graphic symbols may be used. The usual practice is to show piping layouts as single-line drawings in isometric or oblique views, because of the difficulty of reading orthographic projection views. A typical piping layout is shown in **Figure 17-16**.

Structural Steel Drawings

A ***structural steel drawing*** provides construction information for a steel structure. There are two general types of structural steel drawings: design drawings and shop (or "working") drawings. Design drawings show the overall design and dimensions of the structure and specify the sizes and types of material used. They are prepared by structural engineers. Working drawings for the actual fabrication of steel members are prepared by the fabricator under the direction and approval of the design engineer. Working drawings that are sent to the job site for erection purposes must detail connections to be made in the field.

Units shipped to the job site from the fabricator's facility are called ***subassemblies***,

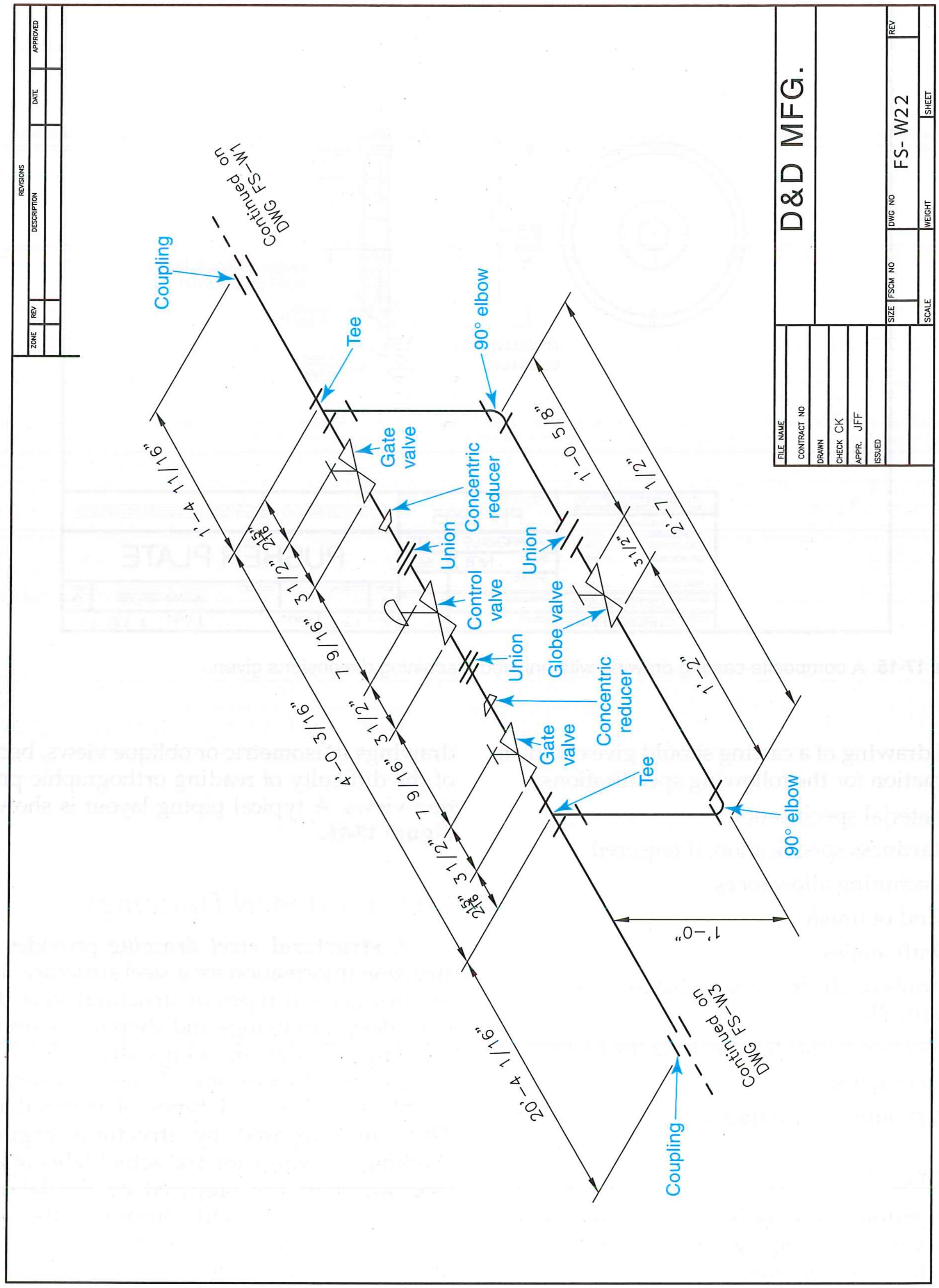


Figure 17-16. A single-line isometric drawing of a piping installation. Valves and other fittings are identified for reference.

Figure 17-17. These large steel intake tubes for a hydroelectric generating plant were fabricated as a subassembly in the shop and shipped to the job site.

Figure 17-17. These are fastened together on the job by rivets or bolts, or they are welded in place, **Figure 17-18**.

Reinforced Concrete Drawings

Reinforced concrete construction is achieved by placing steel rods or beams strategically in the forms and pouring the concrete around these reinforcements, **Figure 17-19**. This type of construction is very strong structurally and is also fire resistant.

Drawings for reinforced concrete construction must show the size and location of the reinforcing steel, as well as the dimensions and shapes of the concrete members, **Figure 17-20**. The rods are represented by long dashes in the elevation view and as darkened circles in the

Figure 17-19. Steel reinforcing rods, like those exposed here during a bridge deck repair project, are embedded in concrete to provide strength. In addition to paving use, reinforced concrete is widely used for structures. (Jack Klasey)

sectioned view. The American Concrete Institute publishes the *Manual of Standard Practice for Detailing Reinforced Concrete Structures*, which is helpful in preparing drawings for structures such as buildings, bridges, and walls.

Welding Drawings

A ***welding drawing*** is an assembly drawing that shows the components of an assembly in position to be welded, rather than as separate parts. Specifying the types of welds to be used on various joints is standard procedure on welding drawings. A series of standard welding symbols for use on drawings has been prepared by the American Welding Society. These symbols and the procedures used to prepare welding drawings are discussed in Chapter 26.

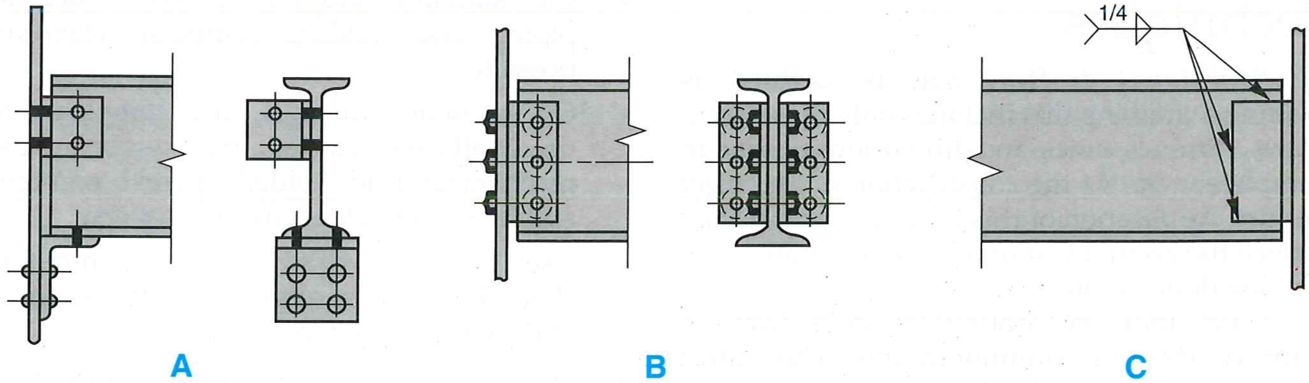


Figure 17-18. Methods of illustrating steel beam connections. A—Rivets. B—Bolts. C—Welds.

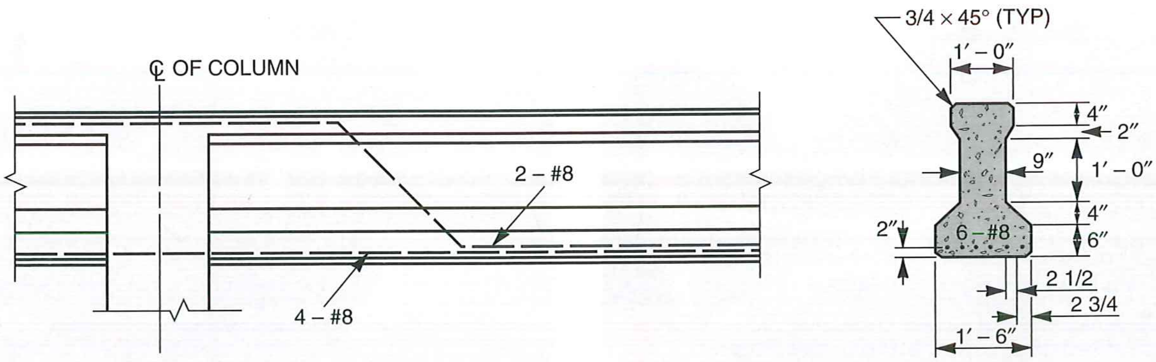


Figure 17-20. A detail of a reinforced concrete member showing the size and location of steel reinforcing rods.

Patent Drawings

A ***patent drawing*** is made when a patent is sought for a machine or other device that lends itself to illustration by a drawing. When applying for a patent requiring a drawing, the drawing must be submitted with an application to the US Patent and Trademark Office (USPTO). Very specific instructions on properly preparing patent drawings are available on the USPTO web site at www.uspto.gov. These instructions provide guidelines for the type of paper and ink, drawing size, line density, and other requirements, such as the manner in which the drawing (or set of drawings) is submitted.

Patent drawings follow standard drafting practices, but the views do not necessarily have to appear in orthographic projection or even be placed on the same sheet. Isometric views or other pictorial views are acceptable if they clearly represent the object for which a patent is desired.

Functional Drafting Techniques

Functional drafting may be defined as making a drawing that includes only those lines, views, symbols, notes, and dimensions needed to completely clarify the construction of an object or part. Application of this technique should not reduce the accuracy or quality of the drawing or the line delineation.

Every industry continually seeks ways to improve drafting communication. This effort arises from the amount of drafting time involved in the planning and development of most industrial projects, and the time spent in reading and interpreting drawings. Functional drafting techniques have successfully reduced drafting time, and thus have been welcomed in most industries.

The following functional drafting techniques have been discussed in other chapters of this text as standard drafting practices. They are listed here as a summary of standard practices:

- Use the minimum number of views.
- Use a partial view, where adequate.
- Eliminate a view whenever a thickness note will suffice.
- Use symmetry to reduce drawing time.
- Eliminate superfluous detail; use schematic or simplified forms whenever possible.
- Omit the drawing of standard parts such as bolts, nuts, and rivets. Locate them conventionally or by a note, and list them in the materials block.
- Avoid unnecessary repetition of detail.
- Omit cross hatching, except where clarity demands its use; use outline sectioning.
- Use standard graphic symbols (such as piping and welding symbols) whenever possible.
- On manual drawings, use templates to draw ellipses, circles, and symbols. Use mechanical lead holders, pencil pointers, and thin-lead holders as time-savers.
- Use tabulated drawings for commonly shaped items that require only the addition of dimensions and/or specifications.
- Use a general tolerance note in the title block for indicating tolerances when possible.

Chapter Summary

A working drawing must contain the information necessary to manufacture, construct, assemble, or install a product or structure. Working drawings may be divided into a number of subtypes depending on their use. Each type serves a distinct purpose. Drawings may be classified as freehand sketches, detail drawings, tabulated drawings, assembly drawings, operation drawings, and layout drawings.

Working drawings have standard formats. On all formal industrial drawings, essential information is recorded in the title block, materials block, and revision block.

All industrial drawings should conform to the standards practiced within the given industry. The standards govern the amount of information on a drawing and how it is presented.

The working drawing serves as a vital link of communication within an industry. It makes possible the production of individual machine parts in separate plants.

Functional drafting involves producing a drawing that conveys the necessary information with minimum time and effort without sacrificing quality and accuracy.

Review Questions

1. What information is provided by a working drawing?
2. A _____ drawing describes a single part that is to be made from one piece of material.
3. A _____ drawing provides information needed to fabricate two or more items that are basically identical but vary in a few characteristics. It lists data in a tabulation block and/or materials list.
4. What type of drawing depicts the assembled relationship or positions of two or more detail parts, or of the parts and subassemblies that comprise a unit?
5. _____ drawings are used in the early concept and product design state and serve to record developing ideas.
6. Where is the title block usually located on a drawing?
7. When a change has been approved and made on the drawing, where is it recorded?
8. _____ is the process of pouring molten metal into a mold where it hardens into the desired form as it cools.
9. A _____ drawing is an assembly drawing that shows the components of an assembly in position to be welded, rather than as separate parts.
10. A _____ drawing is made when a patent is sought for a machine or other device that lends itself to illustration by a drawing.
11. What is *functional drafting*?

Drawing Problems

The following problems are to be drawn using standard drafting practices. They should include all dimensions, specifications, and notes required for production. These problems can be completed manually or using a CAD system. Draw each problem as assigned by your instructor.

The problems are classified as introductory, intermediate, and advanced. A drawing icon identifies the classification.

The given problems include customary inch and metric drawings. Draw the required views for each problem and complete the problem as instructed. Use the dimensions provided. If you are drawing the problems manually, use one of the layout sheet formats given in the Reference Section. If you are using a CAD system, draw a title block or use a template. Use the appropriate drawing commands and tools to complete each problem. Create layers and set up drawing aids as needed. Save each problem as a drawing file and save your work frequently.

Detail Drawings

Study the drawings shown in Problems 1–3. Draw the necessary views and make a detail drawing for each problem. Change the two-place and three-place decimal dimensions to limit dimensions with the following tolerances: .XXX = ± .003; .XX = ± .010. Delete all unnecessary dimensions. Indicate all flat surfaces as 125 microinches (3.2 micrometers) and all bored and counterbored holes as 63 microinches (1.6 micrometers) in texture.