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Engineering Drafting Manual, Volume 2

March 2008

ENGINEERING

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Engineering Drafting Manual, Volume 2

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Introduction

The *Engineering Drafting Manual, Volume 2* contains guidance to aid Engineering personnel in preparing and producing engineering drawings. This guidance is based on specific Lawrence Livermore National Laboratory (LLNL) standards, specifications, and procedures, as well as industry and military standards and specifications. Engineering's objective is to produce drawings that contain all the information required for a single interpretation of the originator's intent by all users of the drawing. The Engineering Directorate, as a decentralized organization, recognizes the independence of the divisions, projects, and programs, relative to engineering and fabrication matters. However, Engineering personnel are often dependent on one another for engineering information and support. Drawings are exchanged and Engineering personnel are often transferred between divisions. These considerations underscore the desirability of having uniform drafting practices.

The guidance set forth in this manual is a resource for reconciling differing viewpoints for engineering drafting procedures. Sections highlight controversial areas and provide recommended solutions, all with the goal of having uniform drawing practices and manufacturing processes throughout the Engineering Directorate. In the event policies conflict, the following order of precedence for requirements should apply:

1. Engineering Policy 5.4, "Drafting"
2. *Engineering Drafting Manual, Volume 1*
3. *Engineering Drafting Manual, Volume 2*

Engineering Policy 1, "Policy Applicability and Authorizations Required for Exceptions or Deviations," defines the authorizations required for exceptions or deviations to these drafting requirements.

SI (metric) units are used throughout the text and illustrations in this manual in accordance with ASME Y14.5M–1994. Customary English units in this manual are noted. SI units are the commonly used units of measure for engineering drawings. However, the units of measure specified on a drawing should be uniform across all drawings within an assembly package, as defined by the owning design organization and the contractual requirements of their customer deliverables.

The drawing examples in this manual are complete only to the extent necessary to illustrate the requirements of the accompanying text and illustrations. Graphics will be updated as funding allows.

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Section 1. Specifications and Standards

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

1.1 Purpose

This section lists readily available past and present specifications and standards used for engineering drawings prepared for the Engineering Directorate. Inclusion on the lists is no indication of current status, i.e. active, inactive, or superseded.

1.2 Specification and Standards Implementation

Engineering requires that the revision letter and/or date of release of specifications and standards shall be included in the notes called out on the face of drawings.

1.3 Reference Documents

- Global Engineering, *Drawing Requirements Manual* (latest edition)
- Information Handling Services (IHS)

  IHS is a provider of technical content and information solutions for standards, regulations, parts data, design guides, and other technical information, and is available to Engineering and other LLNL employees. Access IHS from the LLNL Library web page (choose **Specs & Standards (IHS)**):

  https://library-int.llnl.gov/e-resources/databases.php

Tables 1-1 and 1-2 list specifications available from IHS.

Table 1-1. ME specifications available from IHS

Spec. No.	Spec. Name
ANSI Y14.17-1966	Use of the International System of Units (SI): The Modern Metric System
ANSI Y14.7.1-1971	Gear Drawing Standards – Part 1: for Spur, Helical, Double Helical and Rack
ANSI Y14.7.2-1978	Gear and Spline Drawing Standards Part 2: Bevel and Hypoid Gears
ASME B46.1–2002	Surface Texture (Surface Roughness, Waviness, and Lay)
ASME SI-1–1982	ASME Orientation and Guide for use of SI-1 (Metric) Units - Ninth Edition
ASME Y14.100-2003	Engineering Drawing Practices
ASME Y14.1-1995	Decimal Inch Drawing Sheet Size and Format
ASME Y14.1M-1995	Metric Drawing Sheet Size and Format
ASME Y14.2M-1992	Line Conventions and Lettering
ASME Y14.3M-1994	Multiview and Sectional View Drawings
ASME Y14.4M-1989	Pictorial Drawing
ASME Y14.5M-1994	Dimensioning and Tolerancing
ASME Y14.5.1M-1992	Mathematical Definition of Dimensioning and Tolerancing Principles

Spec. No.	Spec. Name
ASME Y14.6-2001	Screw Thread Representation
ASME Y14.8M-1992	Casting and Forgings
ASME Y14.13M-1981	Mechanical Spring Representation
ASME Y14.15-1966	Electrical and Electronics Diagrams; Information Sheet
ASME Y14.18-1986	Optical Parts
ASME Y14.24-1999	Types and Applications of Engineering Drawings
ASME Y14.26M-1989	Digital Representation for Communication of Product Definition Data
ASME Y14.34M	Associated Lists
ASME Y14.35M-1992	Revision of Engineering Drawings and Associated Documents
ASME Y14.36M-1996	Surface Texture Symbols
ASME Y14.38-1992	Abbreviations and Acronyms
ASME Y14.38a-2002	Abbreviations and Acronyms
ASME Y14.40.0-2002	Basic Rules for the Design of Graphical Symbols for Use in the Technical Documentation of Products - Identical to ISO 81714-1:1999
ASME Y14.40.1-2002	Graphical Symbols for Diagrams, Part 1: General Information and Indexes
ASME Y14.40.2-2002	ASME, Graphical Symbols for Diagrams, Part 2: Symbols Having General Application
ASME Y14.40.3-2002	Graphical Symbols for Diagrams, Part 3: Connections and Related Devices - Identical to ISO 14617-3: 2002
ASME Y14.40.4-2002	Graphical Symbols for Diagrams, Part 4: Actuators and Related Devices - Identical to ISO 14617-2: 2002
ASME Y14.40.5-2002	Graphical Symbols for Diagrams, Part 5: Measurement and Control Devices - ISO 14617-5
ASME Y14.40.6-2002	Graphical Symbols for Diagrams, Part 6: Measurement and Control Functions
ASME Y14.40.7-2002	Graphical Symbols for Diagrams, Part 7: Basic Mechanical Components
ASME Y14.40.8-2002	Graphical Symbols for Diagrams, Part 8: Valves and Dampers - Identical to ISO 14617-8:2002
ASME Y14.40.9-2002	Graphical Symbols for Diagrams, Part 9: Pumps, Compressors , and Fans - Identical to ISO 14617-3: 2002
ASME Y14.40.11-2002	Graphical Symbols For Diagrams, Part 11: Devices for Heat Transfer and Heat Engines - Same as ISO 14617-11
ASME Y14.40.12-2002	Graphical Symbols for Diagrams, Part 12: Devices for Separating, Purification and Mixing
ASME Y14.40.15-2003	Graphical Symbols for Diagrams, Part 15: Installation Diagrams and Network Maps
ASME Y14.41 – 2003	Digital Product Definition Data Practices
ASME Y14.42M	Digital Approval Systems
ASME Y14.43M-2003	Dimensioning and Tolerancing Principles for Gages and Fixtures
AWS2.4-1998	Standard Symbols for Welding, Brazing, and Nondestructive Examination
AWS A1.1-2001	Metric Practice Guide for the Welding Industry

Spec. No.	Spec. Name
AWS A3.0-2001	Standard Welding Terms and Definitions Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying
IEEE/ASTM SI 10	American National Standard for Use of the International System of Units (SI): The Modern Metric System
MIL-PRF-5480	Data, Engineering and Technical: Reproduction

Table 1-2. EE specifications available from IHS

Spec. No.	Spec. Name
ANSI Z35.1	Specifications for Accident Prevention Signs
ANSI/J STD-001	Requirements for Soldered Electrical and Electronic Assemblies
ANSI/J STD-004	Requirements for Soldering Fluxes
ANSI/J STD-005	Requirements for Soldering Pastes
ANSI/J STD-006	Requirements for Electronic Grade Solder Alloys and Fluxed and Non-Fluxed Solid Solders for Electronic Soldering Applications
EDSS Section 11.3	Specification for Electrical Equipment Fabrication
EDSS Section 11.1	Designing and Fabricating Safe Electrical Equipment
EIA-336	Color Coding for Chassis Wiring
EIA-364-41B	Cable Flexing Test Procedure for Electrical Connectors
IEEE 315 1975/ANSI Y32.2-1975	Graphic Symbols for Electrical and Electronics Diagrams
IEEE200-1975/ANSI Y32.16-1975	Standard Reference Designations for Electrical and Electronics Parts and Equipment
IPC/WHMA-A-620	Requirements and Acceptance for Cable and Wire Harness Assemblies
IPC-A-600	Acceptability of Printed Boards
IPC-A-610	Acceptability of Electronic Assemblies
IPC-CM-770	Component Mounting Guidelines for Printed Boards
IPC-D-249	Design Standard for Flexible One-and-Two-Sided Printed Boards
IPC-D-275	Design Standard for Rigid Printed Boards and Rigid Printed Board Assemblies
IPC-D-300	Standard Tolerances for Printed Circuits, Dimensional and Mechanical Tolerances
IPC-D-325	Documentation Requirements for Printed Boards
IPC-D-859	Design Standard for Thick Film Multilayer Hybrid Circuits
IPC-L-108	Specification for Thin Metal Clad Base Materials for Multilayer Printed Boards
IPC-L-109	Specification for Resin Pre-impregnated Fabric for Multilayer Printed Boards
IPC-L-115	Specification for Rigid Metal Clad Base Materials for Printed Boards
IPC-RB-276	Qualification and Performance Specification for Rigid Printed Boards
IPC-S-815	General Requirements for Soldering Electronic Interconnections
IPC-SM-780	Component Packaging and Interconnecting with Emphasis on Surface Mounting
IPC-SM-782	Surface Mount Land Patterns (Configurations and Design Rules)
IPC-SM-817	General Requirements for Dielectric Surface Mounting Adhesives
IPC-SM-840	Qualification and Performance of Permanent Polymer Coating (Solder Mask) for Printed Boards
IPC-T-50	Terms and Definitions for Interconnecting and Packaging Electronic Circuits

Spec. No.	Spec. Name
IPC-2141	Controlled Impedance Circuit Boards and high Speed Logic Design
IPC-2221A	Generic Standard on Printed Board Design
IPC-2223	Sectional Design Standard for Flexible Printed Boards
IPC-2226	Sectional Design Standard for high Density Interconnect (HDI) Printed Boards
IPC-2615	Printed Board Dimensions and Tolerances
IPC-4101A	Specification for Base Materials for Rigid and Multilayer Printed Boards
IPC-4121	Guidelines for selecting Core Constructions for Multilayer Printed Wiring Board applications
IPC-6011	Generic performance Specification for Printed Boards
IPC-6012A	Qualification and Performance Specification for Rigid Printed Boards
IPC-9502	PWB Assembly soldering Process Guideline for Electronic Components
MIL-A-8625	Anodic Coatings for Aluminum and Aluminum Alloys (Anodizing)
MIL-C-45224	Cable and Harness Assemblies, Electrical, Missile System: General Specification for
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-C-85049	Connector Accessories, Electrical, General Specification for
MIL-DTL-16878	Wire, Electrical, Insulated, General Specification for
MIL-E-45782	Electrical Wiring, Procedures for
MIL-R-3065	Rubber, Fabricated Products
MIL-STD-1344	Test Methods For Electrical Connectors
MIL-STD-401	Limits for Electrical Insulation Color
MIL-STD-681	Identification, Coding, and Application of Hook-Up and Lead Wire
MIL-T-7928	Terminals, Lug and Splice, Crimp Style, Copper
MS-3420	Adapter, Cable Clamp to Cable Bushing, Telescoping
UL 508	Industrial Control Equipment
UL 508A	Industrial Control Panels
UL-486	Wire Connectors and Soldering Lugs, for Use With Copper Conductors
UL-498	Attachment Plugs and Receptacles
UL-817	Cord Sets and Power Supply Cords

- Tables 1-3 and 1-4 list specifications available from the Engineering Records Center (ERC).

Table 1-3. ME specifications available from ERC

Spec. No.	Spec. Name
MEL-503650	Square Bevel Washer
MEL-503670	Washer Nylon Flat Round
MEL-504233	Steel Helical Compression Springs with Plain Ends
MEL-627	Tie Rod Nuts
MEL-71-001164	Stainless Steel Bars (type 304)
MEL-72-001188	Heat Treatment of Type 316 Stainless Steel Parts
MEL-72-001204	Steel, Corrosion Resistant Billets and Bars

Spec. No.	Spec. Name
MEL-76-001312	Painting of Laser Structures and Components
MEL-77-001345	Eng Drawings, Prep of
MEL-77-001348	Documentation of Engineering Data

Table 1-4. EE specifications available from ERC

Spec. No.	Spec. Name
LED 21845	High Reliability Component Mounting and Soldering of Printed Wiring Board Assemblies
LED 21846	Preparation and Treatment of Steel and Aluminum Electronic Chassis and Rack Parts
LED 21847	Painting of Steel and Aluminum Electronic
LED 21848	Machining Tolerances
LED 21849	Sheet Metal Fabrication Procedures and Tolerances
LED 21864	Adhesive Masking Paper for Electronics Front Panels
LED 21871	Fabrication, Electronic Equipment, General
LED 21872	Fabrication, Cable Assemblies, Coaxial & Multiconductor Cable
LED 21873	Soldering Specification for Electronic Equipment Fabrication with Wired Interconnections
LED 21874	General Specification for Production of Printed Wiring Boards
LED 21875	General Specification for Production of Printed Wiring Boards with High Reliability Requirements
LED 21876	Component Mounting and Soldering for Printed (Wiring) Board Assemblies
LED21877	LLNL General Requirements for Commercial Off-the-Shelf Equipment

LED01-00-00-A1	EE Standards Manual. Section 1, General Information
LED02-00-00-A1	EE Standards Manual. Section 2, Section & Information Content
LED04-00-00-A1	EE Standards Manual. Section 4, Wire and Cable
LED08-00-00-A1	EE Standards Manual. Section 8, Fiber Optics
LED09-00-00-A1	EE Standards Manual. Section 9, Diodes
LED10-00-00-A1	EE Standards Manual. Section 10, Transistors, SCR's, and Associated Hardware
LED11-00-00-A1	EE Standards Manual. Section 11, Digital Circuits
LED12-00-00-A1	EE Standards Manual. Section 12, Logic Modules and Accessories
LED13-00-00-A1	EE Standards Manual. Section 13, Modular Devices
LED14-00-00-A1	EE Standards Manual. Section 14, Electron Tubes and Readout Devices
LED15-00-00-A1	EE Standards Manual. Section 15, Power Supplies
LED16-00-00-A1	EE Standards Manual. Section 16, Capacitors
LED18-00-00-A1	EE Standards Manual. Section 18, Resistors
LED20-00-00-A1	EE Standards Manual. Section 20, Lamps
LED22-00-00-A1	EE Standards Manual. Section 22, Circuit Protection
LED24-00-00-A1	EE Standards Manual. Section 24, Switches
LED25-00-00-A1	EE Standards Manual. Section 25, Meters
LED26-00-00-A1	EE Standards Manual. Section 26, Relays and Timers

Spec. No.	Spec. Name
LED28-00-00-A1	EE Standards Manual. Section 28, Magnetics
LED30-00-00-A1	EE Standards Manual. Section 30, Transformers
LED35-00-00-A1	EE Standards Manual. Section 35, Misc. Electronic Components
LED43-00-00-A1	EE Standards Manual. Section 43, Drafting and Technical Writing
LED43-10-01-A1	EE Standards Manual. Procurement Specifications
LED43-10-02-A1	EE Standards Manual. Reports (LERS)
LED43-10-03-A1	EE Standards Manual. Notes (LENS)
LED43-10-04-A1	EE Standards Manual. Description & Instruction Documents (D&IS)
LED43-20-01-A1	EE Standards Manual. Engineering and Design Quality, and Configuration Management
LED52-00-00-A1	EE Standards Manual. Section 52, Fabrication and Manufacturing Process
LED55-10-01-A1	EE Standards Manual. Section 55, Materials
LED58-10-01-A1	EE Standards Manual. Section 58, Formulas and Design Data
LED61-10-01-A1	EE Standards Manual. Section 61, Protection and Safety
LED64-10-01-A1	EE Standards Manual. Section 64, Reliability
LED71-9014-02	EE Standards Manual. Section 71, Machine Punch Program. Component/Part Hole Layout Drawings
LED72-00-01-A1	EE Standards Manual. Section 72, Chassis and Parts
LED74-00-01-A1	EE Standards Manual. Section 74, Blank and Special Panels
LED76-00-01-A1	EE Standards Manual. Section 76, Equipment Racks
LED78-00-01-A1	EE Standards Manual. Section 78, Small Parts
LED80-00-01-A1	EE Standards Manual. Section 80, Tools
LED85-00-01-A1	EE Standards Manual. Section 85, Control and Chassis Modules
LED88-00-01-A1	EE Standards Manual. Section 88, Oscilloscopes and CRT Displays

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Section 2. Drawing/Data Elements

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Section 3. Drafting Practices

Section Revision History

Release Date	Author	Revision
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Contents

3.1 Purpose

This section defines LLNL preferred drafting practices for new drawings and revisions to existing drawings. These practices relate to drawing scale, text height, drawing quality, and sectioning.

3.2 Applicable Documents

- Global Engineering, *Drawing Requirements Manual*
- ANSI Y32.2, “Graphic Symbols for Electrical and Electronic Diagrams”
- ANSI Y32.16, “Reference Designations for Electrical and Electronics Parts and Equipment”

3.3 Electronic Circuit Drawings

Circuits on drawings should be easy to follow. Observing the following rules and those found in the above references will produce clear drawings.

1. Major circuits should be placed on an imaginary horizontal line drawn through the center of the drawing. Normally, signal flow should begin on the left and progress through major circuits to the right; auxiliary components, supplies, or secondary parts should be placed above, below, or to the side of major circuits.
2. To the extent reasonable, component orientations should be consistent, i.e., the orientation of cathodes, positive terminals, integrated circuits, and transistors should all be the same on a drawing. Orienting to the top or the right is standard practice.
3. Circuits should be spaced so as to accentuate the function of a unit or units.
4. All leads to other chassis should be identified by designation, destination, and function.
5. Component part values and tolerances should be specified in notes or shown adjacent to the part. Part values or tolerances that differ from those set forth in the notes should be placed within, or adjacent to, the component symbols.
6. Symbols, abbreviations, and reference designations used should be as specified in Sections 22, 24, and 26 of this manual.

3.4 Mechanical Drawings

Drawings should be drawn in third-angle projection and should be so indicated on the drawing. The “third-angle projection” symbol should be located near the title block. The words “SI METRIC” should be placed above these notations.

3.5 Scale

1. Where practical, actual size should be used in drawing details, assemblies, and installations.
2. Where a scale larger or smaller than actual size is used, the size of the final reproduction and its clarity must be kept in mind. Usually, the scale of detail drawings should be the same as that of the related subassembly or assembly.
3. The scale should be indicated on drawings when they are enlarged or reduced from actual size or when two scales are used. Not-to-scale drawings (isometric, tabulated, etc.) should have a note stating "NOT TO SCALE."

3.6 Drawing Quality Requirements for Archiving

To comply with DOE contract requirements, all LLNL documents and models should meet LLNL retention schedule requirements; see http://www-r.llnl.gov/bsd/records/retention/retention_pdf.html. In order to conserve space and reduce the possibility of damage to originals, the Engineering Records Center (ERC) microfilms all documents. Therefore, the following rules should be observed:

1. All drawings shall be of a quality suitable for viewing a reduced-sized print.
2. The most important consideration when preparing drawings to be archived is line quality. Closely spaced parallel lines tend to migrate (flow together) when drawings are reduced. Therefore, it is of the greatest importance that all lines be sharp, opaque, and not crowded.

3.7 Problem/Solution Examples

Potential problems and their recommended solutions relating to drafting practices at LLNL follow.

3.7.1 Drawing Text Height Requirements

The Problem: What are the preferred text height requirements for drawings?

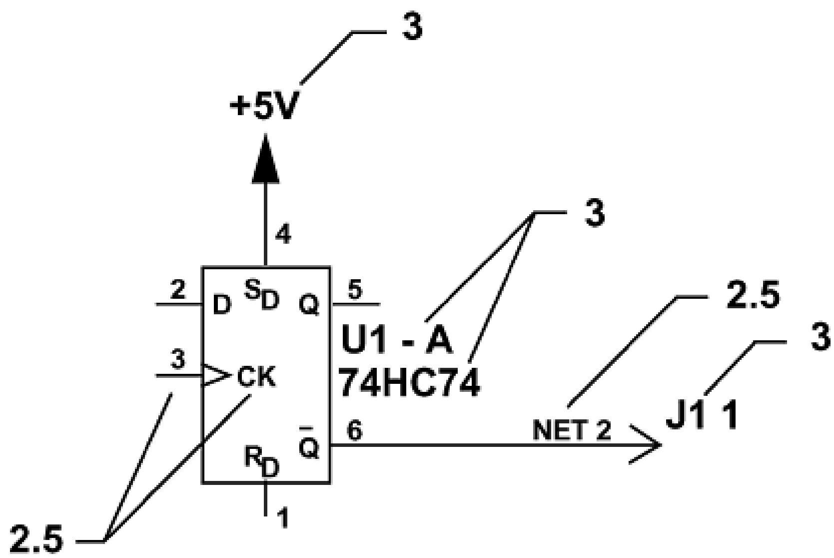
The Solution: The following table defines the minimum text height requirements for LLNL B, C, D, and E size format drawings that will be film archived by the ERC.

Use	Drawing Size	Metric (mm)	Inches
Drawing Number in Title Block Cage Code Revision Letter	B & C	3	.12
	D & E	6	.24
Drawing Title Cage Code Number	All Sizes	6	.24
Section Letters Detail or View Letters Tabulation Numbers		6	.24
Words “Section,” “Detail,” or “View” Zone Letters in Margins/Borders		6	.24
Drawing Block Headings		2.5	.10
Dimensions Drawing Text Tolerances Notes	B & C	3	.12
Tables Revisions Subtitles Parts List	D & E	3	.12

Text Height on Schematics

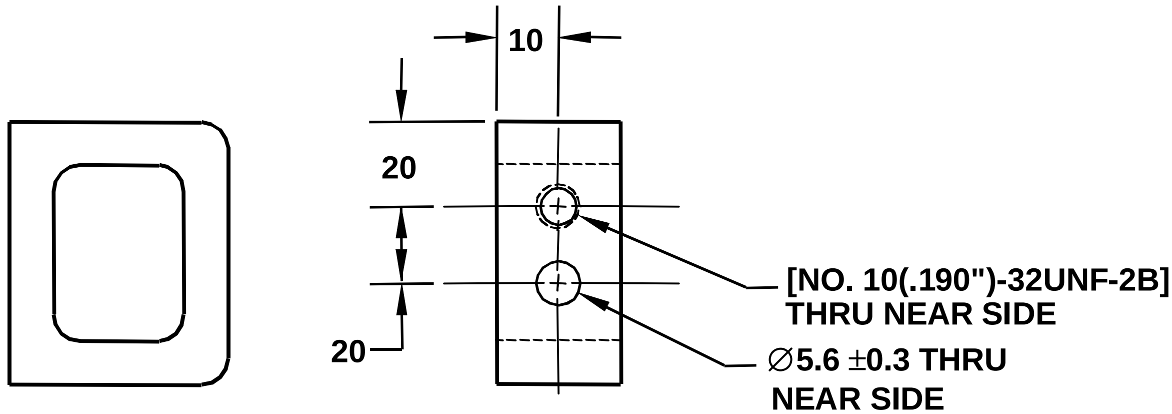
The Problem: What are preferred text height requirements for schematics?

The Solution: Text height requirements (in mm) for schematics are as follows:

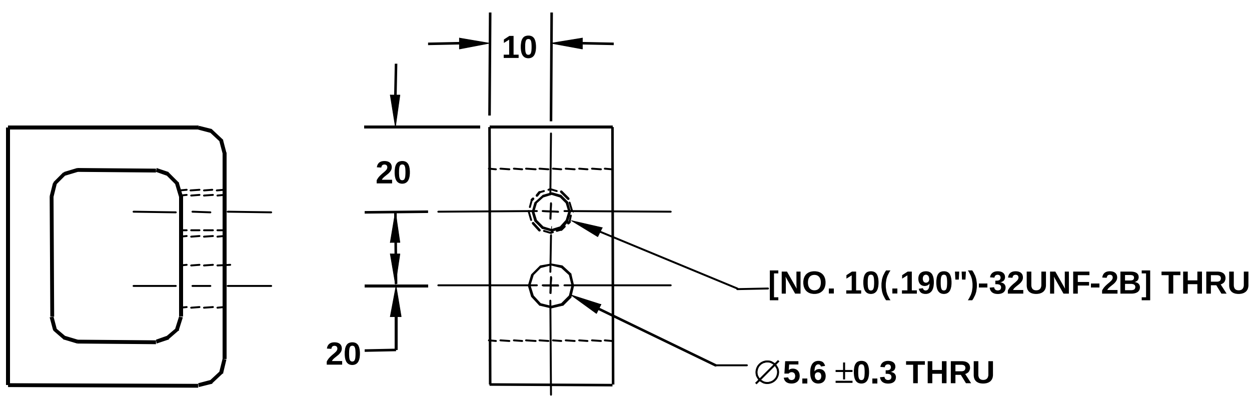


3.7.2 Thread Relief Specification

The Problem: The use of notes when a picture may be better.

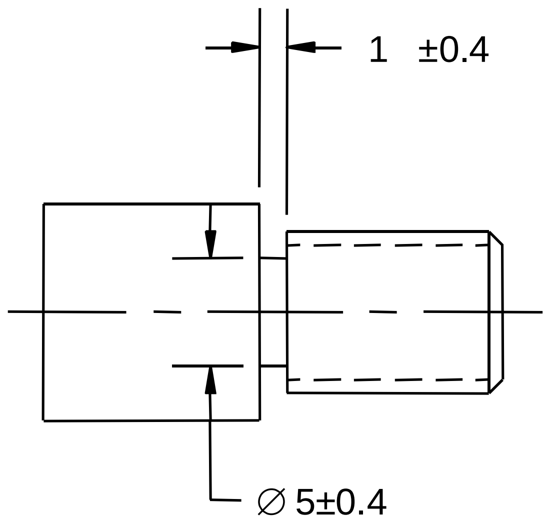


The Solution: Delete “near side” notations and show holes in the side of the frame.

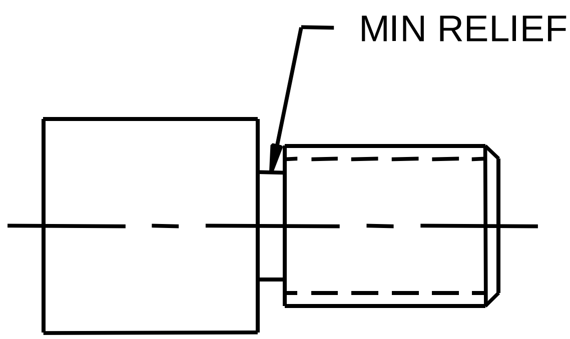


3.7.3 Threaded Relief Specification

The Problem: When a thread relief is dimensioned, it requires inspection.

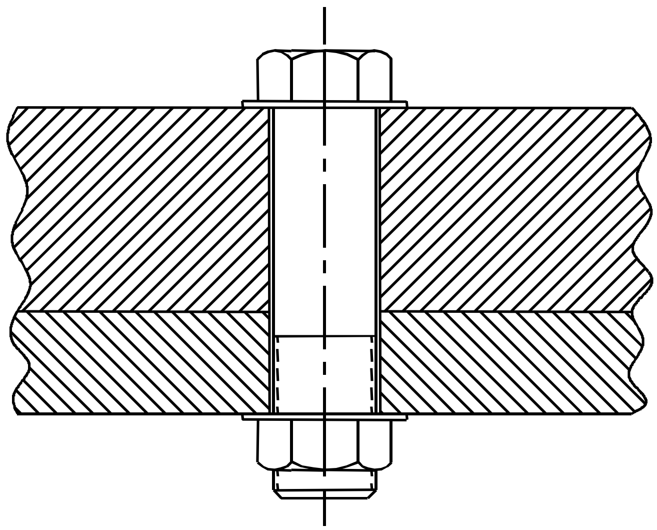


The Solution: If the design will allow a standard relief, show just the graphics with the following callout.

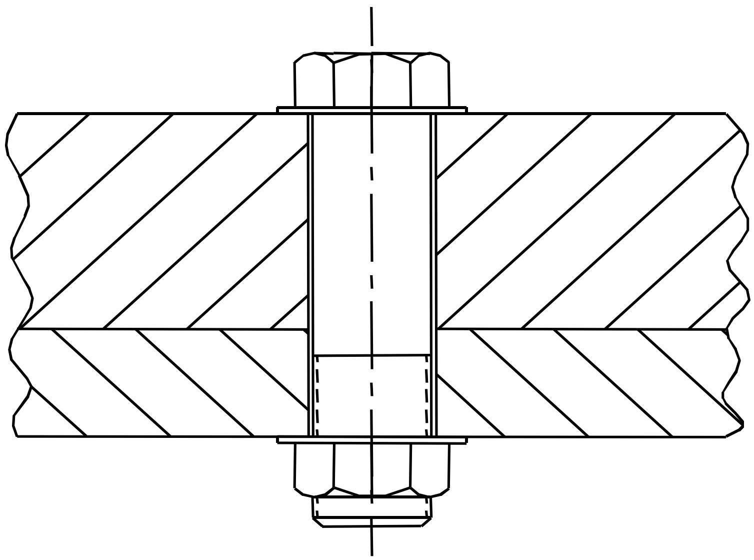


3.7.4 Excessive Section Lines

The Problem: The use of excessive section lines adds little or nothing to drawing clarity and can actually detract from drawing clarity when viewed as a reduced-sized print.

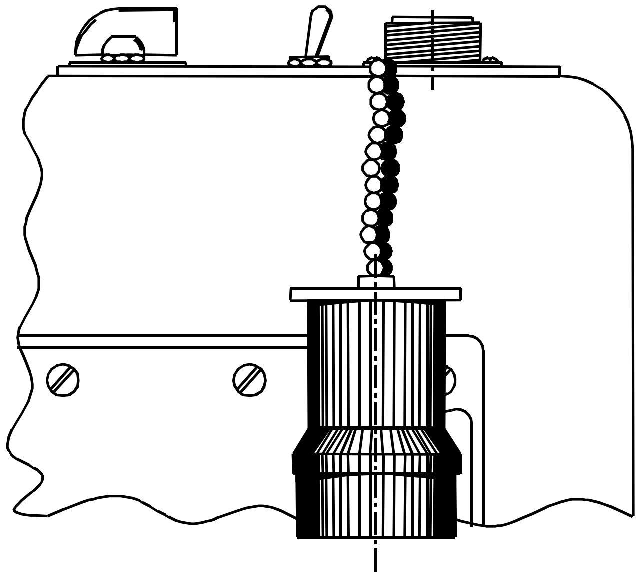


The Solution: Keep section lines to a minimum. Space the lines as generously as possible, yet close enough to clearly define the sectioned areas.

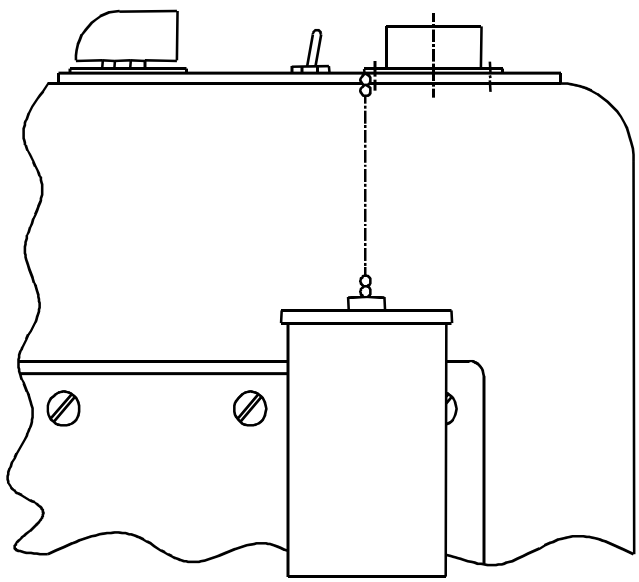


3.7.5 Excessive Detail

The Problem: Excessive detail is time-consuming and detracts from drawing reproducibility.

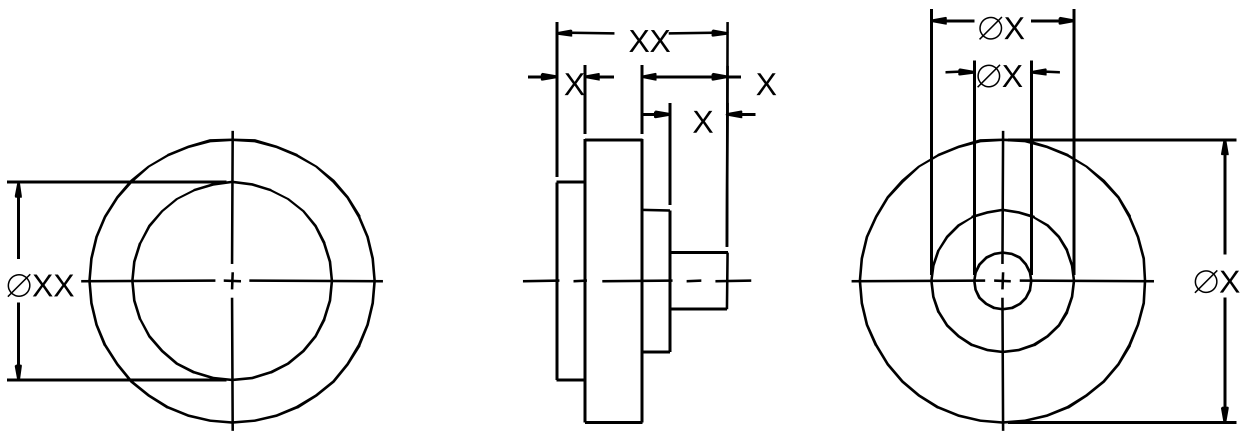


The Solution: Eliminate shading, highlighting, and excessive detail that add nothing to the accuracy, completeness, or clarity of the drawing.

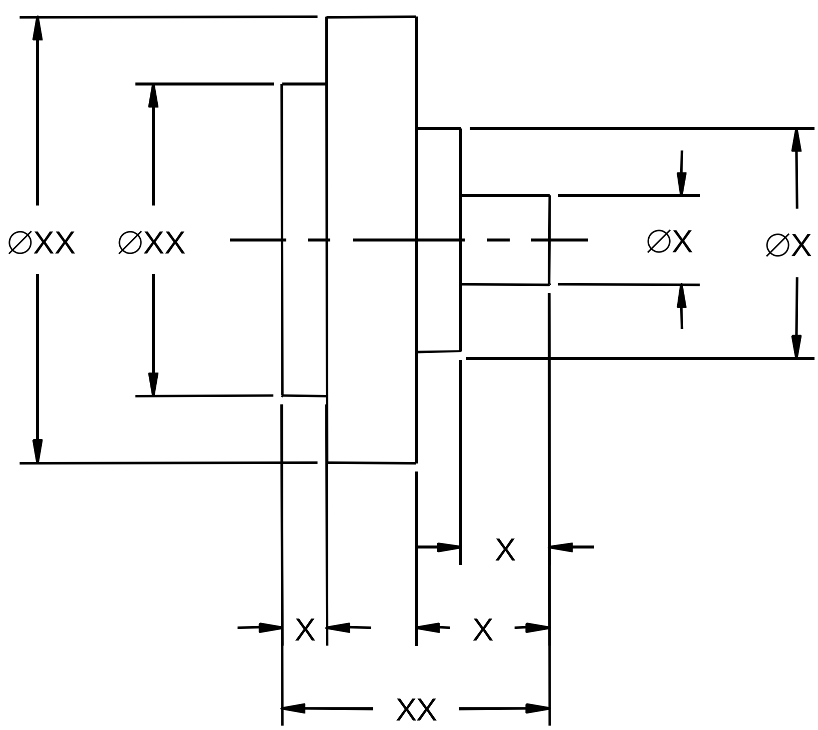


3.7.6 Excessive Views

The Problem: Unnecessary views are time-consuming and detract from drawing clarity.

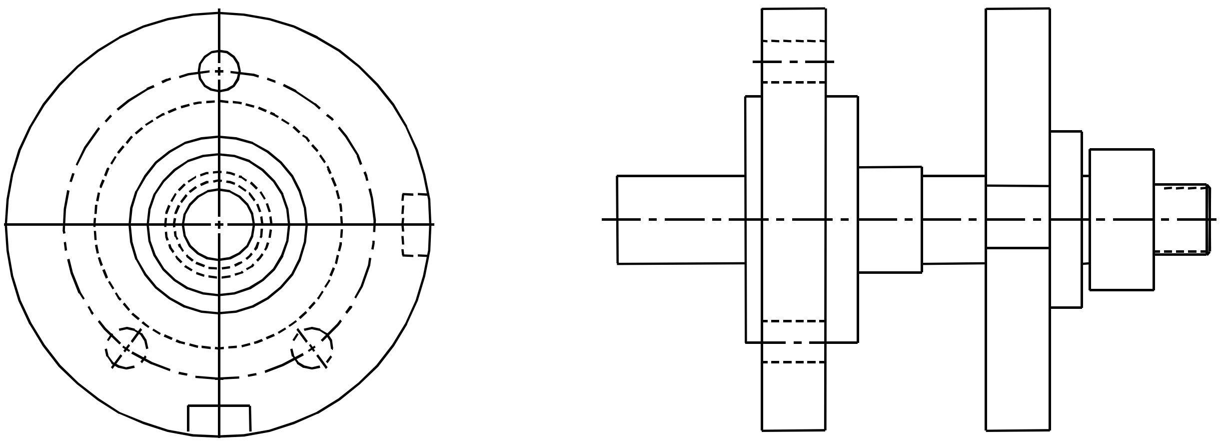


The Solution: A drawing should contain only those views needed for a clear and complete shape description of the object. In this example, only one view is required.

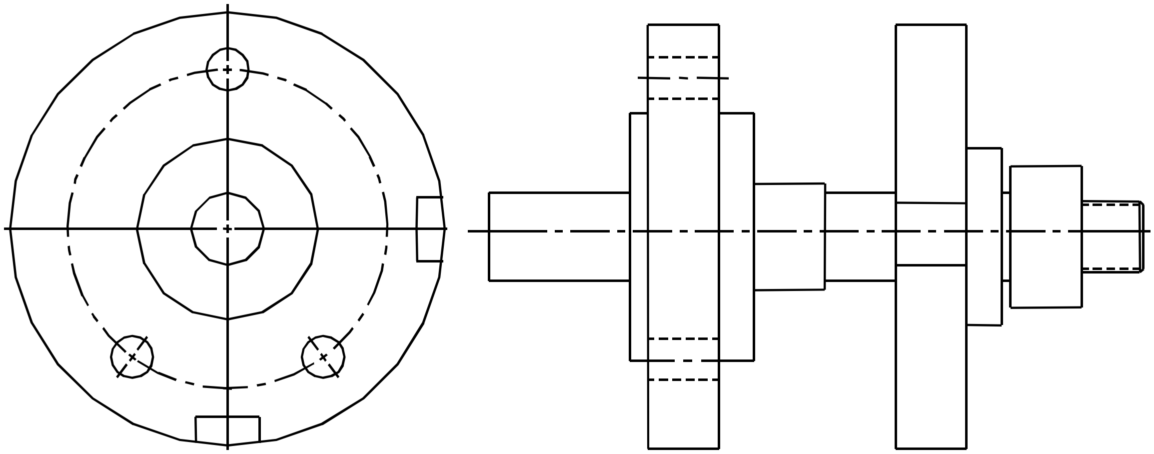


3.7.7 Excessive Hidden Lines

The Problem: Excessive hidden lines cause confusion.

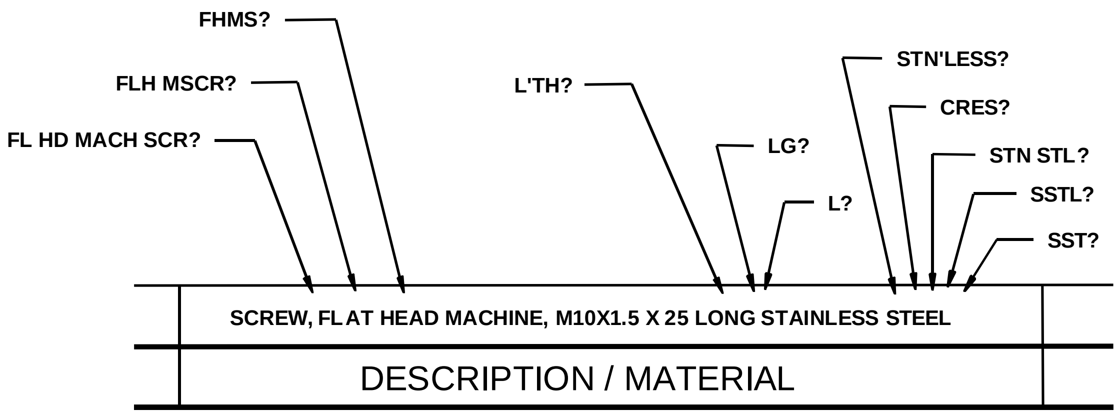


The Solution: Use hidden lines only for clarification.



3.7.8 Inconsistent Abbreviations

The Problem: Inconsistent and incorrect abbreviations are often used on LLNL drawings.

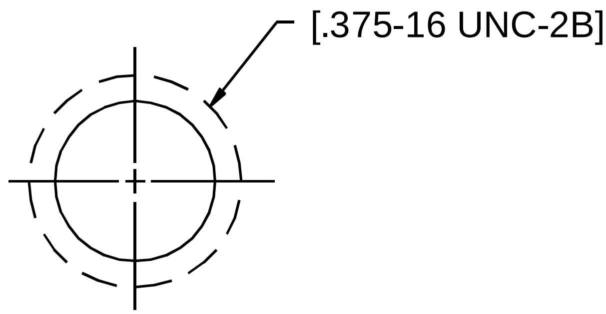


The Solution: For a selected list of common abbreviations used on LLNL drawings, see Section 24 of this manual, "Abbreviations." Additional lists of abbreviations can be found in ANSI Y1.1.

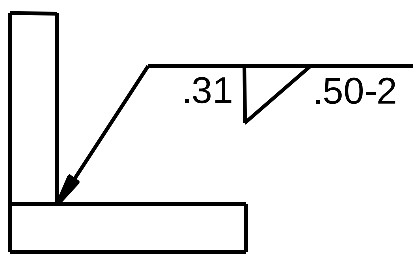
	SCR, FLH MACH, M10x1.5 X 25 L CRES		
	DESCRIPTION / MATERIAL		

3.7.9 Number of Decimal Places Used in Threads, Welds, and Bill of Materials

Thread Example: 3 places on inch thread diameter callout.



Weld Example: 2 places on weld size, and 2 places on both length and pitch. There are to be no trailing zeros on whole numbers.



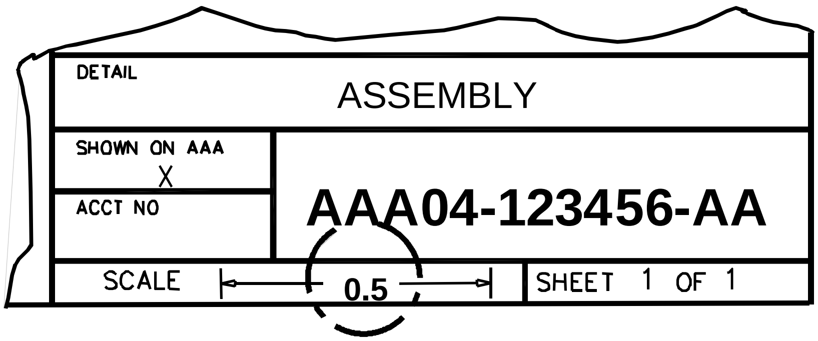
Bill of Materials Example: 3 places on thread diameter and 2 places on screw length. There are to be no trailing zeros on whole numbers.

	SCR, SCH CAP, [#10 (.190) − 32UNF –2A] X [.88] L	
	MATERIAL / DESCRIPTION	

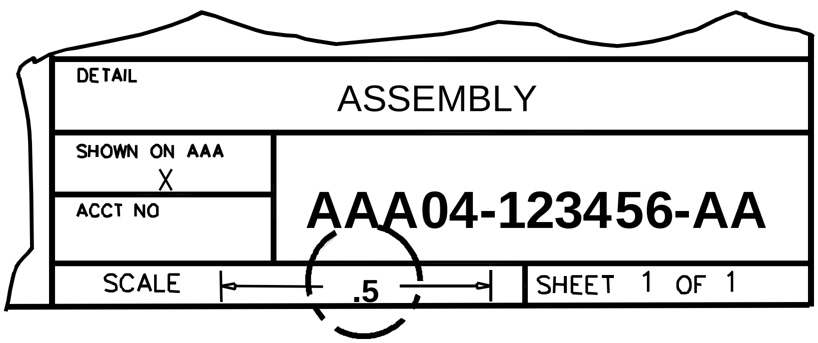
3.7.10 Trailing Zeros in the Drawing Scale

The Problem: How should a drawing or view's scale be specified?

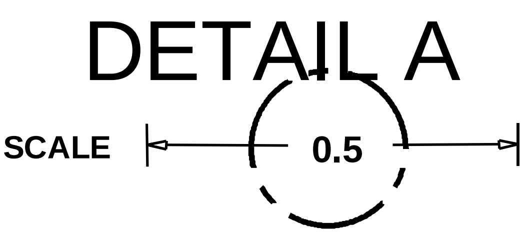
The Solution: Eliminate all trailing zeros when specifying a drawing or view's scale as shown below.



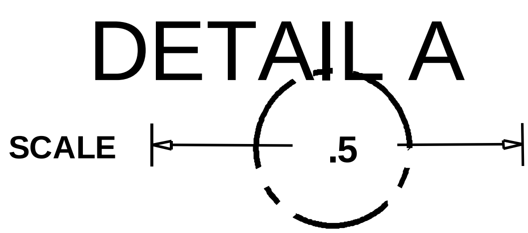
Metric



Inch



Metric



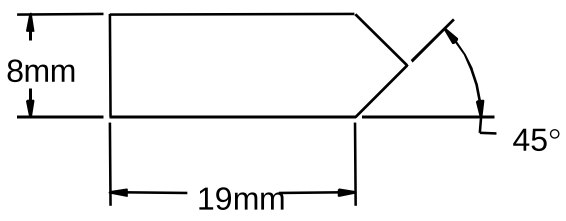
Inch

3.7.11 Specific Drawing Symbols

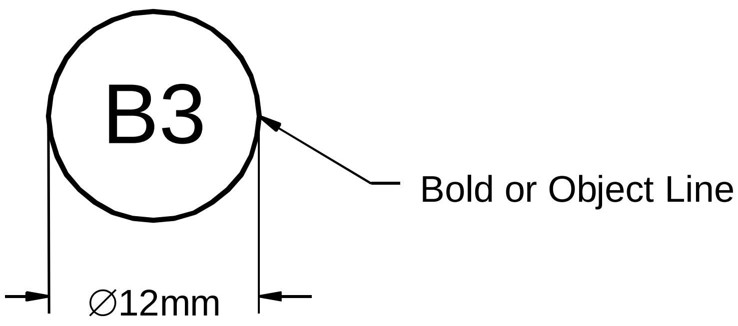
The Problem: What drawing symbols should the design group use?

The Solution: The following symbols are based on national standards with slight modifications to avoid confusion on drawings.

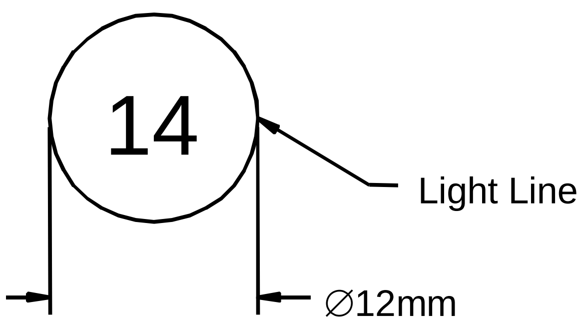
Flagged Note Symbol: This symbol is used to flag notes and features relating to notes. The flag note symbol modifies the Global Engineering standard to allow for three-digit notes.



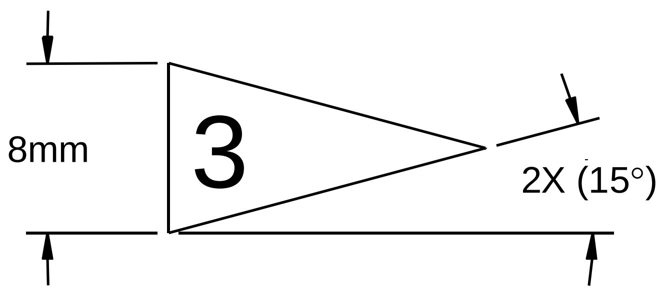
Revision Symbol: Used to indicate revision location on the face of the drawing. The revision symbol is based on ASME Y35, except that the circle has a bold weight to distinguish it from the item number balloon.



Item Balloon: Used to indicate item number on an assembly. The symbol is shown to distinguish between it and the revision symbol above.



Interface Control Identifier Symbol: Used on interface drawings to identify the responsible engineer.



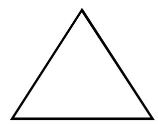
Note: Symbol dimensions are provided for reference only.

3.7.12 Conventional Symbols

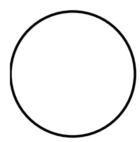
The Problem: What symbols are to be used on LLNL engineering drawings?

The Solution: The following symbols are to be used on LLNL engineering drawings.

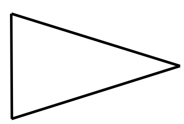
Equilateral Triangle: For drawing revisions.



Circle: For calling out items listed in the Material/Description list.



Flag: Used to reference a note to a feature or an area of a part.

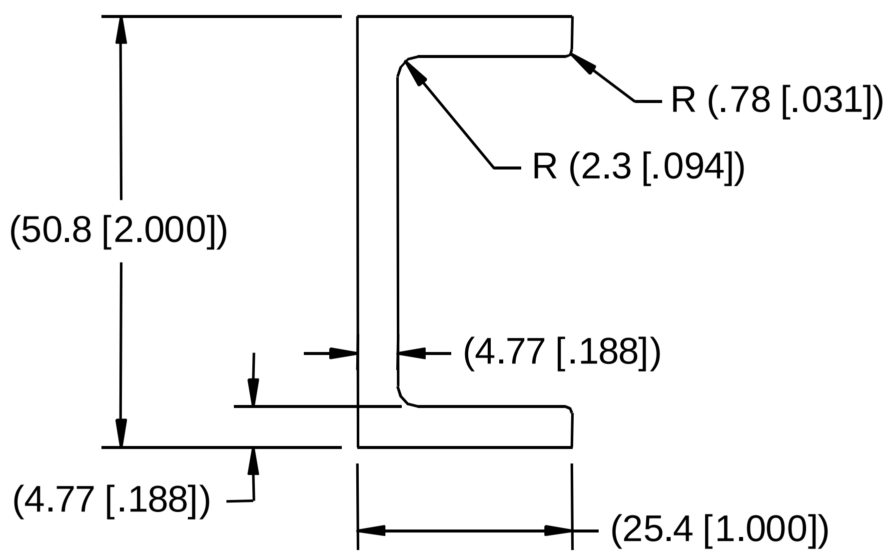


3.7.13 Dimensioning Structural Steel Shapes

The Problem: How do we specify AISC (US Customary) structural steel shapes per ASTM A6/A6M on a drawing and in the bill of materials on metric drawings?

The Solution: Dimension the structural steel shape with a reference dimension, showing the metric dimension first followed by the inch dimension in brackets. In the bill of materials, specify the structural steel size in inches.

Example: C Channel – Standard C2 × 2.3



Note: Show any dimensions as reference only.

	C CHANNEL, C2 X 2.3	STEEL	
	DESCRIPTION / MATERIAL		

Section 4. Types of Engineering Drawings

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

4.1 Purpose

Any engineering drawings produced under contract for LLNL are considered Laboratory property. When a Statement of Work (SOW) and/or contract is awarded, the guidance in this section shall be maintained with regard to engineering drawings, unless specifically changed in the SOW and/or contract.

4.2 Definitions

Third-party drawings are defined as drawings from an independent company that may supply parts and assemblies to LLNL, or who may have a business contract with LLNL. Vendors and some DOE Laboratories are also considered third parties.

4.3 LLNL Engineering Drawings Produced by Other Organizations

This guidance applies to the preparation of third-party engineering drawings in order to submit, archive, reproduce a print, process a drawing for a job order, or make a "reproducible" for revision through the LLNL Engineering Records Center (ERC).

Latest revisions of invoked codes, standards, drawings, or other documents shall be used unless otherwise specified. An exception should be made when only one explicit version of a document is to be utilized, such as for ASME Y14.5M-1994.

Drawings shall be created in accordance with the LLNL *Engineering Policy Manual*, Policy 5.4, "Drafting."

Drawings shall use drawing numbers in accordance with the LLNL *Engineering Policy Manual*, Policy 4.1.2, "Conventions for Numbering Engineering Drawings, Documents, and Parts."

If the contracting company chooses to put their own drawing number on the drawing for their tracking system, the drawing shall also have an LLNL Engineering drawing number applied above, or somewhat near, the title block.

If the contracting company chooses to use their own drawing formats, Quality Assurance (QA) or Quality Control (QC), and approval signature, then the drawings shall have an LLNL approval block for the approver's signature in accordance with subsection 4.4 of this document.

The LLNL contract number shall appear somewhere near the title block, or in the notes of the drawing, and shall be referenced as follows: "This drawing was produced for LLNL under contract number XX." (XX denotes the contract number between LLNL and the contractor.)

4.4 LLNL Reproduction of Third-Party Drawings

When requesting the ERC to produce a print, process a drawing for a Job Order, or make a reproducible for revision from a third-party drawing, a letter of consent from the company or vendor (or LLNL), or a copy of a contract for work on these drawings, shall be on file in the ERC. The third-party, upon giving LLNL permission to copy, also gives LLNL permission to provide these prints to suppliers for manufacturing with the provision that the suppliers must be informed that they may not use the data for their own purposes without the third-party's permission. Also, the suppliers should be instructed to seek clarification of the drawings from LLNL, rather than from the third party, should questions arise. The following is a step-by-step explanation of the process:

- Request a letter of consent from the third party for the purposes described above. A sample letter requesting consent is shown in Figure 4-1.
- Obtain a letter of consent (see Figure 4-2) or a copy of the contract of work. Provide this to the ERC for an AAA or LEA drawing number as appropriate. An AAN number will also be assigned and marked on the permission letter (or copy of contract), archived, and will be referenced on the drawing (see Figure 4-3 for location).
- Insert the AAA or LEA number as the –AA original release and the third-party stamp (see Figure 4-4) on all sheets of the drawing just above the parts list or title block. The stamp must contain the LLNL approver's (or his or her designee's) signature, date, and drawing classification. These stamps are available through the ERC in PRO/E and AutoCAD file formats.
- The third-party Proprietary statement may remain on the drawing. The letter of consent or contract supersedes it.
- Subsequent revisions will carry all of the above information with new dates and approvers as appropriate.

Lawrence Livermore National Laboratory

Date:

Mr. Thomas Merchant
XYZ Industries, Inc.
Street Address
City, State Zip-Code

Dear Tom:

Subject: Permission to Copy and Assign LLNL Numbers to XYZ Industries, Inc. Drawings

As a participant in the (insert project name) Engineering project, the Lawrence Livermore National Laboratory (LLNL) Engineering Records Center has been asked to process drawing packages that include a number of Bud Industries, Inc. drawings. In order to do this and maintain a complete retrievable record of the design package, the Records Center is requesting permission to copy and assign LLNL drawing numbers to Bud Industries, Inc. documents for the purpose of internal document control and procurement of collaborative Bud Industries/LLNL designs.

If you agree, please send us your approval.

Sincerely yours,

(Insert Responsible LLNL Programmatic or Engineering Contact)
(Insert Program or LLNL Engineering Division)

cc:
(Insert other recipients of this letter)
Michael R. McDaniel, LLNL, Engineering Records Center

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Figure 4-1. Sample letter of request.

Date:

(Insert Responsible Programmatic or Engineering Contact)
(Insert Program or LLNL Engineering Division)
Lawrence Livermore National Laboratory
P.O. Box 808
Livermore, CA 94550

Dear Mr. (Insert **Responsible Programmatic Contact**):

Subject: Permission for LLNL to Copy Certain Drawings

Since Lawrence Livermore National Laboratory (LLNL) is a DOE-funded collaborator with XYZ Industries, Inc. on the (insert project name) Engineering project, XYZ Industries, Inc. hereby grants LLNL permission to copy XYZ Industries, Inc. engineering drawings for the purposes described in your letter of request (including assigning LLNL drawings number to the XYZ Industries, Inc. drawings), excepting those XYZ Industries, Inc. drawings which may restrict for purposes of commercialization activities or otherwise. These excepted drawings will be identified to LLNL as soon as XYZ Industries, Inc. makes the determination to restrict. Until then, LLNL may proceed to copy XYZ Industries, Inc. project drawings.

XYZ Industries, Inc. understands that LLNL is not requesting permission to use the drawings for its own purposes other than those associated with the (insert project name) Engineering project. Therefore, XYZ Industries, Inc. is not issuing to LLNL the standard XYZ Industries proprietary disclaimer notice.

XYZ Industries, Inc. understands that LLNL may provide these drawings to suppliers for manufacturing and consents to this redistribution of XYZ Industries, Inc. technical data with the proviso that the suppliers be informed that they may not use the data for their own purposes without XYZ Industries, Inc. permission. Also, your suppliers should be instructed to seek clarification from the LLNL technical contact rather than XYZ Industries, Inc. if they have questions. This should be done to prevent XYZ Industries, Inc. from becoming involved in your procurement process. There have been instances in the past where vendors have naturally sought clarification from the organization whose name appears on the original documentation, for example in the title blocks of drawings and specifications, rather than from their client directly.

Sincerely,

Thomas Merchant
Product Development Manager
XYZ Industries, Inc.

cc: **(Insert other recipients of this letter)**
Michael R. McDaniel, LLNL, Engineering Records Center

Figure 4-2. Sample letter of consent.

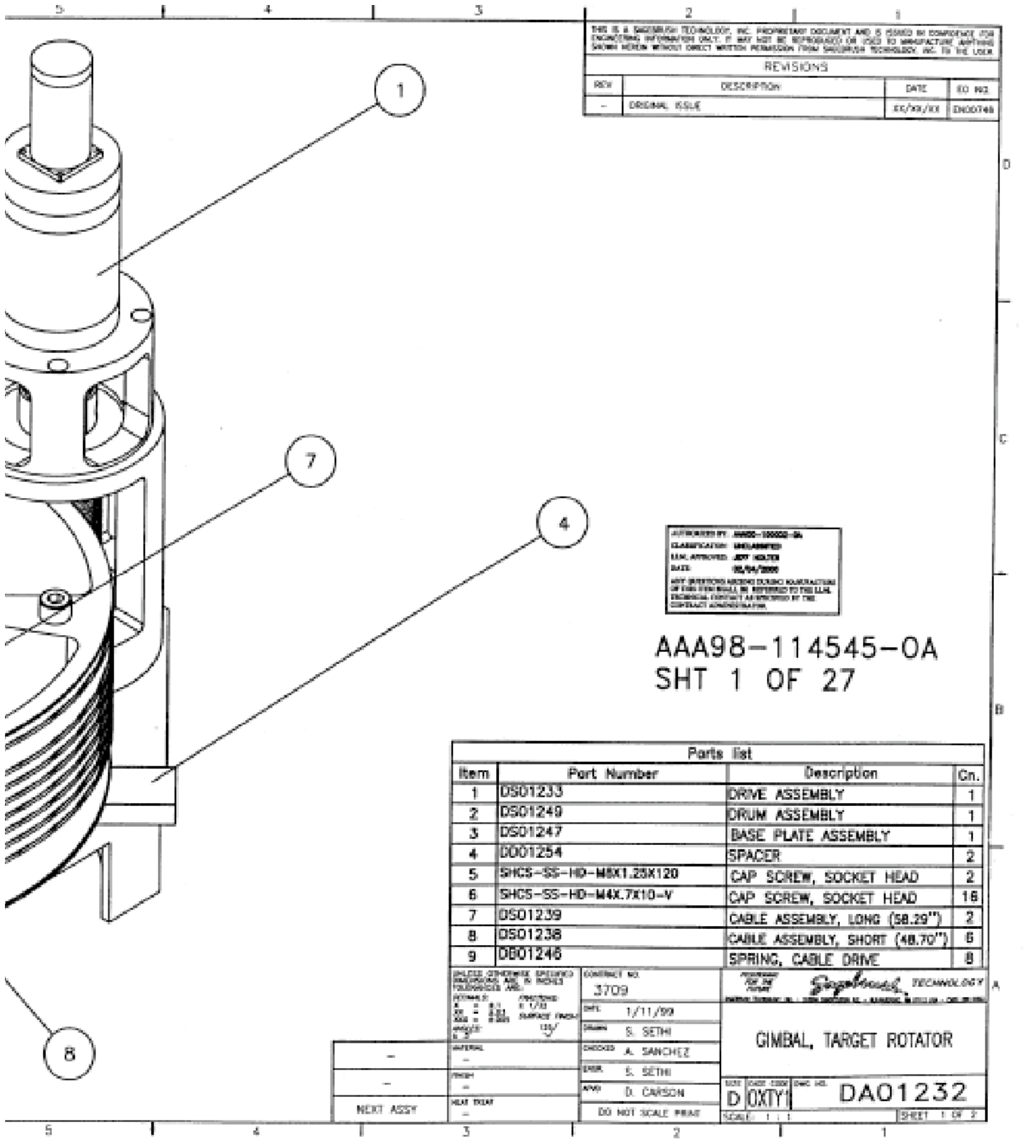


Figure 4-3. Sample of stamp placement.

AUTHORIZED BY:	AAN00-100002-AA
CLASSIFICATION:	UNCLASSIFIED
LLNL APPROVED:	Engineer
DATE:	00/00/0000

ANY QUESTIONS ARISING DURING MANUFACTURE OF THIS ITEM SHALL BE REFERRED TO THE LLNL TECHNICAL CONTACT AS SPECIFIED BY THE CONTRACT ADMINISTRATOR.

Figure 4-4. Third-party stamp.

Section 5. Dimensioning and Tolerancing

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

5.1 Purpose

This section defines LLNL preferred drafting practices for specifying dimensions and tolerances on drawings.

5.2 Applicable Documents

- Global Engineering, *Drawing Requirements Manual* (latest edition)
- ASME Y14.5M-1994, "Dimensioning and Tolerancing"

5.3 Required Accuracy

The tolerance specified should be practical for the part being fabricated and meet requirements for the design. Consider that the tighter the tolerance, the higher the cost of fabrication. With tighter tolerances, the procurement process also becomes more selective, since less-capable vendors must be eliminated from consideration.

5.4 Fundamental Rules

The reader is referred to ASME Y14.5M-1994, Section 1.4, which lists 14 fundamental rules of dimensioning and tolerancing.

5.5 Use of Stock or Standard-Size Items

Whenever possible, dimensions should be specified to make use of readily available materials, parts, tools, and gages. Savings are often possible when drawings specify the following items, if applicable:

- Commonly used materials in stock sizes
- Parts generally recognized as commercially standard items
- Sizes that can be produced with standard tools and inspected with standard gages
- Tolerances from accepted published standards

5.6 Dimensioning Stock or Standard Parts

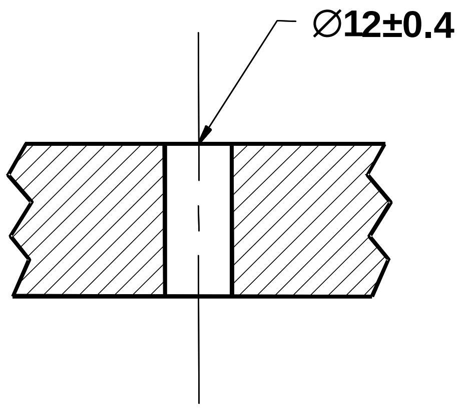
Dimensions of stock parts can be shown as reference dimensions. The method for identifying a reference dimension on drawings is to enclose the dimension within parentheses.

5.7 Problem/Solution Examples

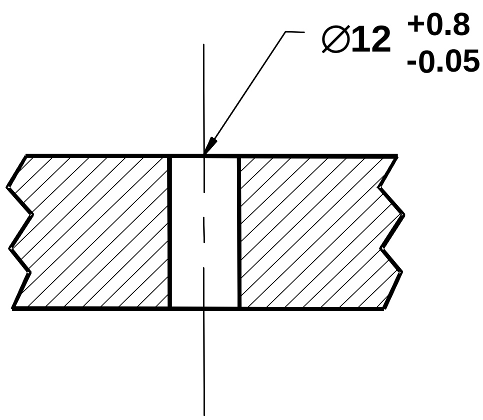
Potential problems and their recommended solutions relating to drafting practices at LLNL follow.

5.7.1 Drilled Hole Specification

The Problem: How should a standard drilled hole be toleranced, when the intent is to allow for a liberal tolerance (and accounting for the fact that drills normally do not drill undersize)?



The Solution: See subsection 26.4, "Machine Shop Practices," for normal drilling operations of preferred drilled hole tolerances.



5.7.2 Dual Dimensioning Metric/Inch

The Problem: What is the proper way to display dual (metric and inch) dimensions when using hard conversion* metric dimensions?

The Solution: ASME Y14.5-1994 (chapters 1 and 2) specifies all the proper methods for dimensioning and tolerancing drawings that utilize single-unit dimensions. Dual-unit drawings are created only when necessary and employ the following bracket method:

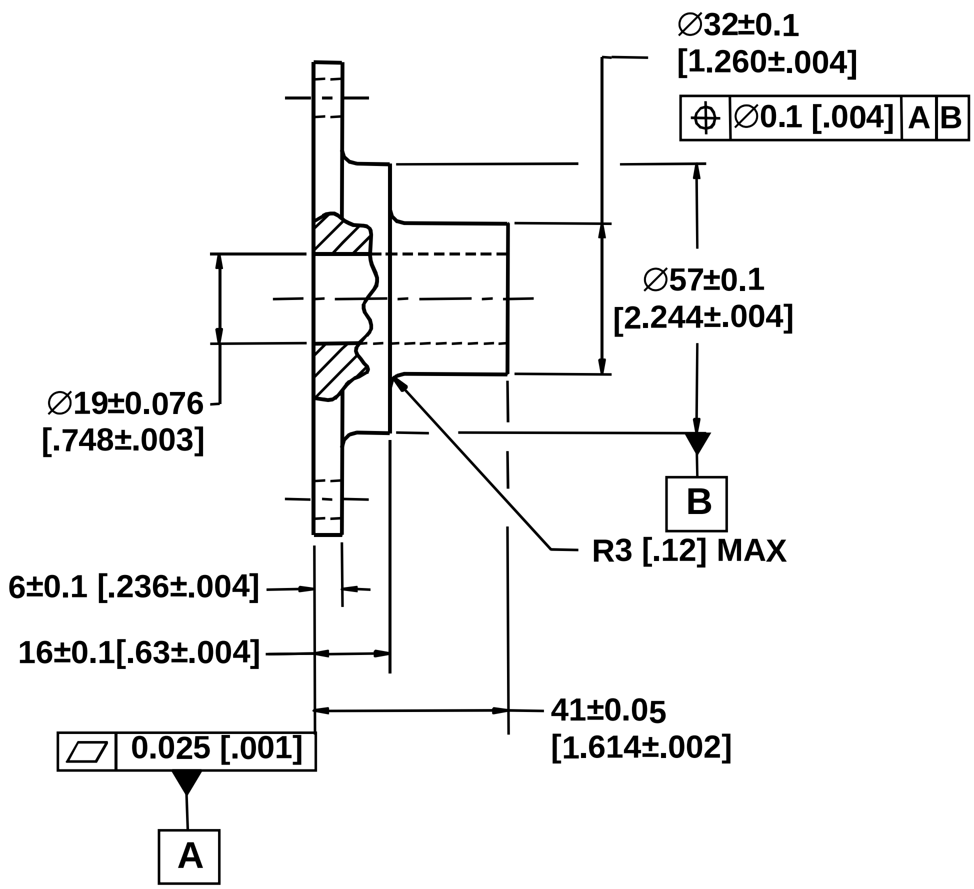
Position of dimension	Dimensions shown on drawing	Comments
← mm → [inches]	|← 31±0.08 →| [1.220±.003]	All inch dimensions should have a minimum of two digits following the decimal point.
← mm [inches] →	|← 31±0.08 [1.220±.003] →|	When a metric dimension is a whole number, the decimal point and trailing zeros may be omitted.
← mm → [inches]	31.39 31.25 |← →| [1.236 1.230]	High limit is placed above low limit.
← mm [inches] →	|← 31.39 31.25 [1.236 1.230] →|	High limit is placed above low limit.
← mm → [inches]	|← 31.25-31.39 →| [1.230-1.236]	Low limit precedes high limit.

Note: Those who produce dual-unit CAD drawings must ensure all values are consistent.

* The reader is referred to Global Engineering's *Drawing Requirements Manual*, Section 5.1.2, for a discussion on "hard conversion" and "soft conversion."

The Problem: What is the proper way to display dual (metric and inch) dimensions when using hard conversion metric dimensions?

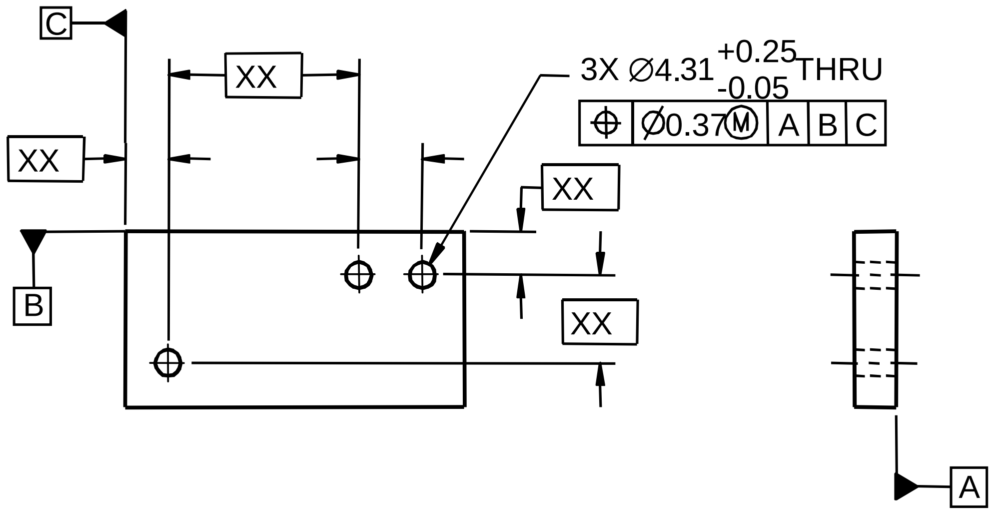
The Solution: ASME Y14.5M-1994 (chapters 1 and 2) specifies the proper methods for dimensioning and tolerancing drawings that utilize single-unit dimensions. Dual-unit drawings are created only when necessary and employ the following bracket method:



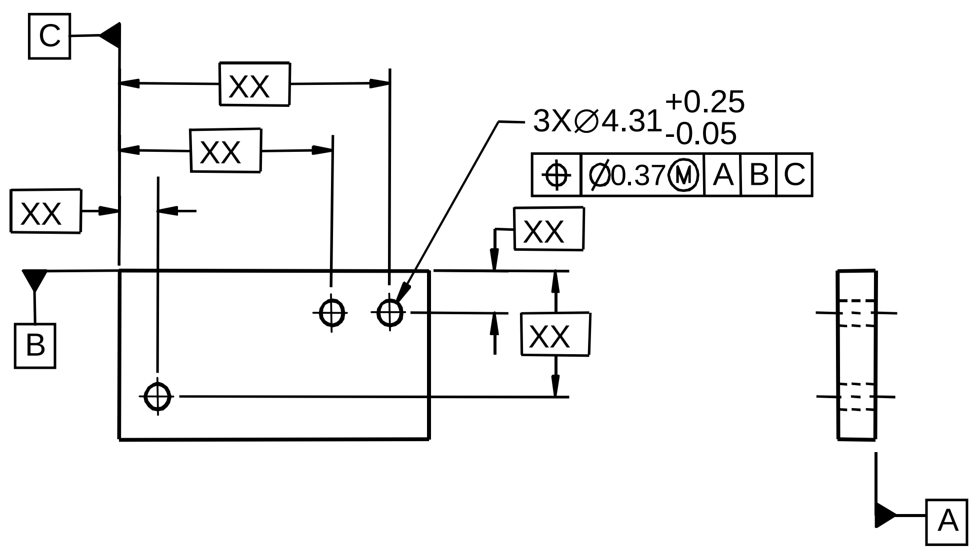
Note: The primary dimensions and tolerances are metric; dimensions and tolerances in brackets are in inches and are for reference only. Care must be taken to insure complete drawing consistency with this method (i.e., feature control frame tolerances, title block tolerances, surface finish symbols, etc. must all employ this dual-unit method).

5.7.3 Chain Dimensioning

The Problem: Chain or hole-to-hole dimensions when the feature control symbol indicates the holes are toleranced from the datums.



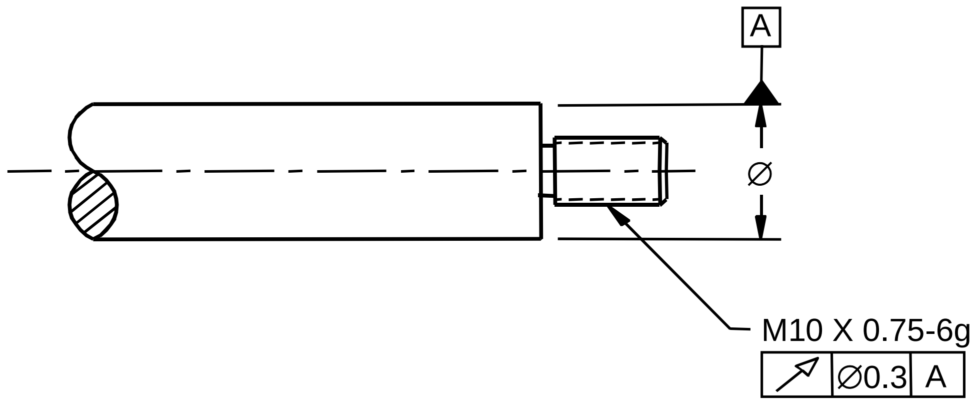
The Solution: It is preferred to dimension from the datums when features are toleranced from the datums.



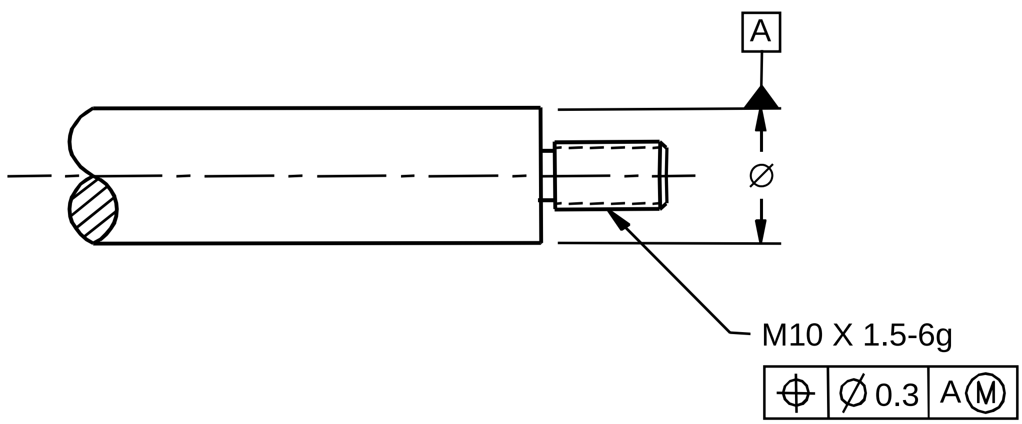
Note: Chain dimensioning is acceptable according to ASME Y14.5M-1994 (2.6a) but is not preferred.

5.7.4 Runout Versus True Position on Threads

The Problem: Which geometric control (runout or true position) is best suited for tolerancing threaded features?



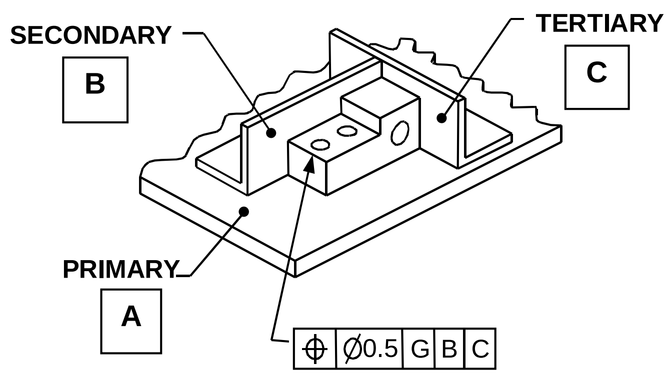
The Solution: Using runout on a threaded feature is unacceptable in all but a few very rare applications (such as a lead screw). A runout tolerance is a surface control (ASME Y14.5M-1994, section 6.7.1). The acceptable method of tolerancing threaded features is to use true position.

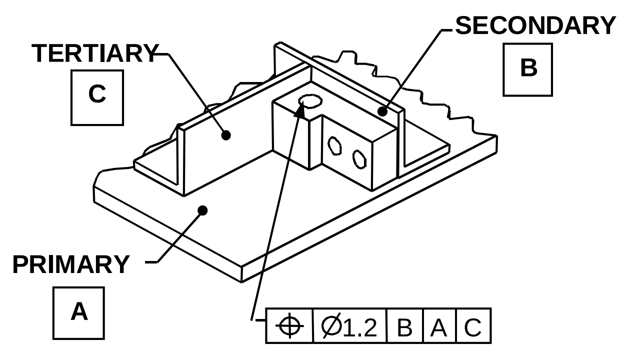


Note: Each tolerance of position (or orientation) specified for a screw thread applies to the axis of the thread derived from the pitch cylinder (ASME Y14.5M-1994, section 2.9).

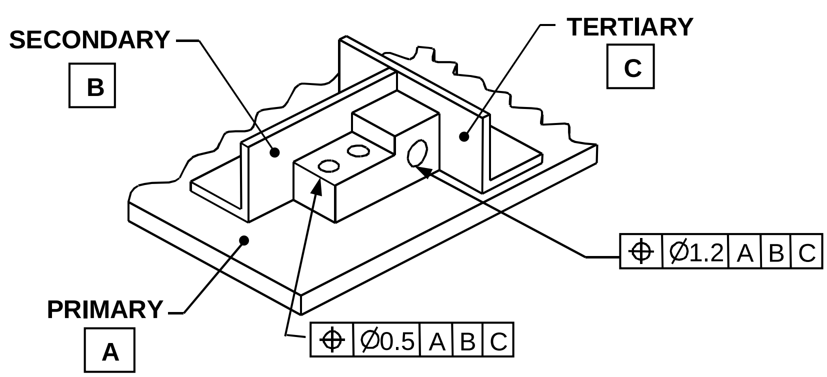
5.7.5 Datum Order of Precedence

The Problem: Changing the datum order of precedence as shown causes unnecessary inspection setups.



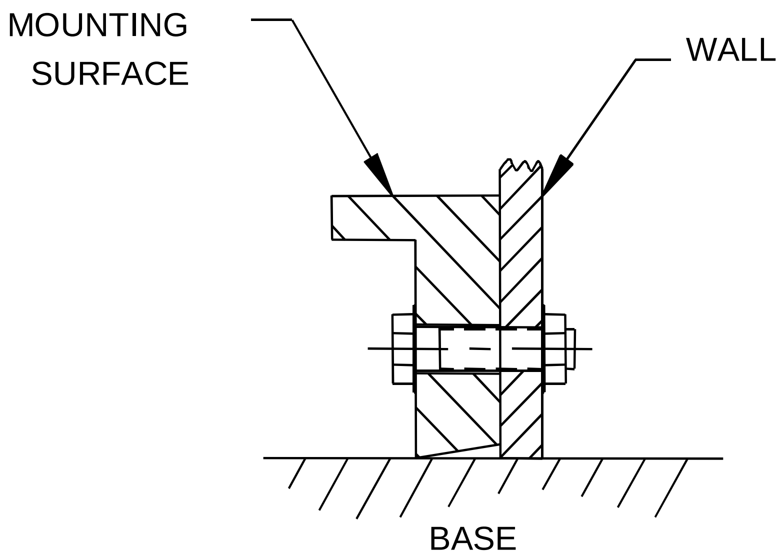


The Solution: Keep the datums in the same order of precedence where design intent permits.



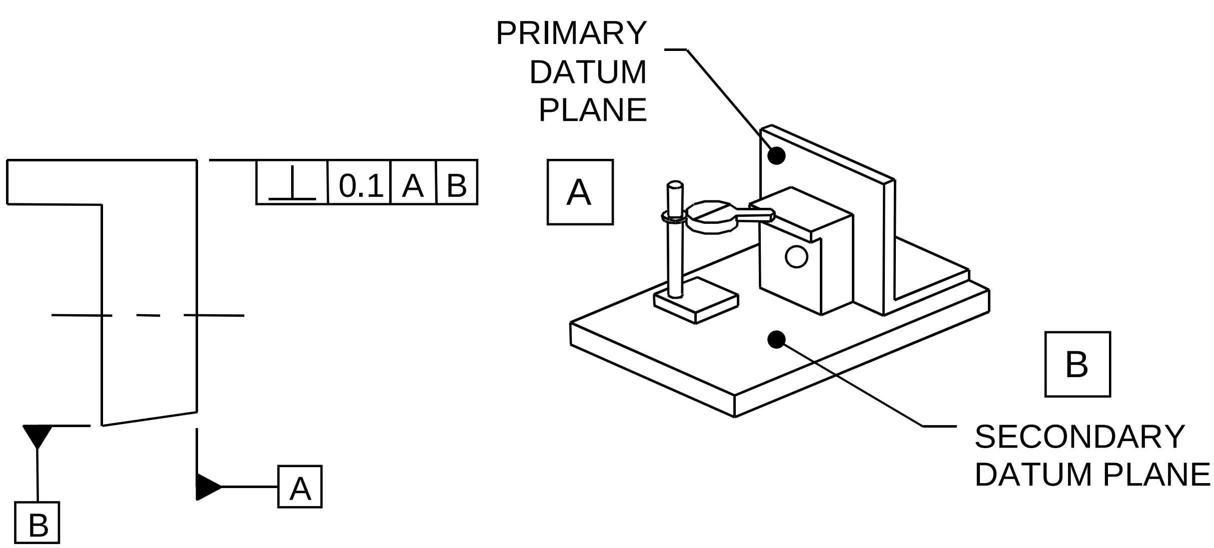
5.7.6 Perpendicular Setup to Two Datums

The Problem: ASME Y14.5M-1994 does not directly define perpendicularity while setup to two datums.



In this example, the mounting surface is to be perpendicular to the wall as a primary requirement and parallel to the load-bearing base as a secondary requirement.

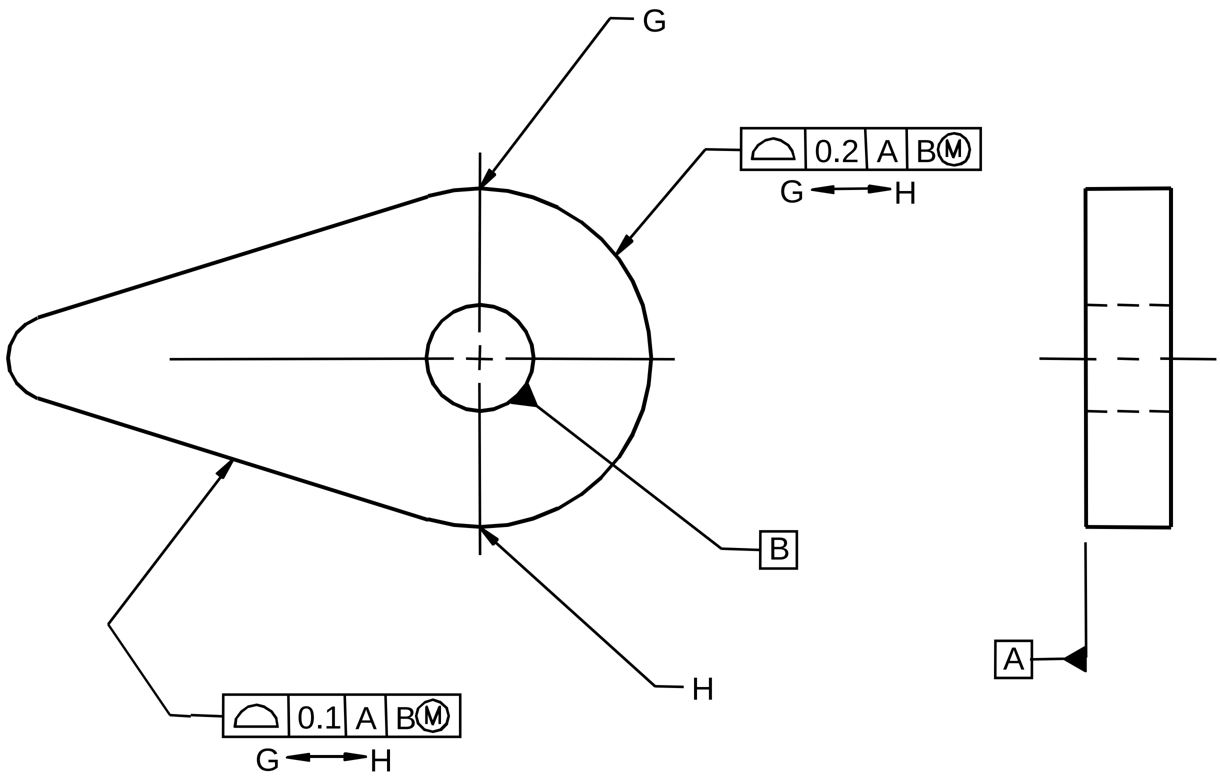
The Solution: Indicate that the mounting surface is to be perpendicular with respect to two datums.



Note: Datum B being a secondary datum, it must contact the load-bearing base at a minimum of two points, which establishes a plane parallel to the mounting surface.

5.7.7 MMC Datum Modifiers With Profile Tolerance

The Problem: ASME Y14.5M-1994 does not clarify the use of MMC datum modifiers with profile tolerancing.



The Solution: The profile tolerance cannot be modified, but datums of size can be modified.

Note: In the example, the two profile tolerances are considered a single composite pattern since their respective feature control frames contain the same datums in the same order of precedence with the same modifying symbols, i.e. no shifting of datum B between profile checks.

5.7.8 Multiple Basic Dimensions

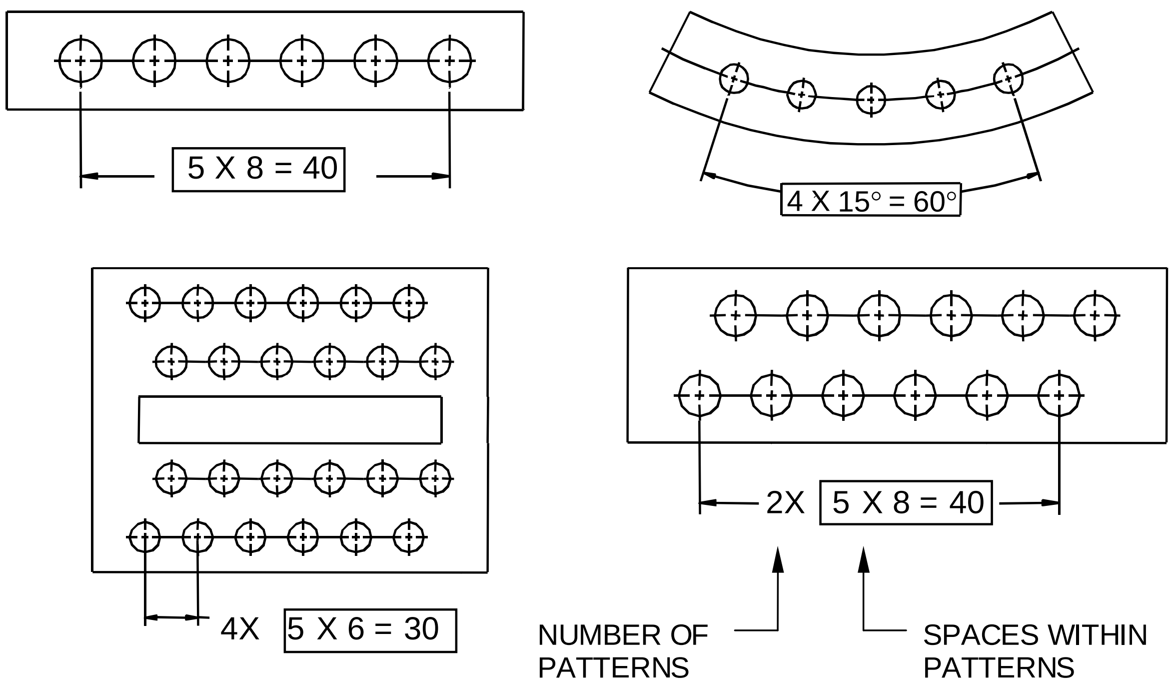
The Problem: When "X" is used in conjunction with a numeral to indicate "places," where is it located when used with a basic dimension?

4X [R 0.5] OR [4X R 0.5]

The Solution: The "X" is located outside the box when used to indicate the number of places.

4X [R 0.5] OR 3X [27.5]

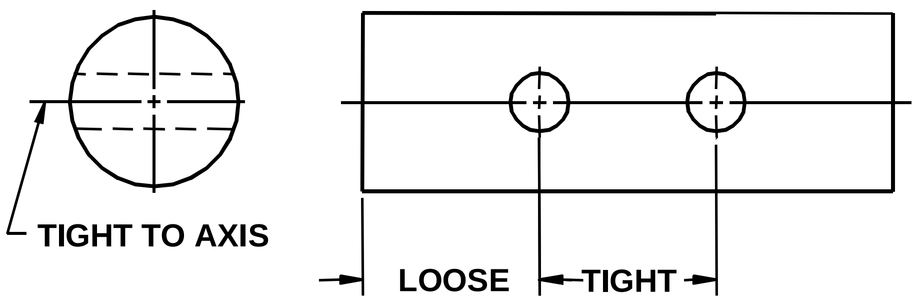
The "X" is located inside the box when used to indicate the number of spaces within a pattern.



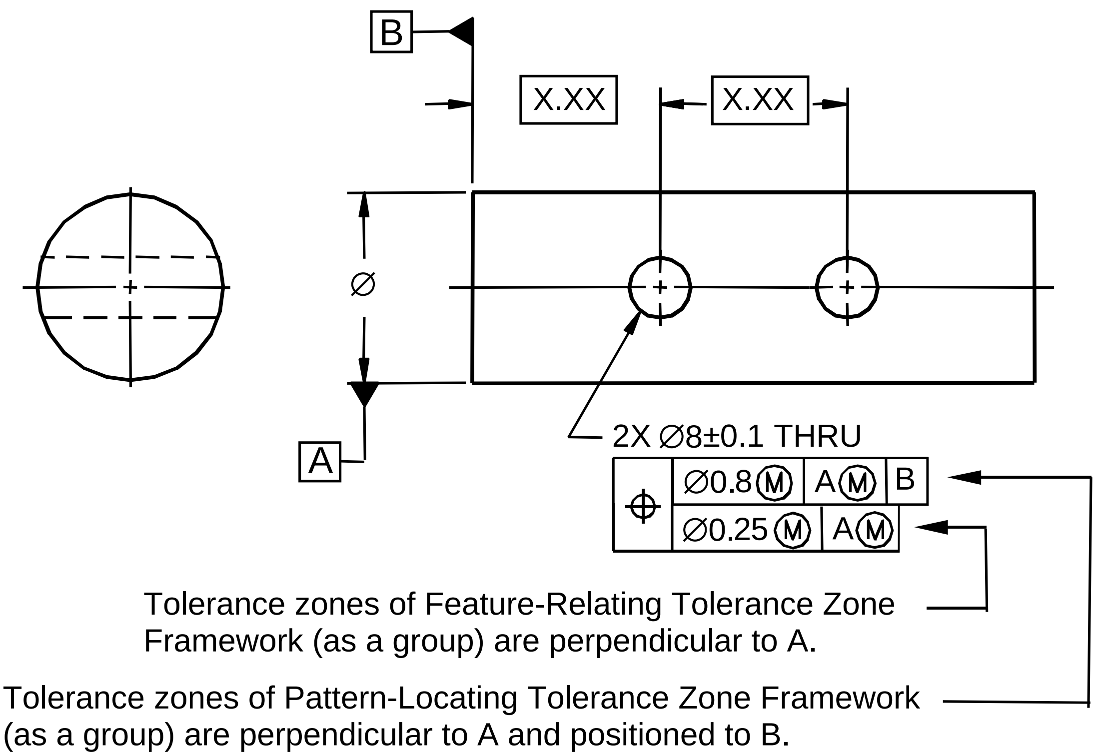
Note: On complex drawings and/or patterns, it may be best to dimension each pattern or spell out the requirements (i.e., 4 PATTERNS).

5.7.9 Positional Tolerancing, Composite Bi-Directional

The Problem: How should a pattern of holes be dimensioned through a round shaft that is loosely toleranced with respect to an end, but tightly toleranced with respect to the shaft axis and the hole-to-hole relationship?



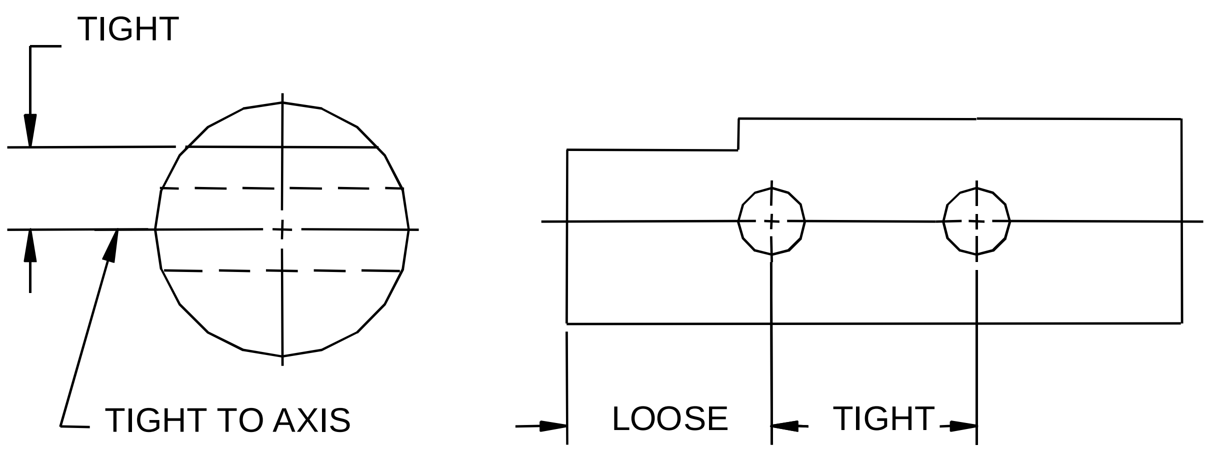
The Solution: Utilize composite positional tolerancing as shown:



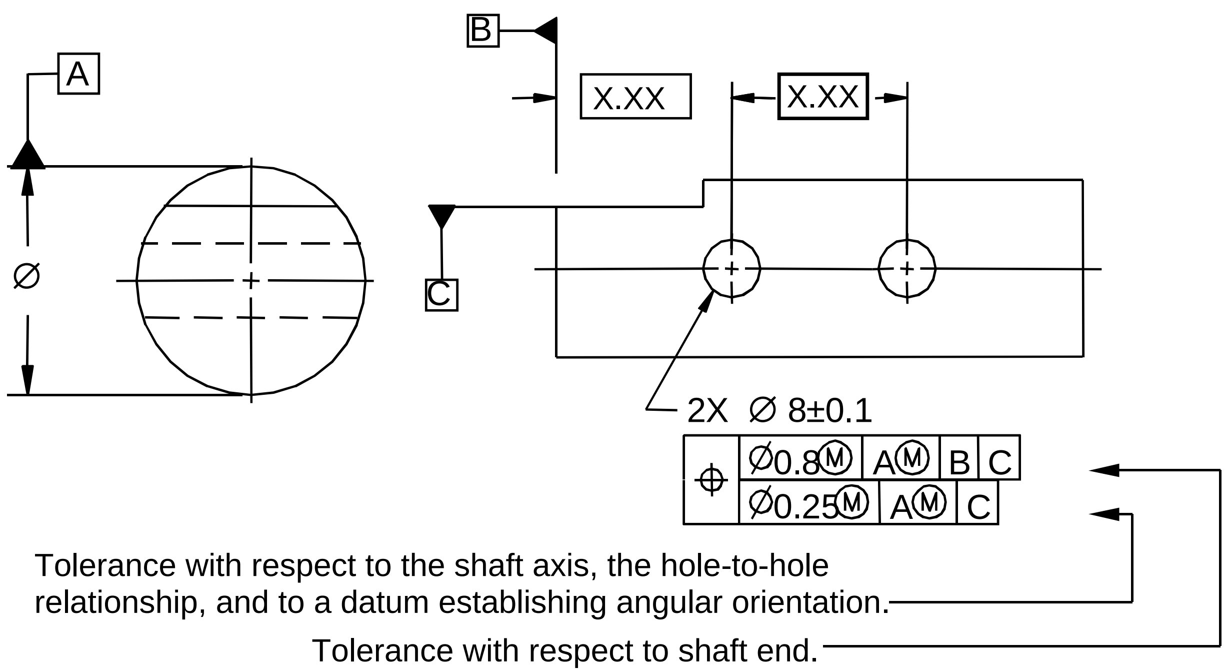
Reference: Y14.5M-1994 FIGS. 5-24, 5-25

5.7.10 Positional Tolerancing, Composite Tri-Directional

The Problem: Dimension a pattern of holes through a round shaft, loosely toleranced with respect to an end, but tightly toleranced with respect to the shaft axis, hole-to-hole relationship, and to a datum establishing angular orientation.



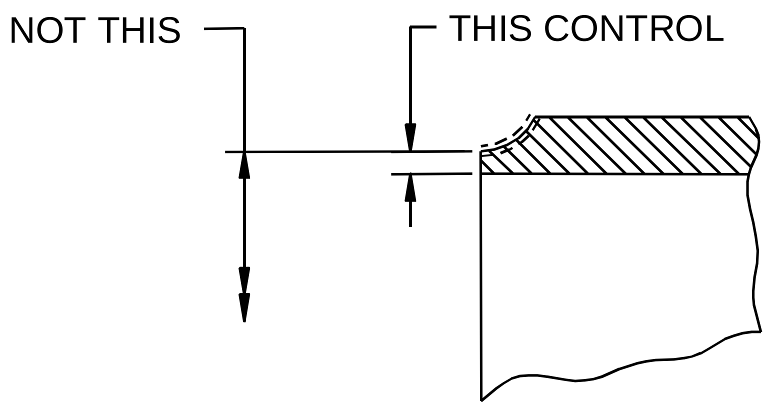
The Solution:



REFERENCE: ASME Y14.5M-1994 Figures 5-25 & 5-26

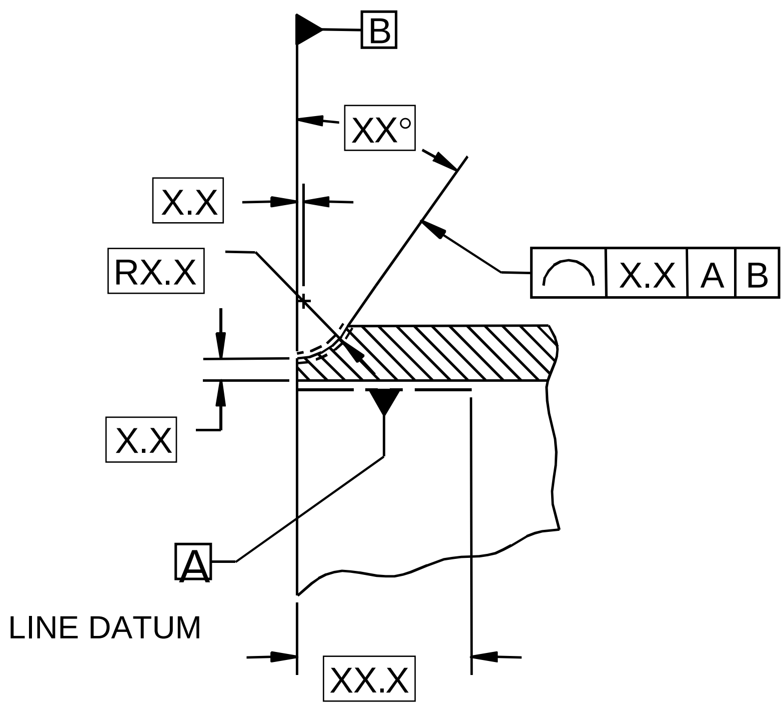
5.7.11 Use of Line Datum

The Problem: The design intent requires controlling the edge profile (thickness) from the actual inner surface.



Using a diameter as a datum would not produce the desired control.

The Solution:

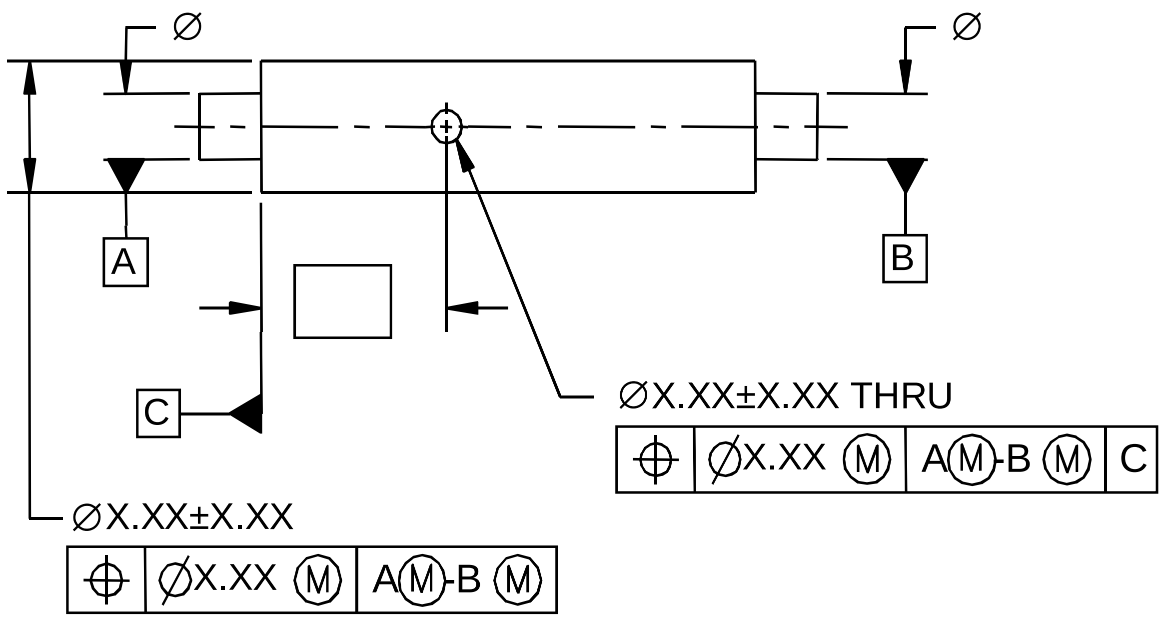


Note: Use of line datums could also be applied to flat surfaces to reduce the effects of waviness.

5.7.12 Position Relative to a Single Datum Axis

The Problem: Y14.5M does not illustrate the use of positional tolerancing when a feature needs to be positioned to two datum diameters that collectively establish a single datum axis.

The Solution:

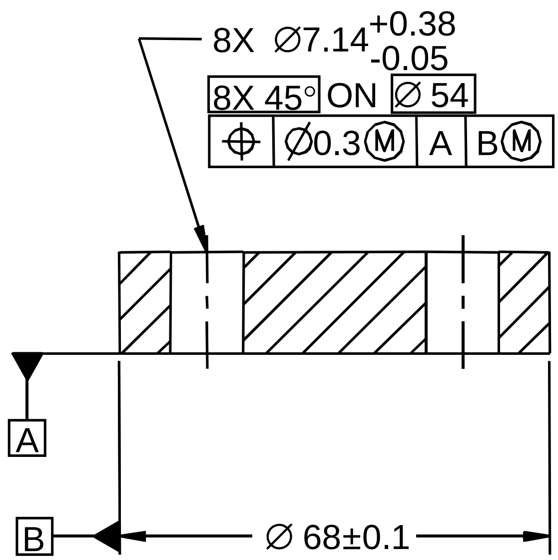


Note: ASME Y14.5M-1994 Figure 6-49 illustrates the use of runout.

5.7.13 Positional Tolerancing – Single View Callout

The Problem: Simplifying positional tolerancing for holes in a single view callout.

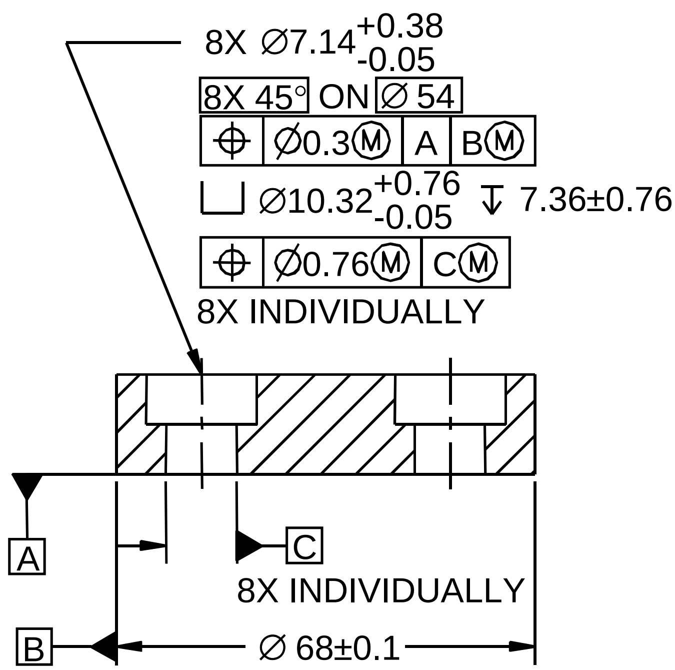
The Solution:



5.7.14 Holes and Counterbores, Different Datum Reference

The Problem: Simplifying positional tolerancing for holes and counterbores having different datum reference in a single-view callout.

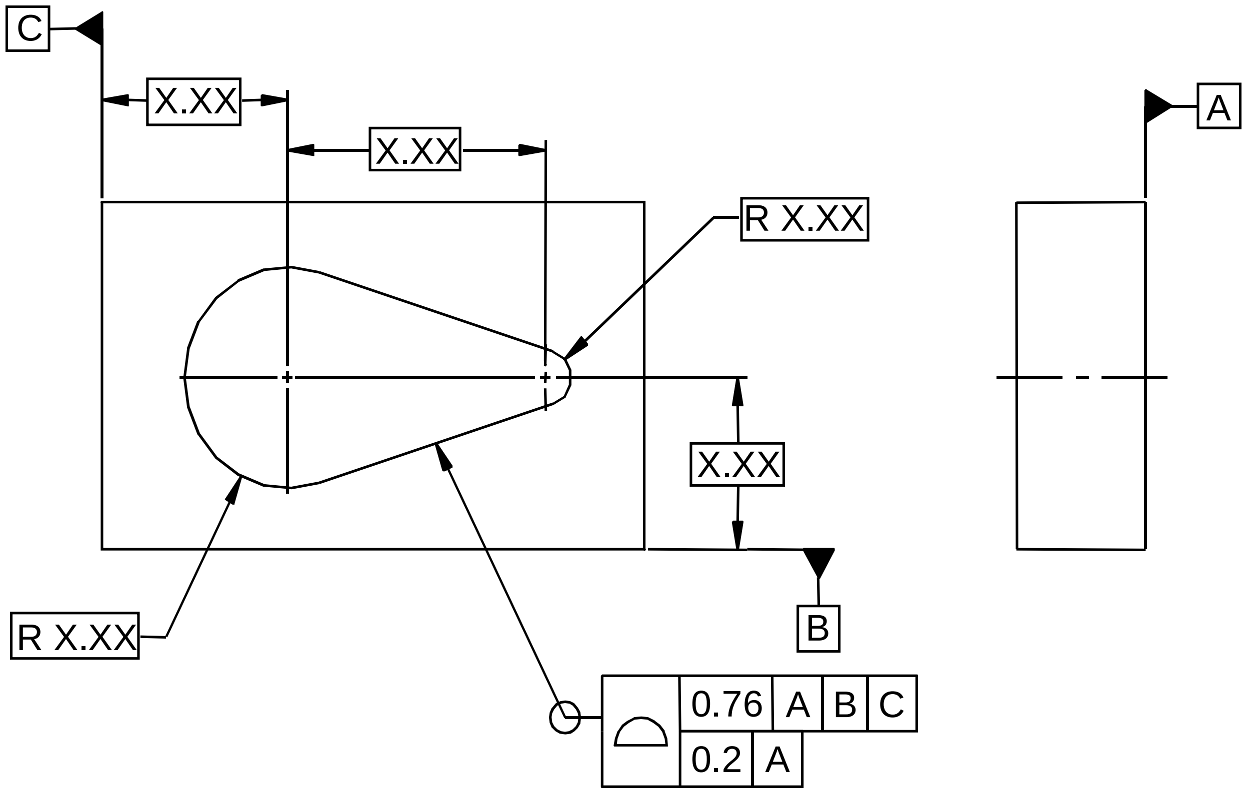
The Solution:



5.7.15 Profile Tolerancing, Composite

The Problem: The feature requires a tight profile tolerance, but allows a larger tolerance with respect to its location.

The Solution: Relax requirements of location using composite profile tolerancing.

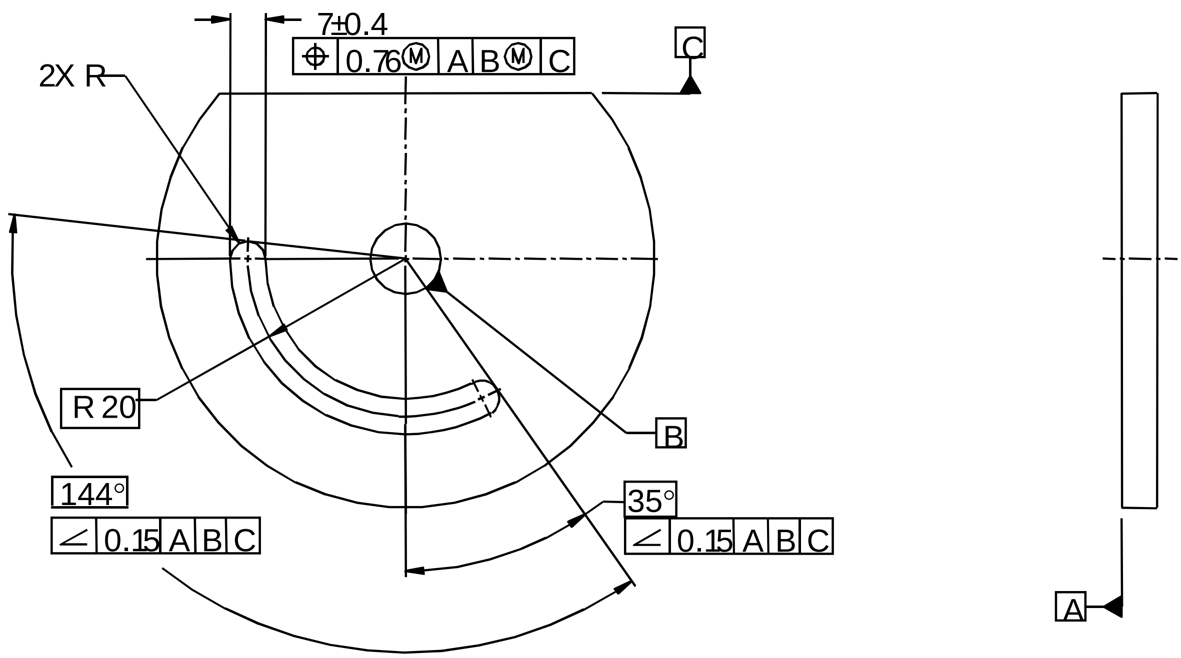


The upper entry of the callout locates the feature profile to the datums within a 0.76 total zone. The lower entry of the callout controls the size and shape of the profile to itself and datum A.

5.7.16 Radial Slot End Location

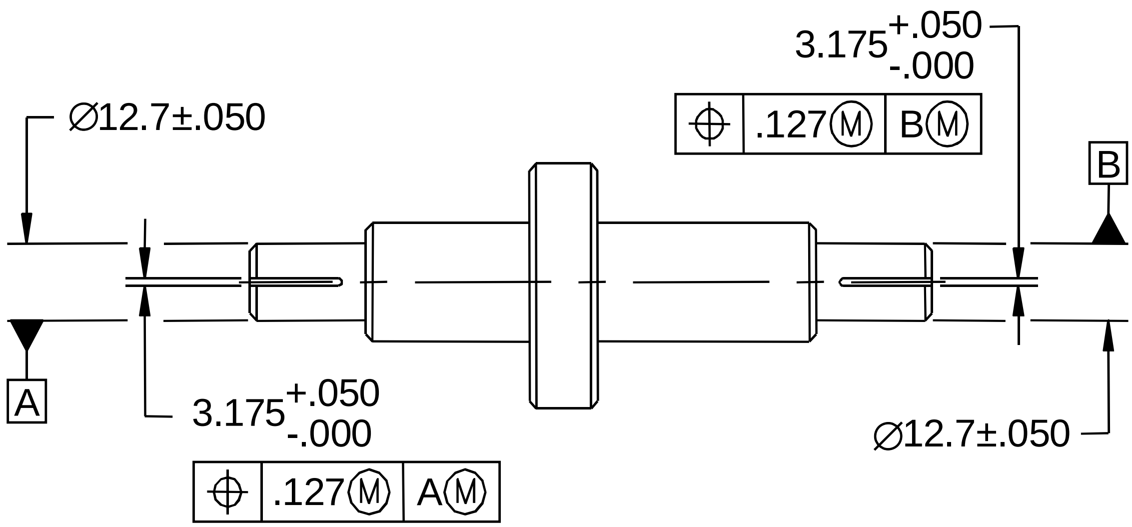
The Problem: Positioning a radial slot and accurately controlling the end locations tighter then the slot size.

The Solution: Use angularity tolerancing.



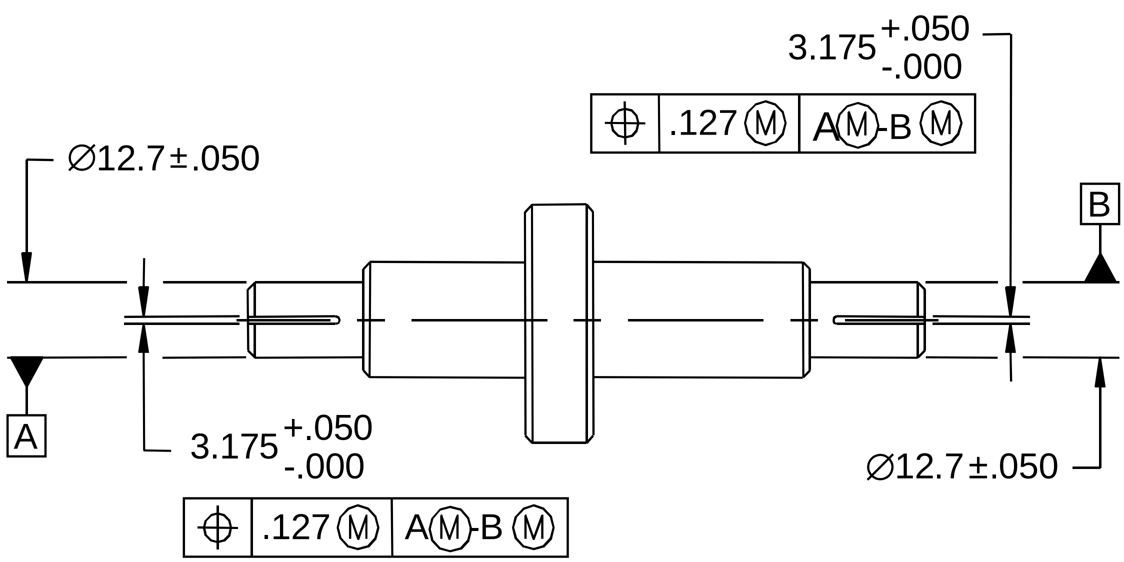
5.7.17 Feature Location

The Problem: How to locate features with respect to each other.



This illustration does not control the orientation of the keyways to each other.

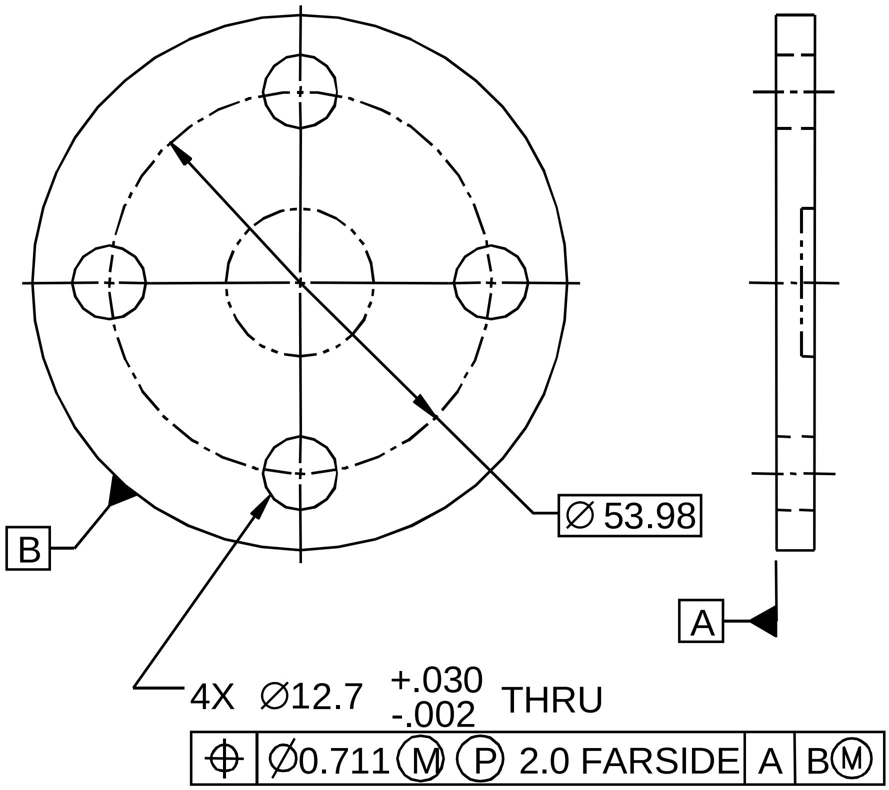
The Solution: Locate features with control frames containing the same datums with the same order of precedence and modifying symbols.



5.7.18 Projected Tolerance Far Side

The Problem: How to describe a projected tolerance on the far side with a single view.

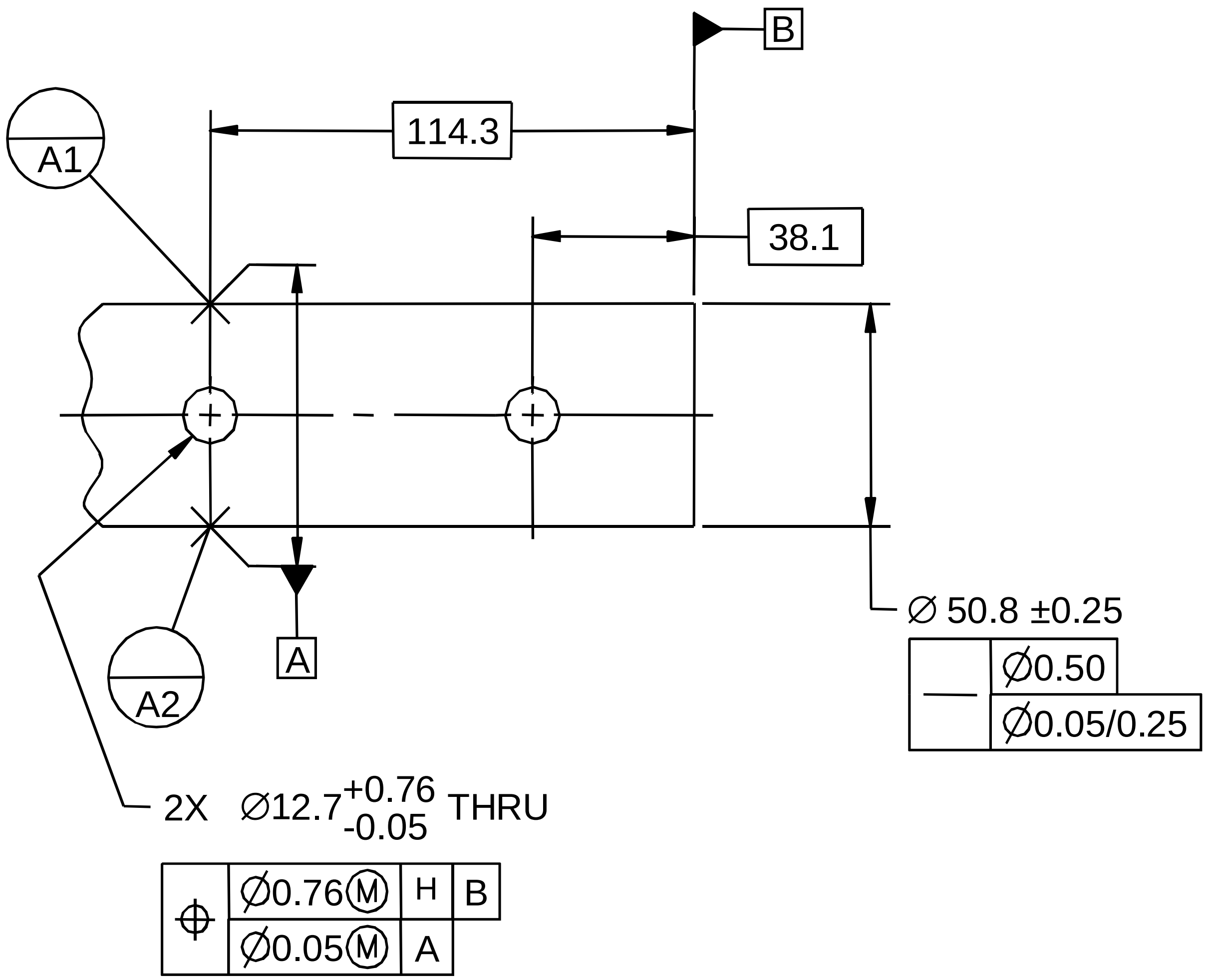
The Solution: It is permissible to call out a projected tolerance on the far side.



5.7.19 Positional Tolerancing Relative to Cross Section

The Problem: Locating holes at the center of a shaft with respect to its cross section.

The Solution: Use circumferential target points and identify each datum individually.



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Section 6. Drawing Layout

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

6.1 Purpose

This section defines LLNL preferred drafting practices for the layout of information on Engineering drawings.

6.2 Applicable Documents

- ASME Y14.1-1995, “Decimal Inch Drawing Sheet Size and Format”
- ASME Y14.1M-1995, “Metric Drawing Sheet Size and Format”

6.3 Preferred Placement of Information on Drawings

The following subsections discuss the preferred locations of subject information blocks on a drawing. Exact locations of blocks can vary by drawing, project, or organization.

6.3.1 Classification Level

The classification level of the drawing should be in the provided block at the top and bottom of the drawing, and also over the title block. See Figure 6-1.

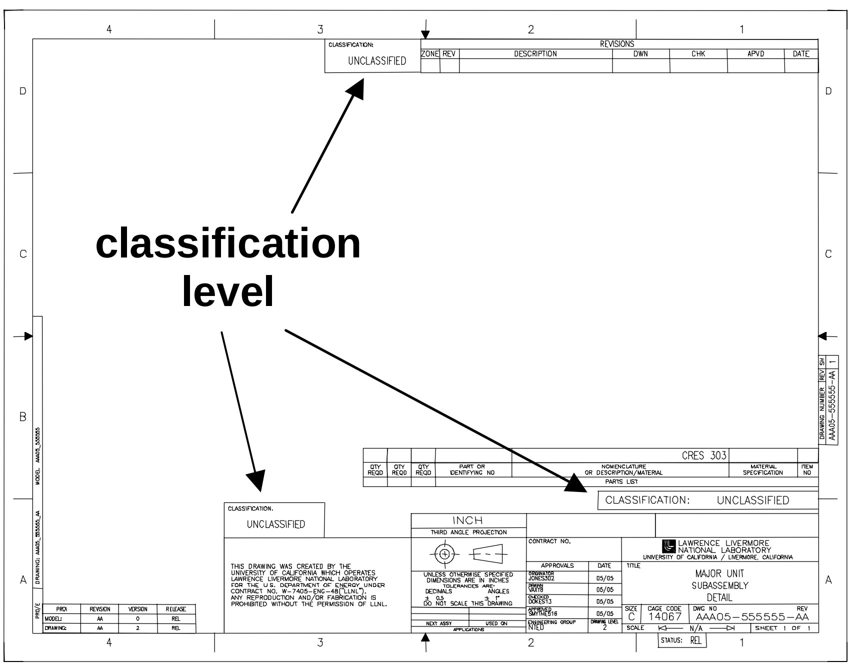

Figure 6-1. Classification level locations

6.3.2 Drawing Information Notices

All pertinent information notices such as Authorized Derivative Classification (ADC) block, Official Use Only (OUO) block, Distribution Control, classification type, Sigma level, and any Unclassified Controlled Information (UCI) notices such as Business Protected Data, Copyright Information, Export Control Information, Patent Sensitive Information, Proprietary/Trade Secrets Protected Data (i.e., Collaborative Research and Development Agreements or CRADA), etc., should be placed above or near the title block. This information should be visible in the lower title block quadrant of the drawing when a print is folded. See Figure 6-2.

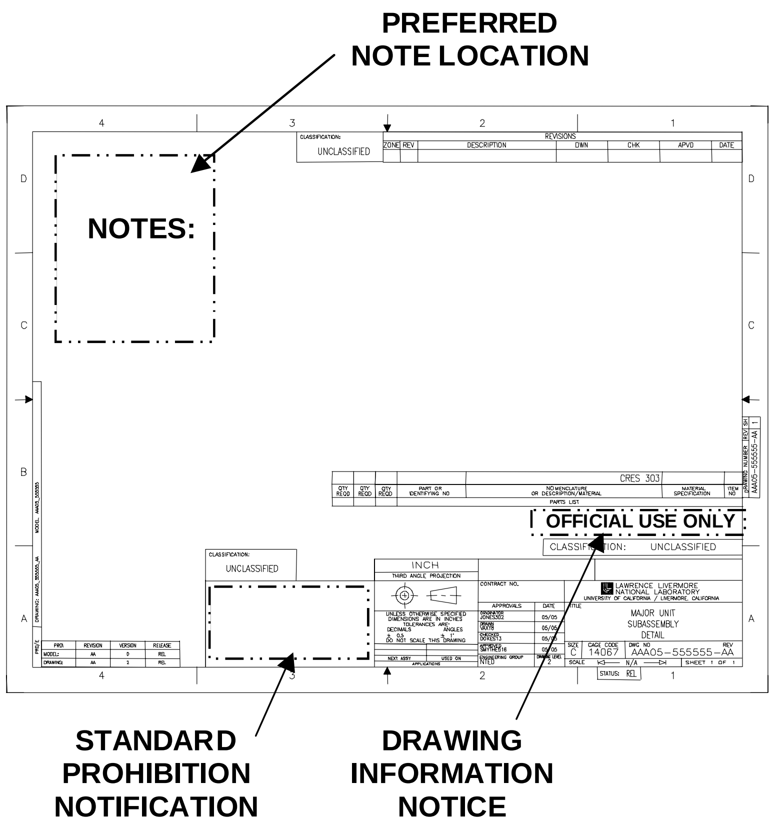

Figure 6-2. Preferred note and notification locations

6.3.3 Standard Prohibition Notification

The standard prohibition notification (reproduced in Figure 6-3) protects the Lawrence Livermore National Security LLC and LLNL from unauthorized distribution or fabrication and, for this reason alone, shall be included on all drawings. Although it is not a formal copyright notice, it serves a similar function. Under the Berne Convention, an author already owns the copyright of his or her work upon its completion. Therefore, including a legal copyright notice could be done, but it is not legally required. Contact the Lab's legal department for more information.

If the question of who owns the intellectual property is unclear, consult the document that forms the relationship between LLNL and the third party (for instance, the Cooperative Research And Development Agreement [CRADA] or a Work for Others Memorandum of Agreement). Obtain clarifying guidance from the third party for a substitution (or a replacement) but not the deletion of the standard prohibition notification.

Protecting intellectual property is the responsibility of the Design Activity (Program), including the person who approves the drawing. It is always assumed that the intellectual property embodied in the drawing belongs to LLNL.

> THIS DRAWING WAS CREATED BY LAWRENCE LIVERMORE NATIONAL SECURITY, LLC, THAT OPERATES LAWRENCE LIVERMORE NATIONAL LABORATORY FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC52-07NA27344 ("LLNL"). ANY REPRODUCTION AND/OR FABRICATION IS PROHIBITED WITHOUT THE PERMISSION OF LLNL

Figure 6-3. Standard prohibition notification.

6.3.4 Preferred Note Location

The preferred location of notes should be in the upper left corner of the drawing. See Figure 6-2.

6.3.5 Tabulation Blocks

The two most common types of tabulation blocks are "quantity type" and "geometry definition." The "quantity type" tabulation is usually listed next to the bill of materials as shown. See Figure 6-4.

It is preferred that the "geometry definition" (X-Y or theta R data type) tabulation block be placed above the notes area. See Figure 6-4.

6.3.6 Parts List and Bill of Materials

The parts list or Bill of Materials (BOM) is placed above all other pertinent notices such as UCI and classification information. See Figure 6-4.

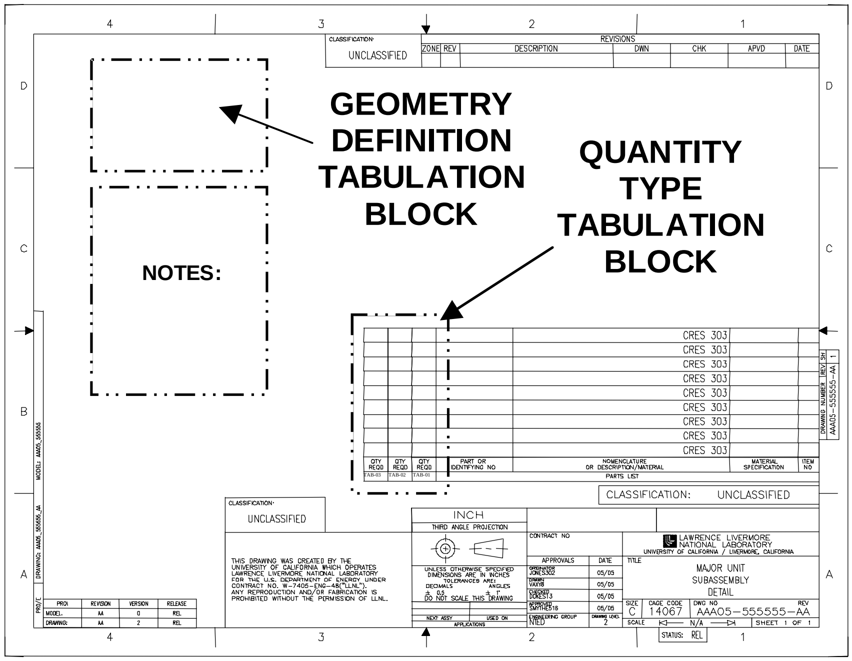

Figure 6-4. Tabulation block locations

6.4 Problem/Solution Examples

Potential problems and their recommended solutions relating to drafting practices at LLNL follow.

6.4.1 Tabulation Block Format

The Problem: The format of "detailed tabulation blocks" is not consistent within the Engineering Directorate.

The Solution: The following examples demonstrate preferred formats. Tolerances should be shown in the drawing field whenever possible.

TAB NO	DESCRIPTION
01	AS SHOWN
02	OPPOSITE HAND

Example 1.

TAB NO	DIM A	DIM B	DIM C
01	1.3	OMIT	3.8±0.2
02	1	0.3	4.8±0.2

Example 2. Metric

02	40	[.375–16UNC–2B]	[ø1.500]
01	36	[.250–20UNC–2B]	[ø1.000]
TAB NO	DIM A	THREAD B	ø STOCK

Example 3. Metric with English dimensioned fasteners and material stock

02	[3.0 SCH 10]	50
01	[2.5 SCH 10]	40
TAB NO	DIM A (PIPE SIZE)	DIM B (BASIC)

Example 4. Metric with English material stock

02	20±0.5	50
01	10±0.5	40
TAB NO	DIM A	WT KG

Example 5. Metric

6.5 Drawing Sheet Sizes and Formats

6.5.1 Sheet Sizes

Section 4 of ASME Y14.1 describes the national standards for drawing sheet sizes. For your convenience, decimal inch sheet sizes are listed in Table 6-1. The drawing margins and borderlines lie within these dimensions (see Figure 6-5). Note that standard drawing formats have the short dimension oriented vertically and the long dimension oriented horizontally. This is mentioned because of the confusion that often occurs with "A-size" drawings when they appear in a (nonstandard) vertical orientation format often used for sketches.

Metric-size paper is not used.

Table 6-1. Decimal inch sheet sizes

Size Designation	V	H	Margins		Comments
			MV	MH	
A (Horizontal)	8.50	11.00	.25	.38	Standard Format
A (Vertical)	11.00	8.50	.38	.25	Sketch Orientation
B	11.00	17.00	.62	.38	Standard Format
C	17.00	22.00	.50	.75	Standard Format
D	22.00	34.00	1.00	.50	Standard Format
E	34.00	44.00	.50	1.00	Standard Format

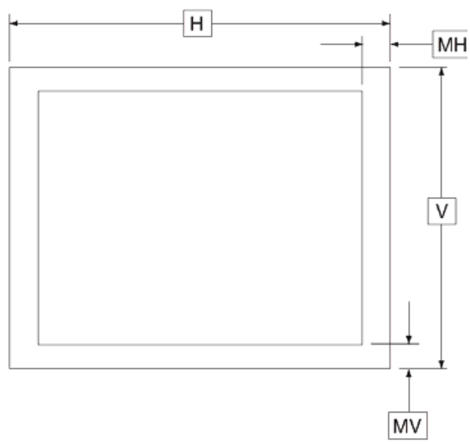

Figure 6-5. Margins and borderlines

6.5.2 Formats for Informal and Formal Drawings

A sample mechanical format is shown in Figure 6-6. These default formats should always be used for SAA, LEA, or AAA Engineering drawings and sketches unless superseded by written documentation from a unique program activity or contract between LLNL and a government or commercial agency. An example would be drawings commissioned under the Nuclear Weapons Complex (NWC) Technical Business Practice (TBP) standards.

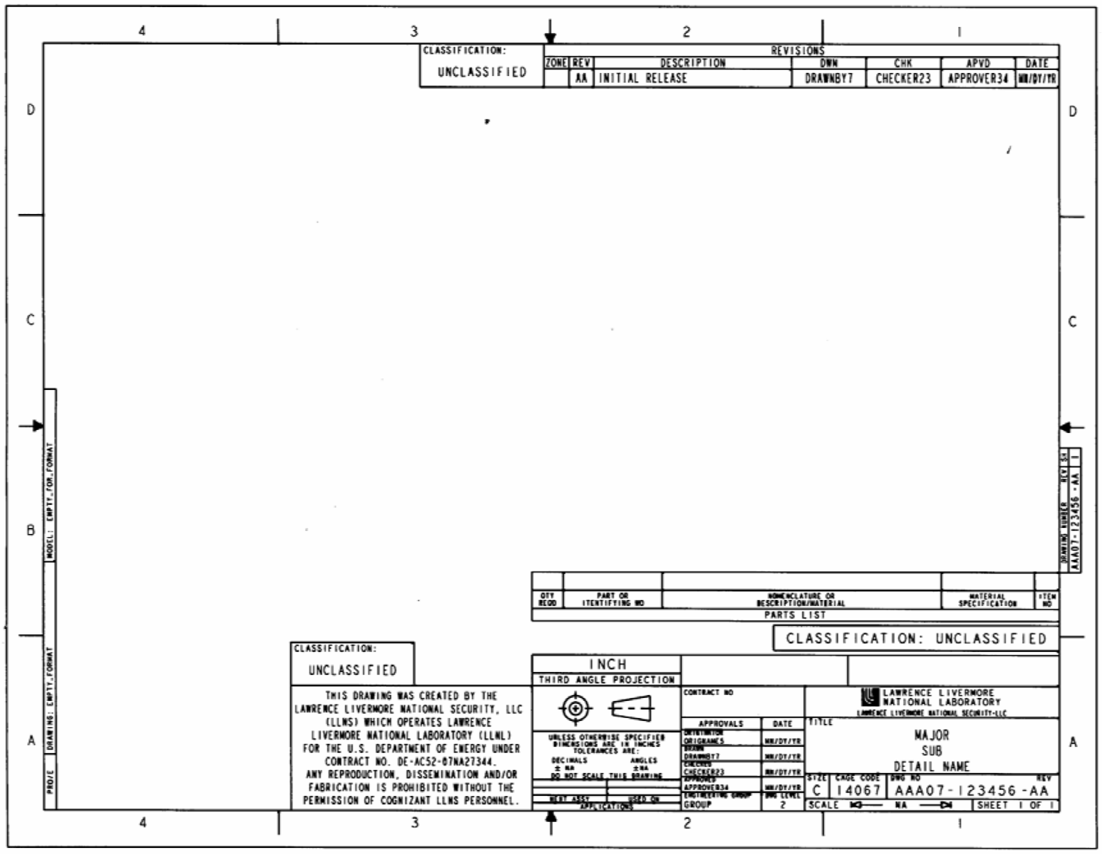

Figure 6-6. Sample Engineering mechanical format

Section 7. Drawing and Part Numbers

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

7.1 Purpose

All released LLNL engineering drawings should be archived in the LLNL Engineering Records Center (ERC) in accordance with Engineering policy. All engineering drawings should be numbered as specified by Engineering.

7.2 Applicable Documents

- *Engineering Policy Manual* Policy 4.1.2, "Conventions for Numbering Engineering Drawings, Documents and Parts"
- *Engineering Records Center Manual*, the implementation manual for Policy 4.1.2.

7.3 Engineering Drawing Numbering System

Refer to Engineering Policy 4.1.2, "Conventions for Numbering Engineering Drawings, Documents and Parts" and the *Engineering Record Center Manual*, Section 2.0, "Engineering Number Systems and Controls" and Section 3.1, "Drawing Numbers."

Policy 4.1.2 and the implementation manual are available on the "Inside Engineering" website at the following location: http://www-eng-r.llnl.gov/about/p2_manual.htm.

7.4 Part Serial Numbering System

Engineering's system for serialization of parts is described in Policy 4.1.2, "Conventions for Numbering Engineering Drawings, Documents and Parts," and the *Engineering Records Center Manual*, Section 6.0, "Part Serial Numbers."

Part serialization provides an accountability of parts under LLNL physical control, originating from LLNL or coming to LLNL after being manufactured elsewhere. The ERC issues part serial numbers from its database, ensuring unique numbers are assigned. Some examples of mandatory part serial numbers are parts and assemblies classified as SECRET, Source and Special (SS) Nuclear Materials parts containing special accountable materials, and parts made of High Explosive (HE) materials.

Section 8. Drawing Titles

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

8.1 Purpose

This section describes how to develop appropriate drawing titles so that similar drawings can be distinguished from one another. It also gives instructions on how to fill out all parts of the title block, and explains the function of each part.

8.2 Applicable Documents

- MIL-STD-12, "Abbreviations for Use on Drawings and in Specifications, Standards and Technical Documents."

8.3 General Titling Policy

All Engineering Directorate drawings should be clearly and distinctively titled to identify the drawing and to allow indexing of the title for computer recording and retrieval.

8.4 Specific Titling Requirements

- Drawing titles are limited to a maximum of 120 characters, including spaces. Titles should be distinctive and sufficiently descriptive to distinguish drawings of similar items.
- Each title should name and describe what the drawing represents in clear, commonly used terms. Titles should be limited to three lines, as shown in Table 8-1. The first line should indicate the major unit. The second line should indicate the subassembly. The third line should indicate the detail information.

Table 8-1. Typical drawing title

1. Major Unit: CHAIN SYSTEM
2. Subassembly: POWER SUPPLY
3. Detail: FRONT PANEL

- Within a package, all drawings shall have the same major unit and subassembly lines in the title. Only the detail line (the third of the three lines) should be different.

- Use of abbreviations should be limited, typically to those of common usage. They should be written only in capital letters: ASSY, AGC, LLNL, etc. An abbreviation should not be used as the first word in the title. (See Section 24, "Abbreviations.")
- Characters used to construct words and titles shall consist only of English letters, Arabic numerals, and the special symbols listed in Table 8-2.

Table 8-2. Special symbols allowed in titles

Symbols	Definition
()	(Parenthesis)
/	(Slash) Interpreted as "and" in Engineering Records Center (ERC) when labeling for archive.
-	(Minus sign; hyphen) Spelled out in ERC when labeling for archive.
+	(Plus sign) Spelled out in ERC when labeling for archive.
=	(Equals sign) Spelled out in ERC when labeling for archive.
$	(Dollar sign) Spelled out in ERC when labeling for archive.
,	(Comma) Spelled out in ERC when labeling for archive.
.	(Period) Interpreted as a decimal period (only in ERC) when labeling for archive

- Foreign language letters, such as alpha and omega, shall be spelled out.
- Subscripts and superscripts should not be used.

8.5 Filling Out the Title Block

The following paragraphs describe the function of each block in the title block and how to fill out each one. The capital letter preceding each description corresponds to a block shown in the example in Figure 8-1. Note that entries other than signatures shall be entered with block letters. Letter heights shall be in accordance with subsection 3.7.1 of this manual, "Drawing Text Height Requirements."

"A" – Design Activity Name and Address Block: This block contains the company trademark, name, and the design activity address (Lawrence Livermore National Laboratory, Lawrence Livermore National Security, LLC).

"B" – Drawing Title Block: Enter the drawing title in accordance with subsection 8.4.

"C" – Size Block: This block contains the letter designating the drawing sheet size.

"D" – CAGE Code Block: This block contains the Commercial and Government Entity Codes (CAGE). The LLNL number is 14067.

"E" – Drawing Number Block: Enter the drawing number in accordance with Section 7, "Drawing and Part Numbers."

"F" – Revision Letter Block: Enter the revision letter in accordance with Section 7, "Drawing and Part Numbers."

"G" – Scale Block: Enter the scale of the drawing as it appears on a 1:1 plotted or printed format sheet. The scale ranges are generally 1:1, 2:1 (twice size), 4:1 (4 times size), 1:2 (half size), 1:4 (one-fourth size), etc. Other scales may be necessary for the design. If there is no scale to the drawing, the word "None" should be entered in the block.

"H" – Sheet Block: Enter "1 of 1" for single-sheet drawings, "1 of 2" for two-sheet drawings, and so forth. The second sheet should have "2 of 2", etc.

"I" – Division: Enter the abbreviation of the division that has responsibility for the drawing. (See Table 8-3.)

Table 8-3. Division number/division group

Division	Abbreviation
Defense Technologies Engineering Division	DTED
Engineering Technologies Division	ETD
Laser Systems Engineering & Operations Division	LSEO
National Security Engineering Division	NSED
Technology Resources Engineering Division	TRED

"J" – Contract Number Block: This block is used when there is a specific contract with LLNL to do a specific engineering assignment.

"K" – Originator Block: Enter the originator's Official User Name (OUN). The originator may be the technician, coordinator, or engineer supplying the work.

"L" – Drawn Block: Enter the OUN of the drafter who originates the drawing (Revision "AA").

"M" – Checked Block: Enter the checker's OUN.

"N" – Approved Block: This block is to include the OUNs of authorized personnel only. Approval signatures, if used, should be legible.

"**O" – Date Blocks:** Enter the dates corresponding to the entry of the name or signature in the adjacent block.

"P" – Standard Tolerance Block: This block contains the standard tolerances that apply to specific dimensions on the drawing. The notation "Unless Otherwise Specified" pertains to dimensions on the drawing that do not have the standard tolerances in this block.

"Q" – CAD Information Block: Enter the software and revision letter in which the drawing was originated, and the database file name.

"R" – Next Assembly Block: Enter the drawing number of each next assembly unless shown on the parts list. When the drawing depicts the final deliverable item, enter the word "Final" or leave blank.

"S" – Used on Block: Enter the model number or other designation assigned to the program.

"T" – Classified Block: Enter the classification of the drawing (per Section 6.3.1)

"U" – Prohibition Declaration Block: Enter the LLNL proprietary rights notation. This notation is used for establishing LLNL's proprietary rights to drawings and shall be included on all drawings.

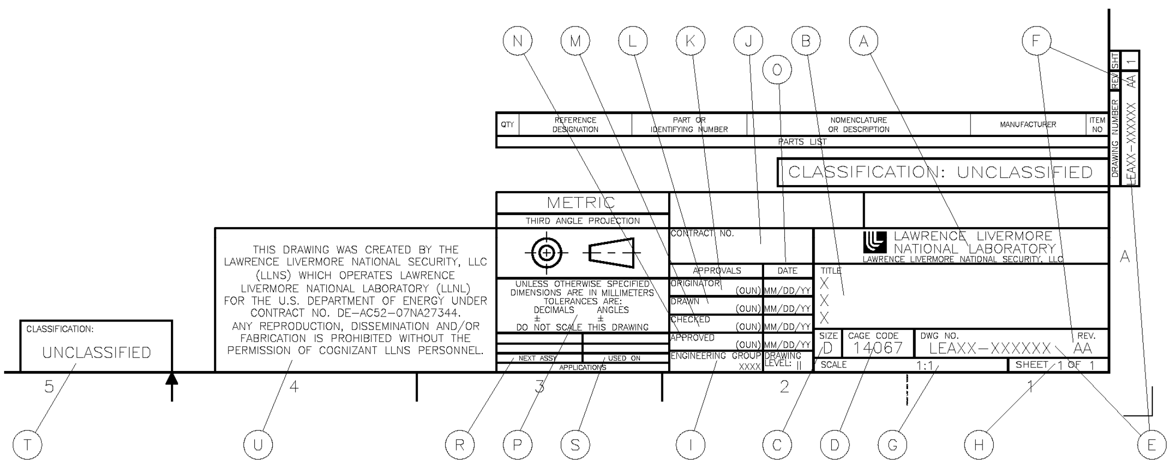

Figure 8-1. Filling out the title block

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Section 9. Drawing Notes

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

9.1 Scope

This section establishes the manner in which notes are to be used on drawings. Notes are provided with preferred wording, although adaptation and revision of notes may occur as appropriate.

9.2 Applicable Documents

- Global Engineering, *Drawing Requirements Manual* (current edition), Section 9, "Drawing Notes."

9.3 Definition

Drawing notes are information (in word form) about specific operations, processes, or instructions required for the manufacture, assembly, or inspection of a part or assembly.

9.4 Requirements

General Notes. General notes apply to entire drawings. They include process instructions, factual information, and/or referral information. Typically, process instruction notes begin with a verb, factual notes begin with a noun, and referral notes begin with the preposition "for." For example:

1. ASSEMBLE IN ACCORDANCE WITH ANSI/J-STD-001.
2. CAPACITORS ARE IN MICROFARADS.
3. FOR PARTS LIST, SEE LEA94-123456.

When a general note is deleted, the note number is not reused. The word "DELETED" should be indicated in place of the deleted text. For example:

1. ASSEMBLE IN ACCORDANCE WITH ANSI/J-STD-001.
2. DELETED.
3. FOR PARTS LIST, SEE LEA94-123456.

Note Location. See *Preferred Drafting and Design* Section 6, "Drawing Layout," for the recommended position of the General Notes column.

Lettering Sizes. Lettering sizes are defined in *Preferred Drafting and Design* Section 3, "Drafting Practices."

Sequencing. Care must be taken to place drawing notes in the proper sequential order to ensure that the steps do not adversely affect fabrication, processing, or handling.

Numbering. Drawing notes are to be numbered consecutively starting with numeral 1.

Local Notes. Local notes appear on the field of the drawing near the point or area to which they apply.

Flag Notes. Flag notes are located with the general notes but apply to specific points or areas on the drawing. A flag note should be identified by a flag symbol. The flag symbol, including the note number, should be shown on the field of the drawing for each applicable instance. Typically, flag notes are process instructions and begin with a verb.

Abbreviations. Abbreviations should be used only when necessary, for example when space is limited or when a complex technical term is used. For clarity, use proper punctuation and periods with abbreviations.

Use Minimum Standard Notes. Use the minimum standard notes shown as required. Add additional notes as needed to simplify the drawing.

9.5 EE Minimum Standard Notes (By Drawing Type)

9.5.1 Schematic Drawing Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
    1.1. ANSI Y32.2, GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAMS
    1.2. ANSI Y32.16, REFERENCE DESIGNATIONS FOR ELECTRICAL AND ELECTRONIC PARTS AND EQUIPMENT
2. FOR ASSEMBLY SEE LEAXX-XXXXXXX.
3. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR A COMPLETE REFERENCE DESIGNATION, PREFIX WITH APPLICABLE UNIT AND ASSEMBLY DESIGNATIONS.
4. RESISTANCE VALUES ARE IN OHMS ± X%, WATTS.
5. CAPACITANCE VALUES ARE IN MICROFARADS ± X%, VOLTS.
6. INDUCTANCE VALUES ARE IN MICROHENRIES ± X %, AMPS.
7. SH | ZONE NET OR SIGNAL CONTINUATION DESCRIPTION.

9.5.2 Cable Assembly Drawing Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
    1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
    1.2. IPC/WHMA-A-620, REQUIREMENTS AND ACCEPTANCE FOR CABLE AND WIRE HARNESS ASSEMBLIES
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.

3. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
4. ASSEMBLE IN ACCORDANCE WITH IPC/WHMA-A-620, CLASS 3.
   4.1. ELECTRICAL CONTINUITY TESTS SHALL BE TWO OHMS OR ONE OHM PLUS THE CABLE LENGTH RESISTANCE, WHICHEVER IS GREATER, WITH A TEST VOLTAGE NOT TO EXCEED 10 VDC OR AC PEAK.
   4.2. HIGH POT TEST SHALL BE CONDUCTED USING THE LOWEST DIELECTRIC WITHSTAND VOLTAGE OF THE ASSEMBLY COMPONENTS OR THE FOLLOWING VALUE, WHICHEVER IS LESS
      4.2.1. 300 VDC +/- 30 VOLTS FOR FLAT OR RIBBON CABLES
      4.2.2. 500 VDC +/- 50 VOLTS FOR OTHER CABLE ASSEMBLIES
      4.2.3. 1250 VAC (1700 VDC) FOR 120, 208, AND 240 VOLT POWER CABLES
      4.2.4. 2000 VAC (2800 VDC) FOR 480 VOLT POWER CABLES.
5. WIRE IN ACCORDANCE WITH WIRE LIST OR WIRING DIAGRAM.
6. MARK NOMENCLATURE SHOWN IN MARKING SCHEDULE WITH 3 [.125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032. MARKING TO READ IN DIRECTION OF CONNECTOR OR TERMINATION.
7. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR A COMPLETE REFERENCE DESIGNATION, PREFIX WITH APPLICABLE UNIT AND ASSEMBLY DESIGNATIONS.
8. SEE TABLE 1 FOR CABLE DESIGNATORS.

For computer-generated labels:

9. MARK NOMENCLATURE SHOWN IN MARKING SCHEDULE WITH 3-4 [.090-.150] HIGH BLACK CHARACTERS. MARKING TO READ IN DIRECTION OF CONNECTOR OR TERMINATION.

For Freon environment:

10. MARK LABEL IN ACCORDANCE WITH TABLE 1 AND MIL-M-4528 USING 1.5-3 [.062-.125] HIGH BLACK CHARACTERS. MARKING TO READ IN DIRECTION OF CONNECTOR OR TERMINATION.

9.5.3 Wiring Harness Drawing Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   1.2. IPC/WHMA-A-620, REQUIREMENTS AND ACCEPTANCE FOR CABLE AND WIRE HARNESS ASSEMBLIES
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.

3. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
4. WIRE IN ACCORDANCE WITH WIRE LIST OR WIRING DIAGRAM.
5. BIND WIRES TOGETHER AT X SPACING USING ITEM X.
6. MARK NOMENCLATURE SHOWN IN MARKING SCHEDULE WITH 3 [125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032; COLOR, BLACK. MARKING TO READ IN DIRECTION OF CONNECTOR OR TERMINATION.
7. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR A COMPLETE REFERENCE DESIGNATION, PREFIX WITH APPLICABLE UNIT AND ASSEMBLY DESIGNATIONS.
8. ASSEMBLE IN ACCORDANCE WITH IPC/WHMA-A-620, CLASS 3.
   - 8.1. ELECTRICAL CONTINUITY TESTS SHALL BE TWO OHMS OR ONE OHM PLUS THE CABLE LENGTH RESISTANCE, WHICHEVER IS GREATER, WITH A TEST VOLTAGE NOT TO EXCEED 10 VDC OR AC PEAK.
   - 8.2. HIGH POT TEST SHALL BE CONDUCTED USING THE LOWEST DIELECTRIC WITHSTAND VOLTAGE OF THE ASSEMBLY COMPONENTS OR THE FOLLOWING VALUE, WHICHEVER IS LESS
     - 8.2.1. 300 VDC +/- 30 VOLTS FOR FLAT OR RIBBON CABLES
     - 8.2.2. 500 VDC +/- 50 VOLTS FOR OTHER CABLE ASSEMBLIES
     - 8.2.3. 1250 VAC (1700 VDC) FOR 120, 208, AND 240 VOLT POWER CABLES
     - 8.2.4. 2000 VAC (2800 VDC) FOR 480 VOLT POWER CABLES.
9. ASSOCIATED DRAWINGS:
   - 9.1. ASSEMBLY DRAWING - LEAXX-XXXXX
   - 9.2. WIRING DIAGRAM - LEAXX-XXXXX

9.5.4 Electro-Mechanical Assembly Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   - 1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING.
2. ASSEMBLE IN ACCORDANCE WITH LLNL ENGINEERING DESIGN SAFETY STANDARDS MANUAL, SECTION 11.3, SPECIFICATION FOR ELECTRICAL EQUIPMENT FABRICATION.
3. PARTIAL REFERENCE DESIGNATIONS ARE SHOWN. FOR A COMPLETE REFERENCE DESIGNATION, PREFIX WITH APPLICABLE UNIT AND ASSEMBLY DESIGNATION.

4. PERMANENTLY MARK DRAWING NUMBER, REVISION LEVEL, AND SERIAL NUMBER (IF APPLICABLE) PER MIL-STD-130 WITH 3 [.125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032; COLOR, BLACK. LOCATE APPROXIMATELY WHERE SHOWN.
5. WIRE IN ACCORDANCE WITH WIRING DIAGRAM.
6. ASSOCIATED DRAWINGS:
   6.1. ASSEMBLY DRAWING - LEAXX-XXXXX
   6.2. WIRING DIAGRAM - LEAXX-XXXXX

9.5.5 Front Panel Fabrication Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   1.2. ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994.
3. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
4. 3 [125]√ FINISH ALL MACHINED SURFACES PER ASME B46.1, SURFACE TEXTURE.
5. REMOVE ALL BURRS AND BREAK SHARP EDGES 0.25 [.010] TO 0.75 [.030] CHAMFER OR RADIUS. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.

Omit this step for steel.

6. CHEMICAL CONVERSION COAT ALL SURFACES IN ACCORDANCE WITH MIL-C-5541, CLASS 3, IMMERSION METHOD; COLOR, GOLDEN.
7. MASK REAR OF PANEL PRIOR TO POWDER COATING.
8. POWDER COAT USING SHERWIN-WILLIAMS POWDURA POLYESTER POWDER COAT, COLOR: PBS4-C009 BLACK OR EQUIVALENT. ALL DIMENSIONS APPLY AFTER COATING.
9. GENERATE SCREEN PRINT TOOL (GERBER DATA) USING GBRXX-XXXXXX.
10. SCREEN-PRINT PANEL OUTSIDE SURFACE USING SUPPLIED SILKSCREEN ON SHEET 2. USE SERICOL POLYSET THERMOSETTING GLOSS INK, COLOR: OPAQUE WHITE PS-311 OR EQUIVALENT.
11. PERMANENTLY MARK DRAWING NUMBER, REVISION LEVEL, AND SERIAL NUMBER (IF APPLICABLE) PER MIL-STD-130 WITH 3 [.125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032; COLOR, BLACK, LOCATE APPROXIMATELY WHERE SHOWN.

12. PACKAGE PARTS IN A MANNER THAT PREVENTS DAMAGE DURING SHIPMENT.

Optional notes:

Add material callout note if not shown elsewhere.

13. MATERIAL: (add material description)

Add note when using silkscreen on an inside surface.

14. SCREEN-PRINT PANEL INSIDE SURFACE USING SUPPLIED SILKSCREEN ON SHEET 2. USE SERICOL POLYSET THERMOSETTING GLOSS INK, COLOR: PS-300 BLACK OR EQUIVALENT.
15. ASSOCIATED DRAWINGS:
    15.1. PARTS LIST: LEAXX-XXXXX
    15.2. ASSEMBLY: LEAXX-XXXXX

9.5.6 Rear Panel Assembly Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
    1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
    1.2. ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
2. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-1994. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
3. 3 [125]√ FINISH ALL MACHINED SURFACES PER ASME B46.1, SURFACE TEXTURE.
4. REMOVE BURRS AND BREAK SHARP EDGES 0.25 [.010] to 0.75 [.030] CHAMFER OR RADIUS. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.

Omit this step for steel.

5. CHEMICAL CONVERSION COAT ALL SURFACES IN ACCORDANCE WITH MIL-C-5541, CLASS 3, IMMERSION METHOD, COLOR GOLDEN.
6. GENERATE SCREEN PRINT TOOL (GERBER DATA) USING GBRXX-XXXXX.
7. SCREEN-PRINT PANEL USING SILKSCREEN SUPPLIED ON SHEET 2. USE SERICOL POLYSET THERMOSETTING GLOSS INK, COLOR: PS-300 BLACK OR EQUIVALENT.
8. PERMANENTLY MARK DRAWING NUMBER, REVISION LEVEL, AND SERIAL NUMBER (IF APPLICABLE) PER MIL-STD-130 WITH 3 [.125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032; COLOR, BLACK, LOCATE APPROXIMATELY WHERE SHOWN.

9. PACKAGE PARTS IN A MANNER THAT PREVENTS DAMAGE DURING SHIPMENT.
10. ASSOCIATED DRAWINGS:
    10.1. PARTS LIST: LEAXX-XXXXX
    10.2. ASSEMBLY: LEAXX-XXXXX

Add material callout note if not shown elsewhere.

11. MATERIAL: (add material description)

9.5.7 Sheet Metal Drawing Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
    1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
    1.2. ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
    1.3. ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
2. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS [ ] ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
3. 3 [125]√ FINISH ALL MACHINED SURFACES PER ASME B46.1, SURFACE TEXTURE.
4. REMOVE BURRS AND BREAK SHARP EDGES 0.25 [.010] to 0.75 [.030] CHAMFER OR RADIUS. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.

Omit this step for steel.

5. CHEMICAL CONVERSION COAT ALL SURFACES IN ACCORDANCE WITH MIL-C-5541, CLASS 3, IMMERSION METHOD; COLOR GOLDEN.
6. PERMANENTLY MARK DRAWING NUMBER, REVISION LEVEL, AND SERIAL NUMBER (IF APPLICABLE) PER MIL-STD-130 WITH 3 [.125] HIGH CHARACTERS USING EPOXY INK IN ACCORDANCE WITH A-A-56032; COLOR, BLACK, LOCATE APPROXIMATELY WHERE SHOWN.
7. PACKAGE PARTS IN A MANNER THAT PREVENTS DAMAGE DURING SHIPMENT.
8. ASSOCIATED DRAWINGS:
    8.1. ASSEMBLY - LEAXX-XXXXX

Add material callout note if not shown elsewhere.

9. MATERIAL: (add material description)

9.5.8 Vendor Interface Control Drawing (VICD) Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   1.2. ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
   1.3. ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
2. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS [ ] ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
3. IDENTIFICATION OF THE SUGGESTED SOURCE (S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM (S).

9.5.9 Source Control Drawing (SCD) Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   1.2. ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
   1.3. ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
2. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS [ ] ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
3. IDENTIFICATION OF THE APPROVED SOURCE (S) OF SUPPLY HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM (S).

9.5.10 Printed Wiring Board Notes

9.5.10.1 Artwork Master, Circuit Card

NOTES: UNLESS OTHERWISE SPECIFIED

1. SEE LEAXX-XXXXXX FOR FABRICATION DETAILS.

9.5.10.2 Assembly, Circuit Card

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:
   1.1. ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING.

1.2. ANSI/J-STD-001, REQUIREMENTS FOR SOLDERED ELECTRICAL AND ELECTRONIC ASSEMBLIES.

1.3. IPC-CM-770, GUIDELINES FOR PRINTED BOARD COMPONENT MOUNTING.

1.4. IPC-A-610, ACCEPTABILITY OF PRINTED BOARD ASSEMBLIES.

2. ALL DIMENSIONS ARE IN U.S. CUSTOMARY (INCHES).
3. ASSEMBLE IN ACCORDANCE WITH ANSI/J-STD-001.
4. MOUNT COMPONENTS IN ACCORDANCE WITH ANSI/IPC-CM-770.
5. VERIFY ACCEPTABILITY IN ACCORDANCE WITH IPC-A-610.
6. FOR ANY CONFLICTS BETWEEN THE REQUIREMENTS IN THE ABOVE SPECIFICATIONS, THE DOCUMENT WITH THE LATEST REVISION SHALL TAKE PRECEDENCE.
7. COMPONENTS NOT IDENTIFIED BY ITEM NUMBER ARE LOCATED IN THE PARTS LIST BY REFERENCE DESIGNATION.
8. SQUARE PADS ETCHED ON BOARD DENOTE PIN ONE (1) ORIENTATION, CATHODE END OF DIODES AND POSITIVE END OF CAPACITORS.
9. MARK ASSEMBLY REVISION LETTER AND SERIAL NUMBER (IF APPLICABLE) WITH .12-.15 HIGH CHARACTERS IN ACCORDANCE WITH MIL-STD-130 USING WHITE NON-CONDUCTIVE EPOXY INK IN ACCORDANCE WITH A-A-56032, TYPE II. LOCATE APPROXIMATELY WHERE SHOWN.
10. ASSOCIATED DRAWINGS: SCHEMATIC LEAXX-XXXXXX

Add following notes as required.

11. APPLY AND MARK BAR CODE LABEL IN ACCORDANCE WITH LLNL INSTRUCTIONS. LOCATE APPROXIMATELY WHERE SHOWN.
12. INSTALL ITEM XX IN ACCORDANCE WITH MANUFACTURER'S INSTRUCTIONS.

9.5.10.3 Fabrication, Circuit Card

NOTES: UNLESS OTHERWISE SPECIFIED

1. APPLICABLE STANDARDS AND SPECIFICATIONS:

1.1. IPC-2615, PRINTED BOARD DIMENSIONS.

1.2. IPC-A-600, ACCEPTABILITY OF PRINTED BOARDS.

1.3. IPC-SM-840, QUALIFICATION AND PERFORMANCE OF PERMANENT POLYMER COATING FOR PRINTED BOARDS.

1.4. IPC-4101, SPECIFICATION FOR BASE MATERIALS FOR RIGID AND MULTILAYER PRINTED BOARDS.

1.5. IPC-6011, GENERIC PERFORMANCE SPECIFICATION FOR PRINTED BOARDS

1.6. IPC-6012, QUALIFICATION AND PERFORMANCE SPECIFICATION FOR RIGID PRINTED BOARDS.

2. ALL BOARD DIMENSIONS ARE IN U.S. CUSTOMARY UNITS (INCHES).
3. VERIFY GERBER AND DRILL DATA PRIOR TO FABRICATION.
4. MANUFACTURE IN ACCORDANCE WITH THE REQUIREMENTS ON THIS MASTER DRAWING, IPC-6011 AND IPC-6012, TYPE 2, CLASS 2, SOLDER MASK OVER BARE COPPER (SMOBC) WITH FINAL FINISH- (to be called out).
5. VERIFY ACCEPTABILITY IN ACCORDANCE WITH IPC-A-600.
6. THE METAL CLAD BASE MATERIAL THICKNESS, THICKNESS TOLERANCE, AND PITS AND DENTS CLASSIFICATION REQUIREMENTS OF IPC-4101 SHALL MEET THE BOARD THICKNESS REQUIREMENTS.
7. FOR ANY CONFLICTS BETWEEN THE REQUIREMENTS IN THE DOCUMENTS ON THIS MASTER DRAWING, THE DOCUMENT WITH THE LATEST REVISION SHALL TAKE PRECEDENCE.
8. APPLY SOLDER MASK TO BOTH SIDES IN ACCORDANCE WITH IPC-SM-840, CLASS H, COLOR GREEN, USING THE SOLDER MASK SHEET(S) OF THE ARTWORK MASTER.
9. SCREEN PRINT COMPONENT LEGEND WITH WHITE NONCONDUCTIVE INK PER A-A-56032 USING THE COMPONENT LEGEND SHEETS(S) OF THE ARTWORK MASTER.
10. MINIMUM CONDUCTOR WIDTH = .XXX
11. MINIMUM ANNULAR RING SHALL BE IN ACCORDANCE WITH IPC-6012, CLASS 3.
12. MINIMUM CONDUCTOR SPACING = .XXX
13. HOLE PATTERN ACCURACY: THE HOLES SHALL BE LOCATED WITHIN .010 DIAMETER OF THE FEATURE CENTER.
14. FINISHED HOLE SIZE: UNLESS OTHERWISE SPECIFIED, ALL HOLES ARE PLATED THRU AND THE FINISHED HOLE DIAMETER SHALL BE WITHIN +/- .003 OF SIZE LISTED IN THE HOLE TABLE. THE FINISHED HOLE SIZE APPLIES AT FINAL INSPECTION.
15. ALL PRINTED BOARDS SHALL BE MANUFACTURED, PROCESSED AND CERTIFIED TO UL 94 V-O FLAMMABILITY CLASSIFICATION REQUIREMENTS. THE FINAL PRINTED BOARD(S) SHALL BE MARKED APPROXIMATELY WHERE SHOWN WITH AT LEAST THE MANUFACTURER'S IDENTIFICATION / DATE CODE AND FULL CLASSIFICATION DESIGNATION IN ACCORDANCE WITH UL 94 MARKING REQUIREMENTS.
16. MATERIAL:

    (2-LAYER)

PLASTIC SHEET, LAMINATED, GLASS EPOXY, COPPER CLAD NEMA FR-4, MIL-S-13949/04-GF, .063 THK 1 OZ. FINISHED COPPER ALL LAYERS.

(MULTI-LAYER)

SEE DETAIL A

PREPREG, GLASS EPOXY, WOVEN, NEMA FR-4,MIL-S-13949/04 GFN/GFK -

PLASTIC SHEET, LAMINATED, GLASS EPOXY, COPPER CLAD NEMA FR-4, MIL-S-13949/04-GF, 1 OZ. FINISHED COPPER ALL LAYERS.

17. LAYER-TO-LAYER SPACING SHALL BE UNIFORM WITH EQUAL DIELECTRIC MATERIAL THICKNESS BETWEEN CONDUCTIVE LAYERS WHEN CURED.
18. ELECTRICAL INTEGRITY TESTS REQUIRED PER IPC-6012:
    18.1. CHECK CONTINUITY OF ALL ELECTRICAL CONDUCTORS
    18.2. VERIFY ABSENCE OF SHORT CIRCUIT
    18.3. CHECK INSULATION RESISTANCE BETWEEN CONDUCTORS.
19. ASSOCIATED DRAWINGS:

    ASSEMBLY DRAWING: LEAXX-XXXXX

    MANUFACTURING DATA (GERBER & DRILL FILES: LEAXX-XXXXX)

    ARTWORK MASTER: LEAXX-XXXXX

9.6 ME Minimum Standard Notes (By Drawing Type)

9.6.1 Fabrication Drawing Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
2. APPLICABLE STANDARDS AND SPECIFICATIONS:

    ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING

    ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS

    ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
3. 3 [125]√ FINISH ALL MACHINED SURFACES PER ASME B46.1, SURFACE TEXTURE.
4. REMOVE ALL BURRS AND BREAK EDGES 0.25 [.010] TO 0.75 [.030] CHAMFER OR RADIUS. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.

Use one of the following marking notes as appropriate:

5. PERMANENTLY MARK PART PER MIL-STD-130 WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN IN 3 [.125] HIGH CHARACTERS. MARKING PROCESS TO BE APPROVED BY LLNL PRIOR TO MARKING PART.
6. BAG AND TAG PART WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE.
7. INSPECTION / ACCEPTANCE TO BE MEASURED AND RECORDED IN SI UNITS.
8. CALCULATED WEIGHT IS XX kg [XX lb].

9.6.2 Separable Assembly Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
2. APPLICABLE STANDARDS AND SPECIFICATIONS:

   ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING

   ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS

   ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
3. CALCULATED WEIGHT IS XX kg [XX lb].

Consult with your Lead Engineer or Lead Designer for validation of torque values with LLNL Safety Standards. List only the fastener size(s) called out on the drawing.

4. TORQUE (identify material) CLASS 8.8/A2 SCREWS TO PARENT MATERIAL USING VALUE(S) INDICATED:

   (Example callout)

   M4 x 0.7 2 N-m [17 lbf-in] (UNLUBRICATED)
5. MARK ASSEMBLY PER MIL-STD-130 WITH DRAWING NUMBER, TABULATION NUMBER, REVISION LETTER AND SERIALIZATION NUMBER IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS.

9.6.3 Inseparable Assembly Notes

NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.

2. APPLICABLE STANDARDS AND SPECIFICATIONS:
   ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
   ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS
3. CALCULATED WEIGHT IS XX kg [XX lb].
4. MARK ASSEMBLY PER MIL-STD-130 WITH DRAWING NUMBER, TABULATION NUMBER, REVISION LETTER AND SERIALIZATION NUMBER IF APPLICABLE, APPROXIMATELY WHERE SHOWN WITH 3 [.125] HIGH CHARACTERS.

9.7 General Notes (By Process)

Notes are listed in a process-prioritized order. Care must be taken to place drawing notes in the proper sequential order to ensure that the steps do not adversely affect fabrication, processing, or handling.

9.7.1 General Notes

NOTES: UNLESS OTHERWISE SPECIFIED:

1. ALL DIMENSIONS ARE IN MILLIMETERS AND VALUES ARE IN SI UNITS. DIMENSIONS AND VALUES IN BRACKETS ARE U.S. CUSTOMARY UNITS CONVERTED FROM MILLIMETERS / SI UNITS.
2. APPLICABLE STANDARDS AND SPECIFICATIONS:
   ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING
   ASME Y14.36M-1996, SURFACE TEXTURE SYMBOLS
   ASME Y14.38A-2002, ABBREVIATIONS AND ACRONYMS

Additional specifications that may be added as necessary:

ANSI/ AWS A2.4, STANDARD SYMBOLS FOR WELDING ISO 724, METRIC SCREW THREADS
ANSI B1.20.3, DRYSEAL PIPE THREADS (NPTF) CLASS I
MIL-S-7742 & FED-STD-H28, INCH SCREW THREADS
FED-STD-H28/12, ACME SCREW THREADS
ANSI B4.1, PREFERRED LIMITS AND FITS FOR CYLINDRICAL PARTS
ANSI B4.2, PREFERRED METRIC LIMITS AND FITS
ANSI/AWS D1.1, STRUCTURAL WELDING CODE- STEEL
ANSI/AWS D1.2, STRUCTURAL WELDING CODE- ALUMINUM
AISC MANUAL OF STEEL CONSTRUCTION
ANSI/AWS D10.4, WELDING OF AUSTENITIC STAINLESS STEEL PIPE AND TUBE

ANSI/AWS D10.7, WELDING OF ALUMINUM PIPE AND TUBING

AWS BRM, BRAZING MANUAL

ANSI Y32.2, GRAPHIC SYMBOLS FOR ELECTRICAL AND ELECTRONIC DIAGRAMS

ANSI Y32.16, REFERENCE DESIGNATIONS FOR ELECTRICAL AND ELECTRONIC PARTS AND EQUIPMENT

ASSEMBLE IN ACCORDANCE WITH LLNL ENGINEERING DESIGN SAFETY STANDARDS MANUAL, SECTION 11.3, SPECIFICATION FOR ELECTRICAL EQUIPMENT FABRICATION.

FABRICATE IN ACCORDANCE WITH IPC/WHMA-A-620 REQUIREMENTS AND ACCEPTANCE FOR CABLE AND WIRE HARNESS ASSEMBLIES.

3. 3 [125]√ FINISH ALL MACHINED SURFACES PER ASME B46.1, SURFACE TEXTURE.
4. REMOVE ALL BURRS AND BREAK EDGES 0.25 [.010] TO 0.75 [.030] CHAMFER OR RADIUS. RADII MUST MAKE A SMOOTH TRANSITION WITH ADJACENT SURFACES.
5. PERMANENTLY MARK PART PER MIL-STD-130 WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS.
6. BAG AND TAG PART WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE.
7. INSPECTION / ACCEPTANCE TO BE MEASURED AND RECORDED IN SI UNITS.
8. CALCULATED WEIGHT IS X kg [Y lbs].
9. CALCULATED WEIGHT IS X g [Y oz].
10. ALL STRUCTURAL STEEL AS FABRICATED AND DELIVERED SHALL MEET TOLERANCE REQUIREMENTS FOR ARCHITECTURALLY EXPOSED STRUCTURAL STEEL AS DEFINED IN SECTION 10 OF THE AISC CODE OF STANDARD PRACTICE. TOLERANCED DIMENSIONS TO CONFORM TO ASME Y14.5M-1994, DIMENSIONING AND TOLERANCING.
11. PERFECT ORIENTATION AT MMC REQUIRED FOR RELATED FEATURES.
12. DATUM A IS ESTABLISHED BY RESTRAINING TO A FLAT CONDITION BY _________ (identify method) _________ (identify extent).
13. PERMANENTLY MARK PART WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN IN 6 [.25] HIGH CHARACTERS. MARKING PROCESS TO BE APPROVED BY LLNL PRIOR TO MARKING PART.

Use for Engineering model based manufacturing (EMBM):

14. MANUFACTURE PART PER MEL98-023, ENGINEERING MODEL BASED MANUFACTURING, (EMBM), OF HARDWARE USING COMPUTER GENERATED SOLID MODELS. DISREGARD MODEL TOLERANCES.
15. ALL DIMENSIONS ARE BASIC HAVING A PROFILE TOLERANCE OF 1 [.040] PER ASME Y14.5M-1994.

9.7.2 Fabrication Notes

Choose those specifications that are applicable for manufacturing:

1. APPLICABLE STANDARDS AND SPECIFICATIONS FOR MANUFACTURING:
   ISO 724, METRIC SCREW THREADS
   ANSI B1.20.3, DRYSEAL PIPE THREADS (NPTF) CLASS I
   MIL-S-7742 & FED-STD-H28, INCH SCREW THREADS
   FED-STD-H28/12, ACME SCREW THREADS
   ANSI B4.1, PREFERRED LIMITS AND FITS FOR CYLINDRICAL PARTS
   ANSI B4.2, PREFERRED METRIC LIMITS AND FITS
   ANSI/AWS D1.1, STRUCTURAL WELDING CODE- STEEL
   ANSI/AWS D1.2, STRUCTURAL WELDING CODE- ALUMINUM
   AISC MANUAL OF STEEL CONSTRUCTION
   ANSI/AWS D10.4, WELDING OF AUSTENITIC STAINLESS STEEL PIPE AND TUBE
   ANSI/AWS D10.7, WELDING OF ALUMINUM PIPE AND TUBING
   AWS BRM, BRAZING MANUAL
2. THREAD RELIEF FOR EXTERNAL THREADS:
   WIDTH = 2X PITCH
   DIAMETER = MINOR DIAMETER - 0.25 [.010]/0.12 [.005]
   RADIUS = 0.5X FULL RADIUS MIN.
   THREAD RELIEF FOR INTERNAL THREADS:
   WIDTH = 2X PITCH
   DIAMETER = MAJOR DIAMETER + 0.25 [.010]/0.12 [.005]
   RADIUS = 0.5X FULL RADIUS MIN.
3. ALL INTERNAL BEND RADII TO BE A MAXIMUM OF 2X MATERIAL THICKNESS.
4. BEND RELIEF IS PERMISSIBLE BUT MUST BE PLUG WELDED FOR LIGHT TIGHTNESS.

9.7.3 Inseparable Assembly Notes

Vacuum- stainless steel weldments:

1. WELD IN ACCORDANCE WITH MEL89-001793. WELD SYMBOLS PER ANSI/AWS A2.4. 0.25 [.010]. MAXIMUM DIAMETRICAL CLEARANCE BETWEEN MATING PARTS. WELDS TO BE VACUUM TIGHT. LEAK RATE TO BE LESS THAN 1 x 10-8 ATM CC/SEC OF HELIUM GAS AS DETERMINED BY A HELIUM MASS SPECTROMETER LEAK DETECTOR.

Aluminum weldments:

2. WELD IN ACCORDANCE WITH ANSI/AWS D1.2 & D10.7. WELD SYMBOLS PER ANSI/AWS A2.4. 0.25 [.010] MAXIMUM DIAMETRICAL CLEARANCE BETWEEN MATING PARTS. STRESS RELIEVE PART AFTER WELDING AND PRIOR TO FINAL MACHINING.

Steel weldments:

3. WELD IN ACCORDANCE WITH ANSI/AWS D1.1. WELD SYMBOLS PER ANSI/AWS A2.4. 0.25 [.010] MAXIMUM DIAMETRICAL CLEARANCE BETWEEN MATING PARTS. STRESS RELIEVE PART AFTER WELDING AND PRIOR TO FINAL MACHINING.

Stainless steel high pressure weldments:

4. WELD IN ACCORDANCE WITH ANSI/AWS D1.1 & D10.4. WELD SYMBOLS PER ANSI/AWS A2.4. 0.25 [.010] MAXIMUM DIAMETRICAL CLEARANCE BETWEEN MATING PARTS. STRESS RELIEVE PART AFTER WELDING AND PRIOR TO FINAL MACHINING.
5. ALL INTERNAL RADII TO BE 0.25 [.010] MAXIMUM.
6. BREAK EDGE TO 3 [.125] RADIUS OR CHAMFER. CORNERS FORMED BY CHAMFERING MUST BE BLENDED TO A SMOOTH SURFACE AND MAY BE HAND BLENDED. SEE EDGE BREAK DETAIL FOR CLARIFICATION.
7. INSTALL THREADED INSERTS PER MANUFACTURER'S INSTRUCTIONS.
8. ALL MACHINING AND CUTTING FLUIDS ARE TO BE COMPATIBLE WITH THE CLEANING METHODS DESCRIBED IN MEL98-001.

Stainless steel low pressure weldments:

9. WELD IN ACCORDANCE WITH ANSI/AWS D1.1 & D10.4. WELD SYMBOLS PER ANSI/AWS A2.4. STRESS RELIEVE PART AFTER WELDING AND PRIOR TO FINAL MACHINING.
10. ALL WELDS ARE TO BE CONTINUOUS. ALL CRACKS AND GAPS BETWEEN ADJOINING PIECES ARE TO BE WELDED. NO SKIPS, OPENINGS OR PINHOLES ARE PERMITTED.

9.7.4 Cleaning/Finishing Notes

Class 100 cleanroom finishes: Parts that need high reflectivity.

On aluminum:

1. ELECTRO-LESS NICKEL PLATE PART PER AMS 2404 FOR HEAT TREATABLE ALUMINUM ALLOYS, 0.04 [.0015] MINIMUM THICKNESS. PLATE PRIOR TO INSTALLING INSERTS AND MASK OFF ALL TAPPED HOLES IF APPLICABLE. AFTER PLATING, RINSING, AND DRYING, PART SHALL BE HEATED AT 230C [450ºF] FOR NOT LESS THAN 4 HOURS. ALL DIMENSIONS APPLY AFTER PLATING.

On steel:

2. ELECTRO-LESS NICKEL PLATE PART PER AMS 2404 FOR HEAT TREATABLE METALS, .04 [.0015] MINIMUM THICKNESS. PLATE PRIOR TO INSTALLING INSERTS AND MASK OFF ALL TAPPED HOLES IF APPLICABLE. AFTER PLATING, RINSING, AND DRYING, PART SHALL BE HEATED AT 400C [750ºF] FOR NOT LESS THAN .5 HOUR. ALL DIMENSIONS APPLY AFTER PLATING.

On stainless steel:

3. ELECTRO-POLISH PART TO A BRIGHT APPEARANCE AND SMOOTH FINISH (SNAG FREE WHEN WIPED WITH A SOFT COTTON CLOTH). PROTECT ALL THREADED HOLES. DIMENSIONS APPLY AFTER ELECTROPOLISHING. THE WORKING VACUUM PRESSURE OF THIS PART IS 1 x 10-6 TORR. [Add last sentence only if applicable.]

Or the less costly process for stainless steel:

4. PASSIVATE PART PER ASTM A380, CODE F. ALL DIMENSIONS APPLY AFTER PASSIVATION.

Surface finishing:

Standard aluminum parts:

5. ANODIZE PART PER MIL-A-8625, TYPE II (SULFURIC ACID) CLASS 2 (DYED) COLOR BLACK, 0.01 [.0004] THICK. NICKEL ACETATE SEAL AFTER ANODIZING. ANODIZE PRIOR TO INSTALLING INSERTS AND MASK OFF ALL TAPPED HOLES. ALL DIMENSIONS APPLY AFTER ANODIZING.

Electrical insulation of aluminum parts:

6. HARD ANODIZE PART PER MIL-A-8625, TYPE III (HARD ANODIC COATING) CLASS 1 (NON-DYED), 0.05 [.002] MINIMUM THICKNESS. ANODIZE PRIOR TO INSTALLING INSERTS AND DO NOT MASK OFF TAPPED HOLES. ALL DIMENSIONS APPLY AFTER ANODIZING.

Electrical insulation of metal parts:

7. COAT PART WITH PARYLENE, TYPE 'C,' 0.050-0.065 [.0020-.0025] THICKNESS. MASK OFF INDICATED SURFACES PRIOR TO COATING. ALL DIMENSIONS APPLY AFTER COATING.

Preparing aluminum and stainless steel weldment surfaces for coatings:

8. BAR SHOT BLAST ENTIRE PART WITH STEEL GRIT SAE 40 OR GARNET 40 TO A UNIFORM FINISH. CAUSTIC ETCH PER MEL81-001627.

Powder coating: Class 100 cleanroom compatible finish.

9. BAR SHOT BLAST ENTIRE PART WITH STEEL GRIT SAE 60 OR GARNET 60 TO A UNIFORM FINISH. CLEAN PART PER ENC-93-907(Al), ENC-93-910 (SST), ENC-93-911 (Ti), ENC-93-912(Cu). POWDER COAT USING HERBERTS-O'BRIEN CORP., HOUSTON, TX 77041-7624. PRODUCT CODE #ELW505S9. SURFACE BAKE TEMPERATURE 175C [350ºF] FOR 20 MINUTES; COLOR: APPLIANCE WHITE, 90% GLOSS OR EQUAL.

Painting instructions (high gloss white):

10. BAR SHOT BLAST ENTIRE PART WITH STEEL GRIT SAE 60 OR GARNET 60 TO A UNIFORM FINISH. CLEAN SURFACES PER MANUFACTURERS INSTRUCTIONS. PRIME USING SHERWIN-WILLIAMS INDUSTRIAL WASH PRIMER P/N P60G2 AND WASH PRIMER CATALYST REDUCER P/N R7K44 OR KEM AQUA WASH PRIMER P/N E61G520, FOLLOWED BY 2.8 VOC CATALYZED EPOXY PRIMER P/N E61A280 (GRAY) AND CATALYST P/N V66V282 PER MANUFACTURER'S INSTRUCTIONS. FINISH COAT TO A HIGH GLOSS WITH SHERWIN-WILLIAMS POLANE HS PLUS WITH CATALYST P/N V66V55 AND MAK R6K30 REDUCER PER MANUFACTURE'S INSTRUCTIONS. COLOR "HIGH GLOSS WHITE" CHIP NO. F63W66 OR CURRENT COLOR EQUIVALENT. CONTACT SHERWIN-WILLIAMS COMPANY, (510) 658-0877 FOR CURRENT COLOR FORMULATION.

Non-reflective cast iron & steel parts:

11. BLACK NICKEL PLATE PART PER MIL-P-18317, SUBSTRATE PER FEDERAL SPEC QQ-N-290, CLASS 1 (NONREFLECTIVE, DECORATIVE FINISH), GRADE F 0.01 [.0004] THICK.
12. VAPOR DEGREASE PART PER xxxxx.

Electrical insulation fiberglass G10 machined parts with cleanroom application:

13. COAT CUT SURFACES WITH 0.01-0.04 [.0005-.0015] THICK EPOXY RESIN. ALL EXPOSED FIBERS MUST BE ENCAPSULATED. ALL DIMENSIONS APPLY AFTER COATING.

Preparing stainless steel surfaces for coatings:

14. BAR SHOT BLAST ENTIRE PART WITH STEEL GRIT SAE 60 OR GARNET 60 TO A UNIFORM FINISH.

15. CAUSTIC ETCH PER MEL81-001627.
16. CLEAN PART(S) PER MEL99-009, GROSS CLEANING OF NIF COMPONENTS AND STRUCTURES. TREATMENT G-VI FOR CHEMICAL CLEANING OF CAST ALUMINUM ALLOY COMPONENTS.

Use for enamel painting (beige):

17. BAR SHOT BLAST ENTIRE PART WITH STEEL GRIT SAE 60 OR GARNET 60 TO A UNIFORM FINISH. CLEAN SURFACES PER MANUFACTURER'S INSTRUCTIONS. PRIME USING SHERWIN-WILLIAMS INDUSTRIAL WASH PRIMER P/N P60G2 AND WASH PRIMER CATALYST REDUCER P/N R7K44 OR KEM AQUA WASH PRIMER P/N E61G520 PER MANUFACTURER'S INSTRUCTIONS. FINISH COAT WITH SHERWIN-WILLIAMS POLANE 2.8T PLUS POLYURETHANE ENAMEL, WITH P/N V66V44 CATALYST AND P/N R7K84 REDUCER PER MANUFACTURER'S INSTRUCTIONS. COLOR "BEIGE" (LOW GLOSS/SMOOTH) CHIP NO. F63-EXH-0115 OR CURRENT COLOR EQUIVALENT. CONTACT SHERWIN-WILLIAMS COMPANY (510) 658-0877 FOR CURRENT COLOR FORMULATION.

Use for powder coating (class 100 cleanroom compatible):

18. POWDER COAT USING HERBERTS-O'BRIEN CORP.,HOUSTON, TX 77041-7624. TGIC POLYURETHANE POWDER PRODUCT CODE #PFW-500-S9, OR LLNL APPROVED EQUIVALENT. ALL COATED SURFACES SHALL BE PREPARED, PRETREATED, COATED, AND BAKED IN ACCORDANCE WITH MANUFACTURER'S SPECIFICATIONS FOR STRUCTURAL STEEL AND HEAVY-DUTY MAINTENANCE APPLICATIONS. COATING PREPARATION SHALL REMOVE MILL SCALE, DIRT, RUST, GREASE, OIL, AND FOREIGN MATTER. THE SELLER SHALL SUBMIT A 152 X 152 [6 X 6] SAMPLE THAT HAS BEEN PREPARED, PRETREATED, COATED, AND BAKED USING THE EXACT PROCESS THAT THE VENDOR IS PROPOSING FOR LLNL APPROVAL. COLOR: WHITE, 90% GLOSS OR EQL.

Use for aluminum parts:

19. ANODIZE PART PER MIL-A-8625, TYPE II (SULFURIC ACID) CLASS 1 (NON-DYED) COLOR CLEAR, 0.01 [.0004] THICK. NICKEL ACETATE SEAL AFTER ANODIZING. ANODIZE PRIOR TO INSTALLING INSERTS AND MASK OFF ALL TAPPED HOLES. ALL DIMENSIONS APPLY AFTER ANODIZING.

Use for Enamel painting aluminum parts:

20. PAINT INDICATED SURFACES ONLY, AFTER ANODIZING. FINISH COAT WITH SHERWIN-WILLIAMS POLANE HS PLUS WITH A CATALYST P/N V66V55 AND MAK R6K30 REDUCER PER MANUFACTURER'S INSTRUCTIONS. COLOR "HIGH GLOSS WHITE" CHIP NO. F63W66 OR CURRENT COLOR EQUIVALENT. CONTACT SHERWIN-WILLIAMS COMPANY, (510) 658-0877 FOR CURRENT COLOR FORMULATION. PAINT SHOULD BE APPLIED AND ALLOWED TO DRY PRIOR TO ASSEMBLY OF

HARDWARE. KEEP ALL UNPAINTED SURFACES AND HOLES CLEAN AND FREE FROM PAINT OVERSPRAY.

21. NICKEL PLATE PART PER QQ-N-290 CLASS I, 0.001 [.00004] TO 0.002 [.00008] THICK. SILVER PLATE PART PER QQ-S-365 TYPE II, 0.005 [.0002] TO 0.01 [.0004] THICK. ALL DIMENSIONS APPLY AFTER PLATING.

Use for steel parts that are NOT for Cleanroom use:

22. SURFACE PREPARATION PER MANUFACTURER'S INSTRUCTIONS. PRIME WITH RUST-OLEUM NO. 3481 GREY PRIMER. FINISH COAT WITH RUST-OLEUM No. 3492 GLOSS WHITE.
23. SURFACE PREP PER MANUFACTURER'S INSTRUCTIONS. PRIME WITH KELLY MOORE NO. 1711 KEL-GUARD WHITE RUST INHIBITIVE PRIMER. FINISH COAT WITH KELLY MOORE NO. 1700-61 KEL-GUARD RUST INHIBITIVE ENAMEL, ARTIC WHITE.

9.7.5 Assembly Notes

1. CLEAN ALL COMPONENTS AT LLNL PER MIL-STD-1246 LEVEL 100.
2. PFPE LUBRICATE BEARINGS USING BRAYCOTE MICRONIC 601EF OR BRAYCOTE 803RP FOR USE IN CLASS 100 CLEANROOM ENVIRONMENTS.

Consult with your Lead Engineer or Lead Designer for validation of torque values with LLNL Safety Standards. List only the fastener size(s) called out on the drawing.

3. TORQUE (Identify material) CLASS 8.8/A2 SCREWS TO PARENT MATERIAL USING VALUE(S) INDICATED:

   (Example callout)

   M4 x 0.7 2 N-m [17 lbf-in] (UNLUBRICATED)
4. MARK ASSEMBLY PER MIL-STD-130 WITH DRAWING NUMBER, TABULATION NUMBER, REVISION LETTER AND SERIALIZATION NUMBER IF APPLICABLE, APPROXIMATELY WHERE SHOWN IN 3 [.125] HIGH CHARACTERS.

   EXAMPLE OF ASSEMBLY MARKING: AAA99-123456-OA & SERIAL NUMBER OR AAA99-123456-01-OA FOR TABULATED ASSEMBLIES.
5. DESIGN REFERENCE: O-RING GROOVE IS FOR XXX [XX.XX] I.D. x XX [.XXX] WIDE. O-RING DIMENSIONS AND TOLERANCES ARE SPECIFIED IN SAE AS-568A.

9.7.6 Identification Notes

1. METAL STAMP DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS PER MIL-STD-130.

2. ENGRAVE DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS PER MIL-STD-130.
3. ELECTRO-CHEMICAL ETCH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS PER MIL-STD-130.
4. ELECTRO-ARC PENCIL MARK DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS PER MIL-STD-130.
5. RUBBER STAMP DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER, AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS PER MIL-STD-130 USING EPOXY INK PER MIL-I-43553. COLOR BLACK, TYPE II (NON CONDUCTIVE INK).
6. TAG WITH DRAWING NUMBER, REVISION LETTER, TABULATION NUMBER AND PART SERIAL NUMBER, IF APPLICABLE, APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS AND BAG.
7. PERMANENTLY MARK PART WITH INDICATED TEXT APPROXIMATELY WHERE SHOWN USING 3 [.125] HIGH CHARACTERS. MARKING PROCESS TO BE APPROVED BY LLNL PRIOR TO MARKING PART.

9.7.7 Inspection/Testing Notes

1. PRESSURE TEST HYDROSTATICALLY WITH DISTILLED WATER AT_____ PSIG FOR A PERIOD OF ______ MINUTES WITH NO PERMANENT DEFORMATION, VISIBLE CRACKS OR LEAKS. PERFORM PRESSURE TEST AFTER FINAL MACHINING.
2. VACUUM TEST PER ASTM E498-95 WITH A MAXIMUM LEAK RATE TO BE LESS THAN 1 x 10-8 ATM CC/SEC OF HELIUM GAS AS DETERMINED BY A HELIUM MASS SPECTROMETER LEAK DETECTOR. VACUUM TEST TO BE PERFORMED AFTER FINAL MACHINING AND PART MUST BE CLEAN AND DRY BEFORE TEST.
3. LEAK RATE TO BE LESS THAN 1 x 10-5 ATM CC/SEC WHEN CHECKED BY HELIUM GAS AS DETERMINED BY A HELIUM MASS SPECTROMETER LEAK DETECTOR.
4. DIMENSIONS INDICATED REQUIRE 100% INSPECTION.

9.7.8 Packaging/Delivery

1. THE SELLER SHALL PACKAGE THE PART TO MAINTAIN CLEANLINESS AND TO PREVENT DAMAGE DURING HANDLING AND SHIPMENT TO THE SITE SPECIFIED ON THE PURCHASE ORDER.
2. SHIPPING CONTAINERS SHALL BE MARKED TO INDICATE THE FOLLOWING:
   - 1. LLNL PURCHASE ORDER NUMBER.
   - 2. SHIPPING ADDRESS AS SPECIFIED ON THE PURCHASE ORDER, INCLUDING THE BUILDING NUMBER.
   - 3. "LLNL CONTACT" AS SPECIFIED ON THE PURCHASE ORDER.
   - 4. CONTENTS CONTAINED IN THE PACKAGE(S).
   - 5. SELLER'S NAME.
   - 6. "TOP SIDE UP", IF REQUIRED.
   - 7. "FRAGILE", IF REQUIRED.

9.7.9 Specialty Notes

Insert for Source Control Drawings:

1. ITEM(S) DESCRIBED ON THIS DRAWING ARE APPROVED OR SUGGESTED FOR USE IN THE APPLICATION(S) SPECIFIED HEREON. A SUBSTITUTE ITEM SHALL NOT BE USED WITHOUT PRIOR APPROVAL BY LLNL.
2. IDENTIFICATION OF THE APPROVED OR SUGGESTED SOURCE(S) HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABLITY AS A SOURCE OF SUPPLY FOR THE ITEM(S) DESCRIBED ON THIS DRAWING.

Section 10. Parts List Preparation

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

10.1 Purpose

This section establishes procedures and requirements for preparing parts lists for Engineering Directorate electronics drawings. The parts list may be included on an assembly drawing, a subassembly drawing, or a separate drawing that has its own number and is referenced to an assembly drawing.

10.2 Applicable Documents

None.

10.3 Introduction

A parts list is an itemized list of all parts, components, and materials needed to construct a unit or an assembly. In addition to parts and materials, the parts list contains a list of all documents (drawings and/or specifications) needed to construct the unit.

Information presented on the parts list should be sufficient and suitable for the needs of all foreseeable end users, including (but not limited to) buyers, fabricators, technicians, estimators, drafters, and engineers, both within LLNL and outside. All Engineering Directorate drawings shall be titled in accordance with Section 8.4 of this manual.

10.4 Description of Parts List

The parts list may be included on the assembly drawing, in which case it is located above the title block, or it may be on a separate document in parts list format.

10.4.1 Parts List on an Assembly Drawing

The assembly drawing parts list is filled out as follows. See Figure 10-1:

"A"- ITEM NO.: Numbers inserted in this column refer to the ballooned item numbers on the assembly drawing.

"B"- MANUFACTURER: Name of company that produced the item.

"C" - NOMENCLATURE OR DESCRIPTION: An appropriate description of the item should be inserted in this column.

"D"- PART OR IDENTIFING NUMBER: Enter the manufacturer's number and vendor equivalent part numbers when more than one supplier may be available.

"E"- REFERENCE DESIGNATION: Enter the reference number assigned to the part in the assembly.

"F"- QUANTITY REQUIRED: The quantity of each part required for this assembly should be listed in this column.

10.4.2 Separate Parts List Forms

A separate parts list is composed of two different potential 8.5” × 11” forms:

Title and Revision Sheet: The first page of a parts list should be the Title and Revision Sheet. This sheet contains the drawing number, drawing title, group code, number of sheets, drawing reference information, drafter’s and originator’s name, check and approval signature blocks, and revisions status and history. See Figure 10-2**.**

Parts and Material Sheet: The next section of a parts list should contain Parts and Material sheets, which list information on parts, components, and materials. See Figure 10-3**.**

10.4.3 Formats for Parts Lists

Parts lists for engineering drawings can be formatted in two ways:

- Listed in the field of the drawing. See Figure 10-1.
- As a separate parts list having a unique drawing number. When this method is used, the parts list number shall be cross-referenced on the associated assembly drawing and the assembly drawing number shall be cross-referenced on the parts list. See Figures 10-2 and 10-3 for a sample of a separate parts list.

The method selected is determined by the program, specified in the contract of work, or specified in a configuration management document.

As a minimum for mechanical drawings, the following shall be identified in the parts list:

- Item number
- Number required per assembly
- Part number (this may be an LLNL drawing number, a project-designated part number, or a commercial part number)
- Nomenclature or description
- Material (material specification, if required)

As a minimum for electrical drawings, the following shall be identified in the parts list:

- Item number
- Number required per assembly
- Reference Designation
- Description
- Manufacturer (manufacture specification, if required)
- Part number (this may be an LLNL drawing number, a project-designated part number, or a commercial part number)

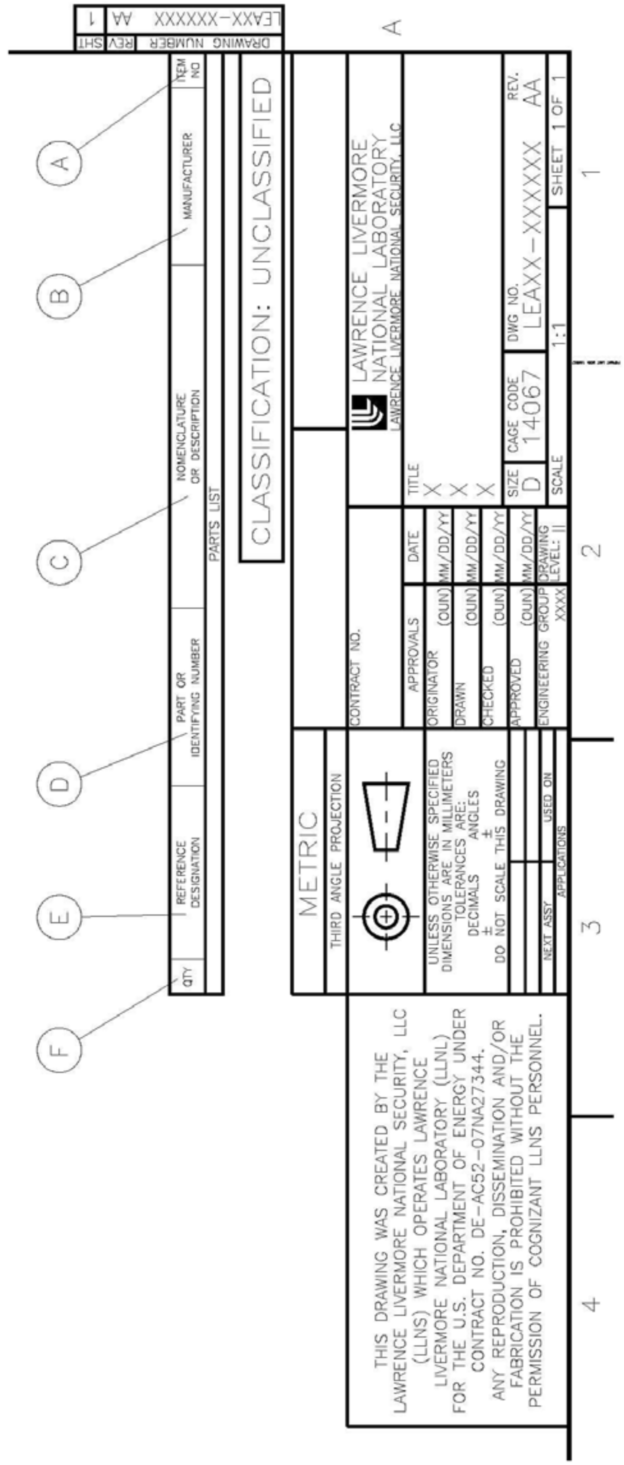

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Figure 10-1. Sample Parts List Format on an Assembly Drawing

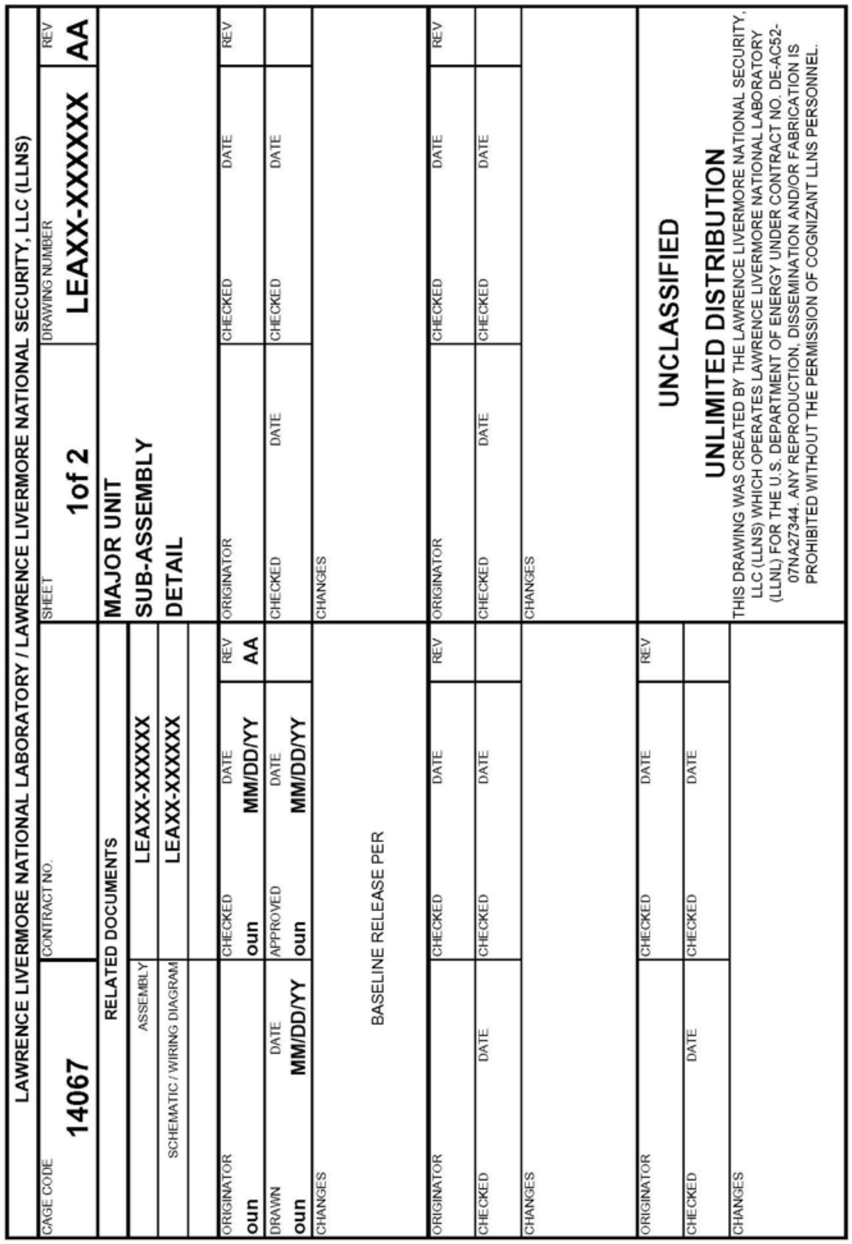

Figure 10-2. Sample EE Parts List (sheet 1 of 2)

CAGE CODE **14067** SHEET **2** OF **2** **LEAXX-XXXXXX-AA**

ITEM	QTY	REFERENCE DESIGNATOR	DESCRIPTION	MFG / SPEC	PART NO. OR LLNL DWG NO.

UNCLASSIFIED

Figure 10-3. Sample EE Parts List (sheet 2 of 2)

10.5 Description of Parts and Materials

10.5.1 Generic Description

Each item listed in the Parts and Materials section should be described with a complete generic description. When used in conjunction with a manufacturer's name and catalog or type number, this description should provide sufficient information for the procurement of the item.

10.5.2 Sources of Information for Generic Description

The preferred sources for generic descriptions of an item should be the manufacturer's catalog and/or data sheet.

10.5.3 Guidelines for Parts Descriptions

The following are guidelines for the minimum requirements for generic descriptions of common components, parts, and materials.

Resistors

- Resistance value
- Power rating
- Tolerance
- Type and configuration

Examples and suggested format:

1. RESISTOR, 10K, 1/2W, 5%, METAL FILM
2. RESISTOR, 0.33 OHM, 25W, 10%, NON-INDUCTIVE WIREWOUND, COOL-OHM P27E OR EQUIVALENT

Capacitors

- Capacitance value
- Working voltage
- Tolerance
- Type and configuration

Examples and suggested format:

1. CAPACITOR, 0.01 MICROFARAD (OR μF), 100V, 10%, CERAMIC RECTANGULAR, CK05
2. CAPACITOR, 5 MICROFARAD (OR μF), 1 KV, +80% -20%, MYLAR METAL CAN, OIL-FILLED, MAXWELL 30411

Integrated Circuits

- Device Number
- Type or function
- Case Type

Examples and suggested format:

1. INTEGRATED CIRCUIT (OR IC), 7400, QUAD 2-INPUT NAND GATE, 14-PIN DIP
2. INTEGRATED CIRCUIT (OR IC), AD290A, ISOLATION AMPLIFIER, TO-99, 8-PIN, ANALOG DEVICES

Lamps

- Type
- Bulb number
- Volts
- Base type

Examples and suggested format:

1. LAMP, INCANDESCENT, T 1-3/4, 28V, MIDGET SCREW
2. LAMP, NEON GLOW, 120V, S.C. MIDGET FLANGE

Connectors

- General Type
- Number of contacts
- Male/female or pin/socket

Examples and suggested format:

1. CONNECTOR, CIRCULAR, PANEL RECEPTACLE, 32 CRIMP CONTACTS, 20 GUAGE, MALE, MS3122E18-32P
2. CONNECTOR, COAXIAL BNC RECEPTACLE, ISOLATED PANEL MOUNT, KINS KC79-67 TYPE

Wire

- AWG number
- Conductor type
- Insulation type
- Voltage type
- Shielded wire type
- Color, if applicable

Examples and suggested format:

1. WIRE, 18AWG, STRANDED TINNED COPPER, SILICONE RUBBER, 60KV
2. CABLE, COAXIAL, RG213/U

Screws and Associated Hardware

- Screw type
- Size/thread
- Length
- Drive Type
- Material
- Plating

Examples and suggested format:

1. SCREW, MACHINE, HEX HEAD, M6 X 1-6G X 63.5MM [1/4-20UNC X 2 1/2"], STEEL, CAD PLATE
2. SCREW, WOOD, FLAT HEAD, SLOT DRIVE, 10 X 1", STEEL, HOT DIP ZINC

Metals

- Material
- Alloy
- Size and shape

Examples and suggested format:

1. ALUMINUM, 5052-H32, 3.15MMM [.125"] SHEET
2. ALUMINUM, 6061-T6, 76.2MM [3] X 76.2 [3] X 6.35 [1/4] ANGLE
3. STEEL, 1009 CR, 18 GA. SHEET

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Section 11. Identification Marking

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Section 12. Threads and Fasteners

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

12.1 Purpose

This section defines LLNL preferred drafting practices for specifying fastener threads and tapped holes on drawings.

12.2 Applicable Documents

- ANSI Y14.5M, "Dimensioning and Tolerancing"
- Oberg, Jones, and Horton, *Machinery's Handbook*, Industrial Press Inc., New York

12.3 Definitions

Fastener: A fastener is a mechanical device used for holding two or more objects together.

12.4 Threaded Fasteners

12.4.1 Machine Screws

There are many types of machine screws in use. The most commonly used types are illustrated in Figure 12-1.

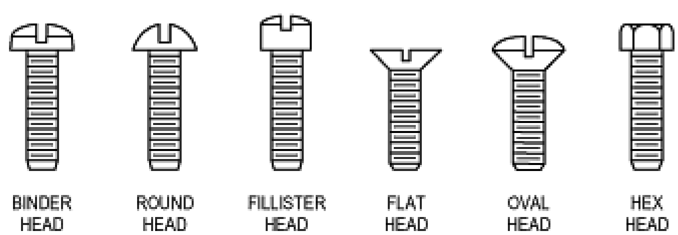


Figure 12-1. Machine screws

When using English screw threads, even-numbered thread sizes shall be used unless special circumstances warrant the use of an odd-numbered size.

Select clearance hole sizes using the clearance hole sizing tables in Section 26 of this manual, "Reference Data."

When holding parts together, clearance holes may be drilled through the parts to be fastened. The screw is then inserted through the holes. At least one-and-one-half threads should protrude beyond the nut when fully tightened (see Figure 12-2).

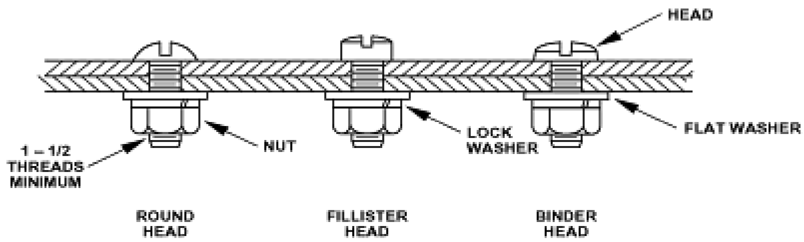


Figure 12-2. Typical screw fastener installations

Flat head and oval head screws are used where flush or semi-flush mounting is required. They are set into countersunk holes as shown in Figure 12-3. The height of the head should always be less than the thickness of the material whenever possible, and the countersink should not break through the lower surface of the material except when there are special design considerations. The countersink angle normally used should be 82 degrees in the case of English fasteners and 90 degrees in the case of metric fasteners.

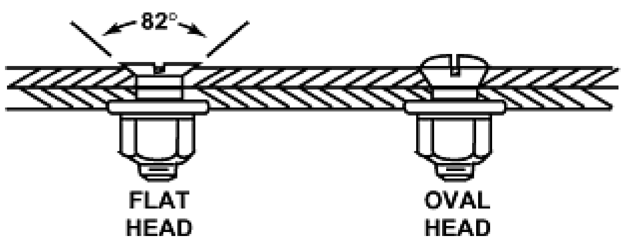


Figure 12-3. Countersunk screw fastener installations

12.4.2 Self-Tapping Screws

Self-tapping screws should not be used in place of machine screws for standard fabrication purposes.

12.5 Rivets

Rivets are used for the permanent fastening of sheet metal parts when a tight, permanent joint is required. A riveted joint is formed when a rivet is inserted through the aligned clearance holes of two or more plates and then compressed.

Many types of rivets are available, but only two types of standard rivets will be discussed in this section: the universal head (AN470AD) and the 100-degree countersink head (AN426AD) for flush mounting. Figure 12-4 shows these two types of rivets, and depicts the configuration of the rivets after they have been compressed.

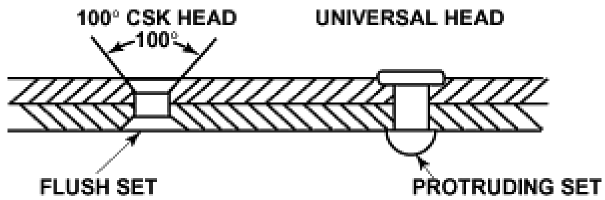


Figure 12-4. Typical rivet installations

These two types of standard rivets are made from type 2117 aluminum alloy. Subsection 12.6.18, “Standard Inch Rivet Sizes,” provides information for specifying the sizes of these two types of rivets. If a special type of rivet is required, the manufacturer’s catalog will provide adequate design information.

Subsection 12.6.19, “Standard Rivet Head Clearances,” provides information for determining the proper clearance of rivet heads from each other, from the edge of the sheet metal, and from bends; and for providing adequate working space for riveting tools.

12.6 Reference Data and Problem/Solutions

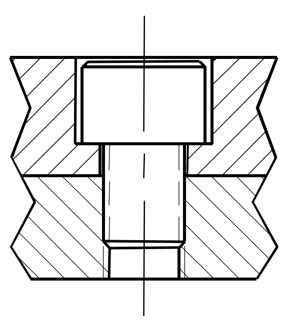
Reference data and Problem/Solution examples follow relating to threads and fasteners at LLNL.

12.6.1 Drill, Counterbore, & Positional Tolerances, Fixed (Metric)

Table 12-1. For metric flat countersunk head cap screws

<table>
<tr><th>Screw Size</th><th>Preferred Thread Pitch</th><th>Hole Clear Dia</th><th>Hole Clear Tol</th><th>Head Dia</th><th>CBore Dia</th><th>CBore Tol</th><th>CBore Depth</th><th>Depth Tol</th><th>Tol Dia Clearance Hole</th><th>Tol Dia Tapped Hole</th></tr>
<tr><td>M2</td><td>0.4</td><td>2.4</td><td>+0.12
-0.05</td><td>3.5</td><td>4</td><td rowspan="2">+0.18
-0.05</td><td>3</td><td rowspan="15">±0.75</td><td>0.16</td><td>0.24</td></tr>
<tr><td>M3</td><td>0.5</td><td>3.4</td><td>+0.14
-0.05</td><td>5.5</td><td>6</td><td>4</td><td>0.16</td><td>0.24</td></tr>
<tr><td>M4</td><td>0.7</td><td>4.5</td><td rowspan="2">+0.18
-0.05</td><td>7</td><td>8</td><td rowspan="3">+0.22
-0.05</td><td>5</td><td>0.2</td><td>0.3</td></tr>
<tr><td>M5</td><td>0.8</td><td>5.5</td><td>8.5</td><td>10</td><td>6</td><td>0.2</td><td>0.3</td></tr>
<tr><td>M6</td><td>1</td><td>6.6</td><td rowspan="2">+0.22
-0.05</td><td>10</td><td>11</td><td>7</td><td>0.24</td><td>0.36</td></tr>
<tr><td>M8</td><td>1.25</td><td>9</td><td>13</td><td>15</td><td rowspan="2">+0.27
-0.05</td><td>9</td><td>0.4</td><td>0.6</td></tr>
<tr><td>M10</td><td>1.5</td><td>11</td><td rowspan="3">+0.27
-0.05</td><td>16</td><td>18</td><td>11</td><td>0.4</td><td>0.6</td></tr>
<tr><td>M12</td><td>1.75</td><td>13.5</td><td>18</td><td>20</td><td rowspan="2">+0.33
-0.05</td><td>13</td><td>0.6</td><td>0.9</td></tr>
<tr><td>M16</td><td>2</td><td>17.5</td><td>24</td><td>26</td><td>17</td><td>0.6</td><td>0.9</td></tr>
<tr><td>M20</td><td>2.5</td><td>22</td><td rowspan="2">+0.33
-0.05</td><td>30</td><td>33</td><td rowspan="3">+0.39
-0.05</td><td>21</td><td>0.8</td><td>1.2</td></tr>
<tr><td>M24</td><td>3</td><td>26</td><td>36</td><td>40</td><td>25</td><td>0.8</td><td>1.2</td></tr>
<tr><td>M30</td><td>3.5</td><td>33</td><td rowspan="2">+0.39
-0.05</td><td>45</td><td>48</td><td>31</td><td>1.2</td><td>1.8</td></tr>
<tr><td>M42</td><td>4.5</td><td>45</td><td>63</td><td>66</td><td rowspan="2">+0.46
-0.05</td><td>43</td><td>1.2</td><td>1.8</td></tr>
<tr><td>M48</td><td>5</td><td>52</td><td>+0.48
-0.05</td><td>72</td><td>75</td><td>49</td><td>1.6</td><td>2.4</td></tr>
</table>

* The above depth and tolerance dimensions provide a recessed head clearance of at least 0.25.
** Use MMC for clearance hole positional tolerances.



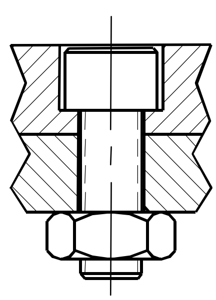
Fixed fastener

12.6.2 Drill, Counterbore, & Positional Tolerances, Floating (Metric)

Table 12-2. For metric countersunk head cap screws

Screw Size	Preferred Thread Pitch	Hole Clear Dia	Hole Clear Tol	Head Dia	CBore Dia	CBore Tol	CBore Depth	Depth Tol	Tol Dia Clearance Hole
M2	0.4	2.4	+0.12 -0.05	3.5	4	+0.18 -0.05	3	±0.75	0.4
M3	0.5	3.4	+0.14 -0.05	5.5	6		4		0.4
M4	0.7	4.5	+0.18 -0.05	7	8	+0.22 -0.05	5		0.5
M5	0.8	5.5		8.5	10		6		0.5
M6	1	6.6	+0.22 -0.05	10	11		7		0.6
M8	1.25	9		13	15	+0.27 -0.05	9		1
M10	1.5	11	+0.27 -0.05	16	18		11		1
M12	1.75	13.5		18	20	+0.33 -0.05	13		1.5
M16	2	17.5		24	26		17		1.5
M20	2.5	22	+0.33 -0.05	30	33	+0.39 -0.05	21		2
M24	3	26		36	40		25		2
M30	3.5	33	+0.39 -0.05	45	48		31		3
M42	4.5	45		63	66	+0.46 -0.05	43		3
M48	5	52	+0.48 -0.05	72	75		49		4

* The above depth and tolerance dimensions provide a recessed head clearance of at least 0.25.
** Use MMC for clearance hole positional tolerances.



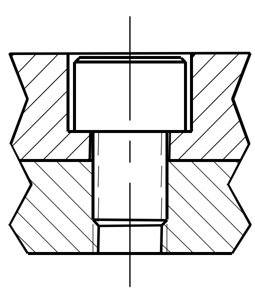
Floating fastener

12.6.3 Drill, Counterbore, & Positional Tolerances, Fixed (Inch)

Table 12-3. For American standard hexagon and spline socket head cap screws

<table>
<tr><th>Screw Size</th><th>Body Dia</th><th>Hole Clear Dia</th><th>Hole Clear Tol</th><th>Head Dia</th><th>CBore Dia*</th><th>CBore Tol</th><th>CBore Depth</th><th>Depth Tol</th><th>Tol Dia Clearance Hole**</th><th>Tol Dia Tapped Hole</th></tr>
<tr><td>**0**</td><td>.060</td><td>.073</td><td rowspan="4">+.006
-.002</td><td>.096</td><td>.133</td><td rowspan="4">+.015
-.002</td><td>.100</td><td rowspan="18">±.030</td><td>.004</td><td>.006</td></tr>
<tr><td>**1**</td><td>.073</td><td>.089</td><td>.118</td><td>.155</td><td>.113</td><td>.006</td><td>.008</td></tr>
<tr><td>**2**</td><td>.086</td><td>.106</td><td>.140</td><td>.176</td><td>.126</td><td>.007</td><td>.011</td></tr>
<tr><td>**3**</td><td>.099</td><td>.120</td><td>.161</td><td>.188</td><td>.139</td><td>.007</td><td>.011</td></tr>
<tr><td>**4**</td><td>.112</td><td>.136</td><td rowspan="4">+.010
-.002</td><td>.183</td><td>.219</td><td rowspan="4">+.020
-.002</td><td>.152</td><td>.009</td><td>.013</td></tr>
<tr><td>**5**</td><td>.125</td><td>.154</td><td>.205</td><td>.250</td><td>.165</td><td>.010</td><td>.016</td></tr>
<tr><td>**6**</td><td>.138</td><td>.170</td><td>.226</td><td>.266</td><td>.178</td><td>.012</td><td>.018</td></tr>
<tr><td>**8**</td><td>.164</td><td>.194</td><td>.270</td><td>.312</td><td>.204</td><td>.011</td><td>.017</td></tr>
<tr><td>**10**</td><td>.190</td><td>.219</td><td rowspan="5">+.015
-.002</td><td>.312</td><td>.344</td><td rowspan="5">+.030
-.002</td><td>.230</td><td>.010</td><td>.016</td></tr>
<tr><td>**1/4**</td><td>.250</td><td>.281</td><td>.375</td><td>.406</td><td>.290</td><td>.011</td><td>.017</td></tr>
<tr><td>**5/16**</td><td>.312</td><td>.344</td><td>.469</td><td>.500</td><td>.352</td><td>.010</td><td>.016</td></tr>
<tr><td>**3/8**</td><td>.375</td><td>.406</td><td>.562</td><td>.594</td><td>.415</td><td>.011</td><td>.017</td></tr>
<tr><td>**7/16**</td><td>.438</td><td>.469</td><td>.656</td><td>.688</td><td>.478</td><td>.011</td><td>.017</td></tr>
<tr><td>**1/2**</td><td>.500</td><td>.531</td><td rowspan="3">+.030
-.002</td><td>.750</td><td>.781</td><td rowspan="3">+.060
-.002</td><td>.540</td><td>.011</td><td>.017</td></tr>
<tr><td>**5/8**</td><td>.625</td><td>.688</td><td>.938</td><td>1.000</td><td>.665</td><td>.024</td><td>.036</td></tr>
<tr><td>**3/4**</td><td>.750</td><td>.812</td><td>1.125</td><td>1.188</td><td>.790</td><td>.024</td><td>.036</td></tr>
<tr><td>**7/8**</td><td>.875</td><td>.938</td><td rowspan="2">+.060
-.002</td><td>1.312</td><td>1.375</td><td rowspan="2">+.090
-.002</td><td>.915</td><td>.024</td><td>.036</td></tr>
<tr><td>**1**</td><td>1.000</td><td>1.062</td><td>1.500</td><td>1.625</td><td>1.040</td><td>.024</td><td>.036</td></tr>
</table>

* The above depth and tolerance dimensions provide recessed head clearance of at least .010.
** Use MMC for clearance hole positional tolerances.



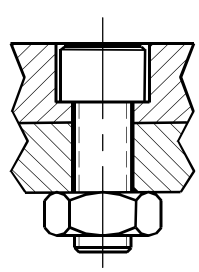
Fixed fastener

12.6.4 Drill, Counterbore, & Positional Tolerances, Floating (Inch)

Table 12-4. For American national standard hexagon and spline socket flat countersunk head cap screws

Screw Size	Body Dia	Hole Clear Dia	Hole Clear Tol	Head Dia	CBore Dia*	CBore Tol	CBore Depth	Depth Tol	Tol Dia Clearance Hole**
0	.060	.073	+.006 -.002	.096	.133	+.015 -.002	.100	±.030	.004
1	.073	.089		.118	.155		.113		.006
2	.086	.106		.140	.176		.126		.007
3	.099	.120		.161	.188		.139		.007
4	.112	.136	+.010 -.002	.183	.219	+.020 -.002	.152		.009
5	.125	.154		.205	.250		.165		.010
6	.138	.170		.226	.266		.178		.012
8	.164	.194		.270	.312		.204		.011
10	.190	.219	+.015 -.002	.312	.344	+.030 -.002	.230		.010
1/4	.250	.281		.375	.406		.290		.011
5/16	.312	.344		.469	.500		.352		.010
3/8	.375	.406		.562	.594		.415		.011
7/16	.438	.469		.656	.688		.478		.011
1/2	.500	.531	+.030 -.002	.750	.781	+.060 -.002	.540		.011
5/8	.625	.688		.938	1.000		.665		.024
3/4	.750	.812		1.125	1.188		.790		.024
7/8	.875	.938	+.060 -.002	1.312	1.375	+.090 -.002	.915		.024
1	1.000	1.062		1.500	1.625		1.040		.024

* The above depth and tolerance dimensions provide recessed head clearance of at least .010.
** Use MMC for clearance hole positional tolerances.



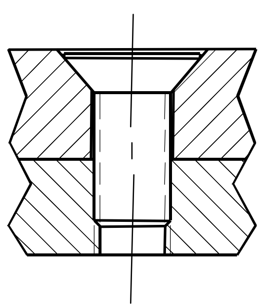
Floating fastener

12.6.5 Drill, Countersink, & Positional Tolerances, Fixed (Metric)

Table 12-5. For metric flat countersunk head cap screws

Screw Size	Preferred Thread Pitch	Hole Clear Dia	Hole Clear Tol	Head Dia	CSink Dia	CSink Tol	CSink Angle	Angle Tol	Tol Dia Clearance Hole	Tol Dia Tapped Hole
M2	0.4	2.4	+0.12 -0.05	4	4.6	±0.15	90°	±2°	0.16	0.24
M3	0.5	3.4	+0.14 -0.05	6	6.6				0.16	0.24
M4	0.7	4.5	+0.18 -0.05	8	8.8	±0.25			0.2	0.3
M5	0.8	5.5		10	10.8				0.2	0.3
M6	1	6.6	+0.22 -0.05	12	13	±0.35			0.24	0.36
M8	1.25	9		16	17.5	±0.45			0.4	0.6
M10	1.5	11	+0.27 -0.05	20	21.5				0.4	0.6
M12	1.75	13.5		24	26				0.6	0.9
M16	2	17.5		32	34				0.6	0.9
M20	2.5	22	+0.33 -0.05	40	43	±1			0.8	1.2
M24	3	26		48	51				0.8	1.2
M30	3.5	33	+0.39 -0.05	60	64				1.2	1.8
M42	4.5	45		84	88				1.2	1.8
M48	5	52	+0.48 -0.05	96	101				1.6	2.4

* The above depth and tolerance dimensions provide a flush to recessed head clearance.
** Use MMC for clearance hole positional tolerances.



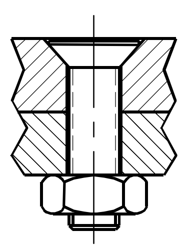
Fixed fastener

12.6.6 Drill, Countersink, & Positional Tolerances, Floating (Metric)

Table 12-6. For American national standard hexagon and spline socket flat countersunk head cap screws

Screw Size	Preferred Thread Pitch	Hole Clear Dia	Hole Clear Tol	Head Dia	CSink Dia	CSink Tol	CSink Angle	Angle Tol	Tol Dia Clearance Hole
M2	0.4	2.4	+0.12 -0.05	4	4.6	±0.15	90°	±2°	0.4
M3	0.5	3.4	+0.14 -0.05	6	6.6				0.4
M4	0.7	4.5	+0.18 -0.05	8	8.8	±0.25			0.5
M5	0.8	5.5		10	10.8				0.5
M6	1	6.6	+0.22 -0.05	12	13	±0.35			0.6
M8	1.25	9		16	17.5	±0.45			1
M10	1.5	11	+0.27 -0.05	20	21.5				1
M12	1.75	13.5		24	26				1.5
M16	2	17.5		32	34				1.5
M20	2.5	22	+0.33 -0.05	40	43	±1			2
M24	3	26		48	51				2
M30	3.5	33	+0.39 -0.05	60	64				3
M42	4.5	45		84	88				3
M48	5	52	+0.48 -0.05	96	101				4

* The above depth and tolerance dimensions provide a flush to recessed head clearance.
** Use MMC for clearance hole positional tolerances.



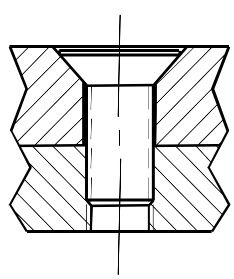
Floating fastener

12.6.7 Drill, Countersink, & Positional Tolerances, Fixed (Inch)

Table 12-7. For American national standard hexagon and spline socket flat countersunk head cap screws

Screw Size	Body Dia	Hole Clear Dia	Hole Clear Tol	Head Dia	CSink Dia*	CSink Tol	CSink Angle	Angle Tol	Tol Dia Clearance Hole**	Tol Dia Tapped Hole
0	.060	.073	+.006 -.002	.138	.160	±.006	82°	±2°	.004	.006
1	.073	.089		.168	.193				.006	.008
2	.086	.106		.197	.226				.007	.011
3	.099	.120		.226	.256				.007	.011
4	.112	.136	+.010 -.002	.255	.292	±.010			.009	.013
5	.125	.154		.281	.323				.010	.016
6	.138	.170		.307	.352				.012	.018
8	.164	.194		.359	.402				.011	.017
10	.190	.219	+.015 -.002	.411	.465	±.020			.010	.016
1/4	.250	.281		.531	.585				.011	.017
5/16	.312	.344		.656	.710				.010	.016
3/8	.375	.406		.781	.835				.011	.017
7/16	.438	.469		.844	.898				.011	.017
1/2	.500	.531	+.030 -.002	.938	1.000	±.030			.011	.017
5/8	.625	.688		1.188	1.281				.024	.036
3/4	.750	.812		1.438	1.531				.024	.036
7/8	.875	.938	+.060 -.002	1.688	1.813	±.060			.024	.036
1	1.000	1.062		1.938	2.063				.024	.036

* The above depth and tolerance dimensions provide a flush to recessed head clearance.
** Use MMC for clearance hole positional tolerances.



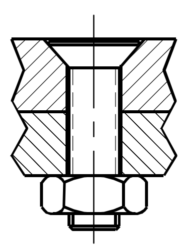
Fixed fastener

12.6.8 Drill, Countersink, & Positional Tolerances, Floating (Inch)

Table 12-8. For American national standard hexagon and spline socket flat countersunk head cap screws

Screw Size	Body Dia	Hole Clear Dia	Hole Clear Tol	Head Dia	CSink Dia*	CSink Tol	CSink Angle	Angle Tol	Tol Dia Clearance Hole**
0	.060	.073	+.006 -.002	.138	.160	±.006	82°	±2°	.010
1	.073	.089		.168	.193				.014
2	.086	.106		.197	.226				.018
3	.099	.120		.226	.256				.018
4	.112	.136	+.010 -.002	.255	.292	±.010			.022
5	.125	.154		.281	.323				.026
6	.138	.170		.307	.352				.030
8	.164	.194		.359	.402				.028
10	.190	.219	+.015 -.002	.411	.465	±.020			.026
1/4	.250	.281		.531	.585				.028
5/16	.312	.344		.656	.710				.026
3/8	.375	.406		.781	.835				.027
7/16	.438	.469		.844	.898				.028
1/2	.500	.531	+.030 -.002	.938	1.000	±.030			.028
5/8	.625	.688		1.188	1.281				.060
3/4	.750	.812		1.438	1.531				.060
7/8	.875	.938	+.060 -.002	1.688	1.813	±.060			.060
1	1.000	1.062		1.938	2.063				.060

* The above depth and tolerance dimensions provide a flush to recessed head clearance.
** Use MMC for clearance hole positional tolerances.

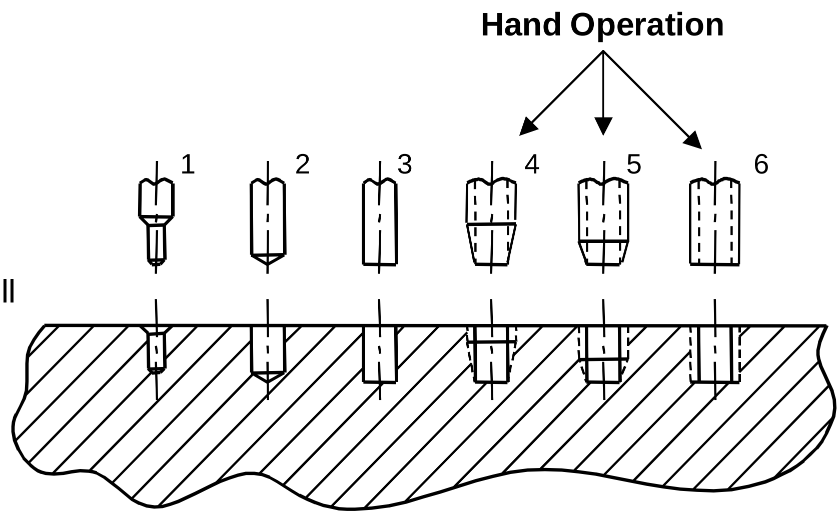


Floating fastener

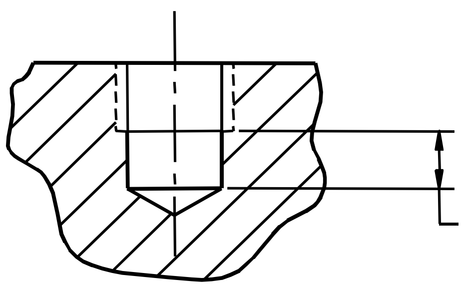
12.6.9 Tapped Holes (M10 and Smaller)

The Problem: Flat bottom tapped holes require many time-consuming steps to fabricate.

Steps Required:
1. Center drill
2. Tap drill
3. Flat Bottom Drill
4. Taper Tap
5. Plug End Tap
6. Bottom Tap



The Solution: If the design permits, the drill depth should be deeper than the thread depth. This provides chip clearance and speeds up the fabrication, as it only requires steps 1, 2, and 4 shown above.

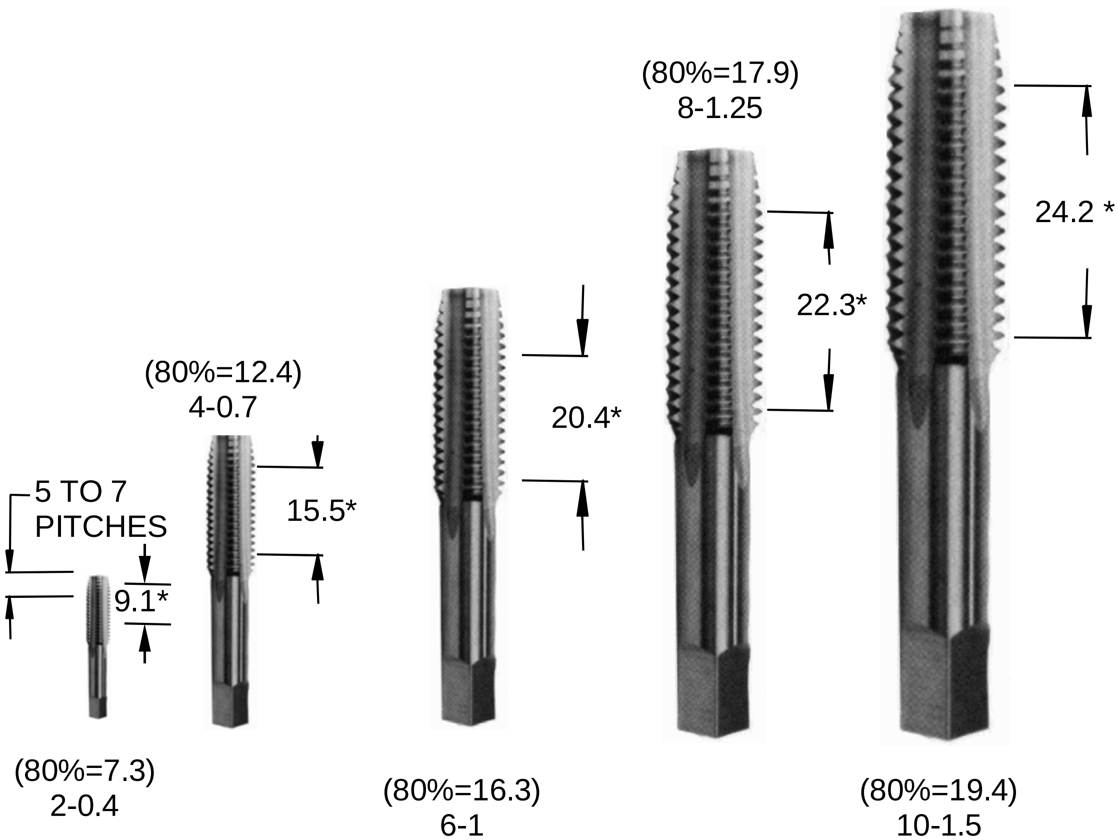


INCH:
MIN. 6P NUMBERED SIZES
MIN. 5P FRATIONAL SIZES

METRIC:
MIN. 6P FOR M1.6 TO M6
MIN. 5P FOR M8 AND LARGER

The Problem: Excessive depth of a tapped hole requires special tooling.

The Solution: Do not tap a hole deeper than 80% of the full thread length of a standard tap unless it cannot be avoided.

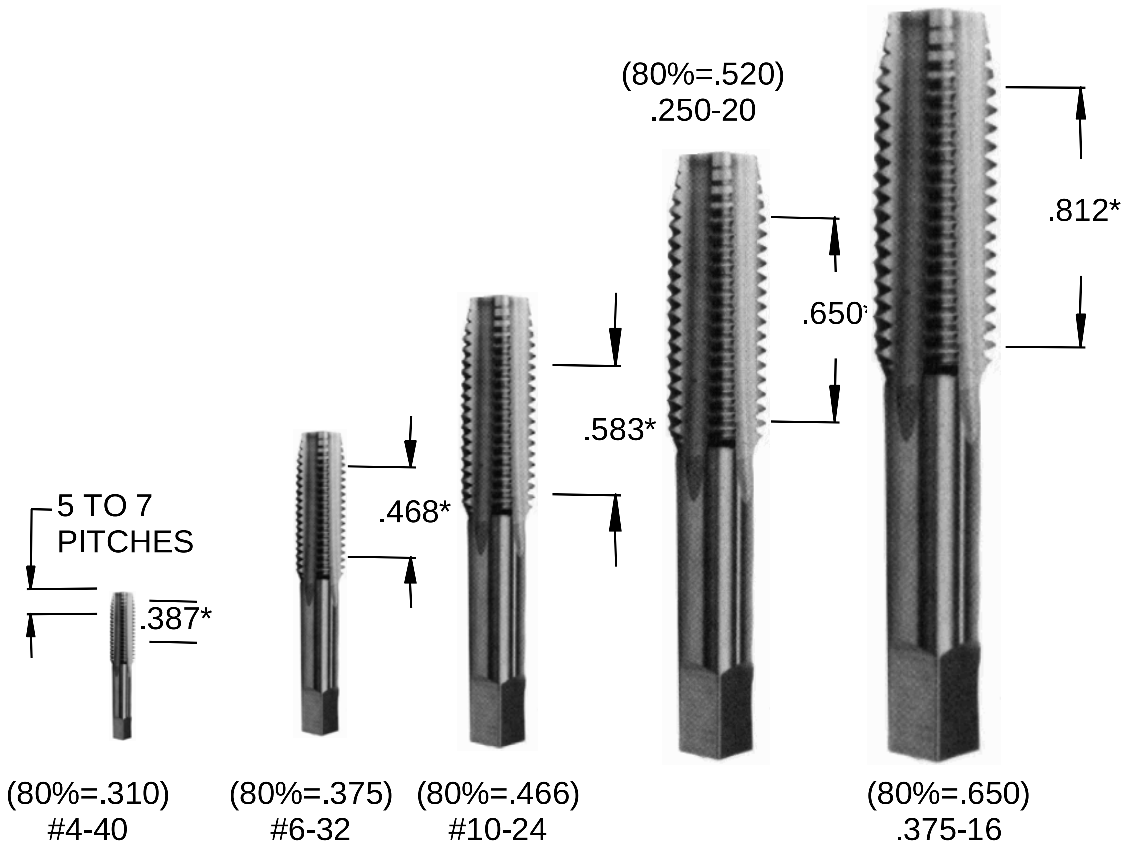


***FULL LENGTH OF THREAD**

12.6.10 Tapped Holes (.375 Inch and Smaller)

The Problem: Excessive depth of a tapped hole requires special tooling.

The Solution: Do not tap a hole deeper than 80% of the full thread length of a standard tap unless it cannot be avoided.

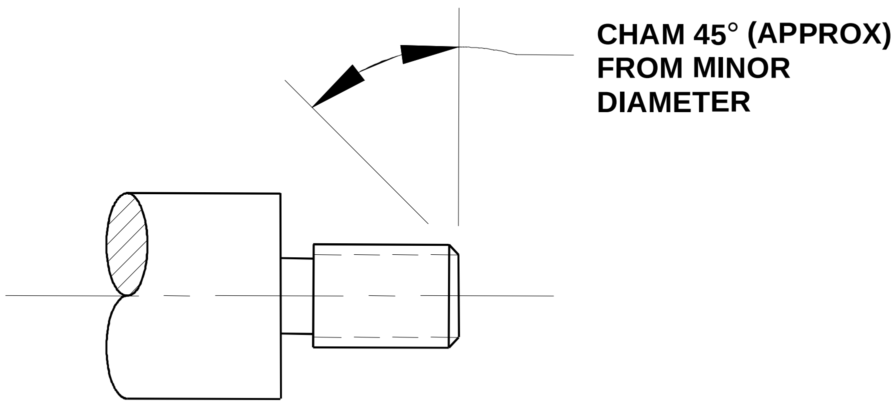


***FULL LENGTH OF THREAD**

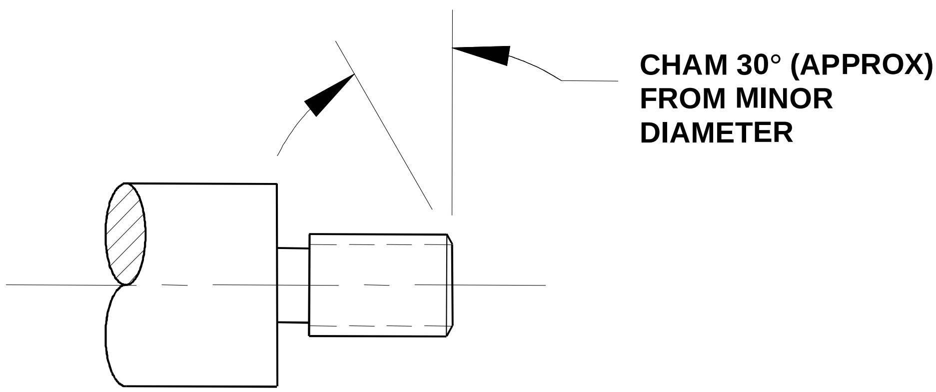
INCH

12.6.11 Threaded Chamfer

The Problem: A 45° chamfer on machined threads requires special tool setup, costing extra time and money.



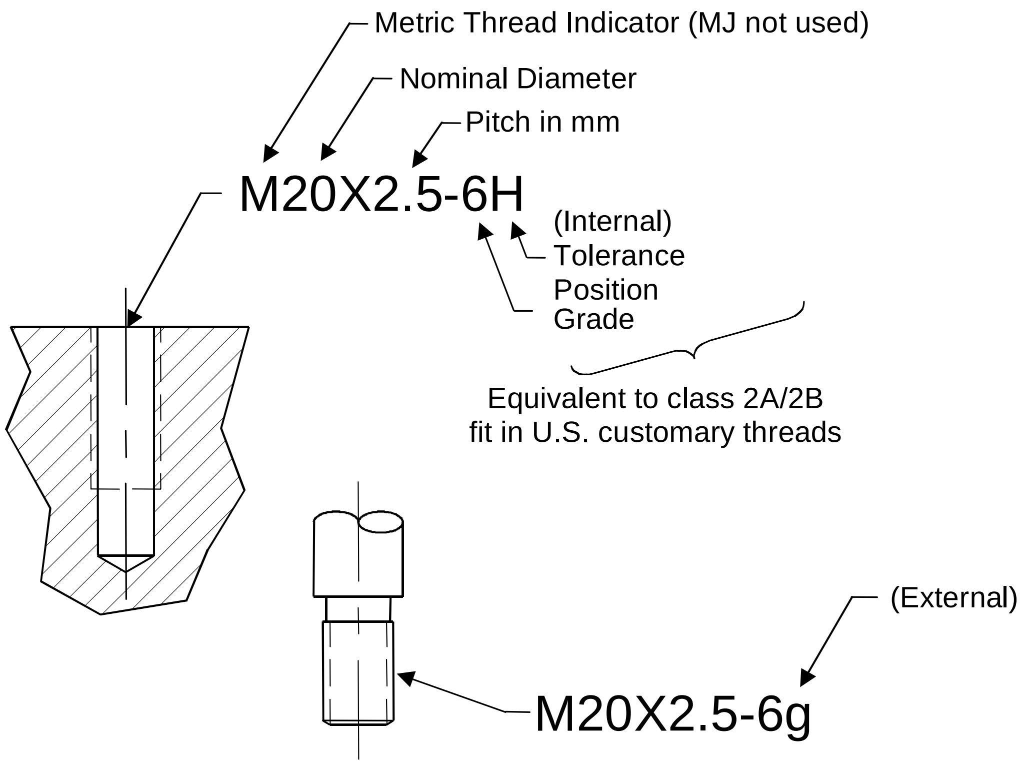
The Solution: A 30° chamfer allows the machinist to use the same tool setup that cut the threads.



12.6.12 Screw Thread Specification – Metric Series

The Problem: How should metric series screw threads (M, MJ) be specified?

The Solution:



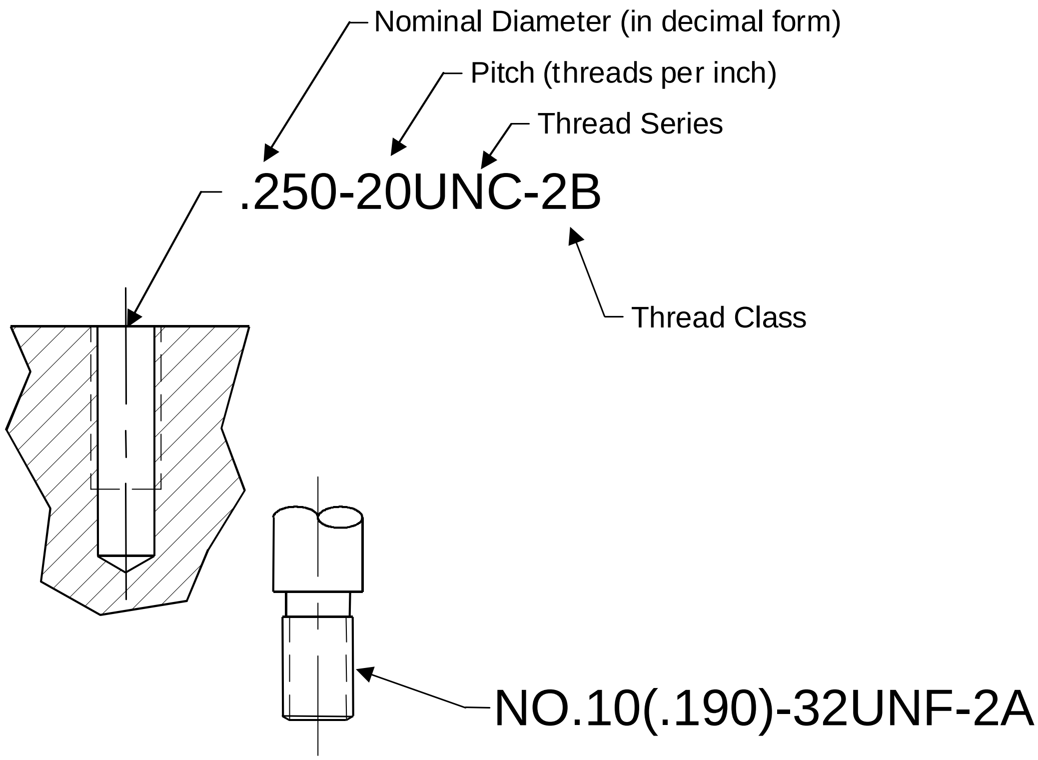
Grades	Description
3	
4	Tighter than average tolerance
5	
6	Medium quality, nominal lengths
7	
8	Looser than average tolerance
9	

Position Tolerances		Description
External	Internal	
E	E	Large allowance
g	G	Small allowance
h	H	No allowance

12.6.13 Screw Thread Specification – Inch Series

The Problem: How should inch series screw threads be specified?

The Solution: ANSI Y14.6-1978 recommends that screw threads be specified by decimals. ANSI Y14.6-1978 is the reference standard listed in ASME Y14.5M-1994.



Thread Series	Description
UNC	Coarse thread series
UNF	Fine thread series
UNEF	Extra-fine thread series
UN	Constant pitch series
UNS	Special threads

Thread Class		Description
External	Internal	
1A	1B	Large clearance between mating threads
2A	2B	Nominal clearance between mating threads
3A	3B	Little clearance between mating threads

Note: For left-hand threads, the symbol LH is to be placed after the thread class call-out (i.e., NO.8(.164)32UNC-2A-LH)

12.6.14 Inch Series Thread Call Out

The Problem: How should an inch series thread on a drawing be called out?

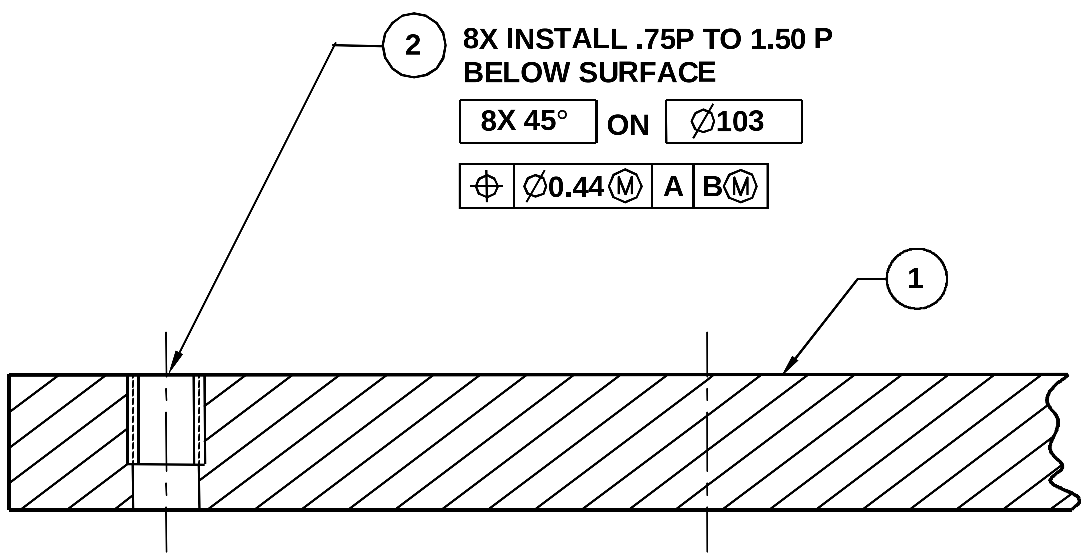
The Solution:

Type of Drawing	Numbered Thread	Fractional Thread
Metric Drawing	[NO.10(.190") –32UNF-2B]	[.250"-20UNC-2B]
Inch Drawing	NO.10(190)-32UNF-2B	.250-20UNC-2B

12.6.15 Threaded Insert Call Out

The Problem: What is the preferred threaded insert call out?

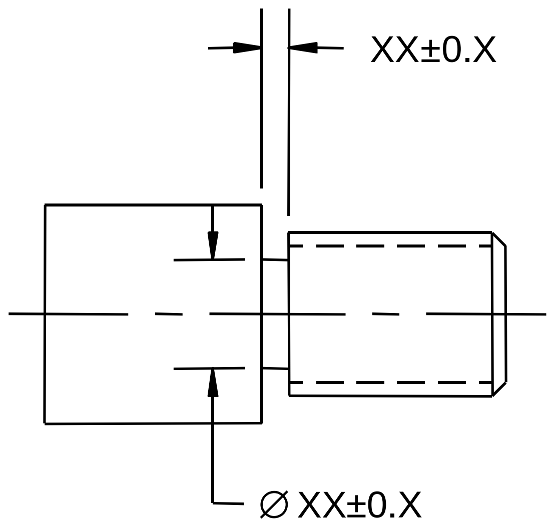
The Solution:



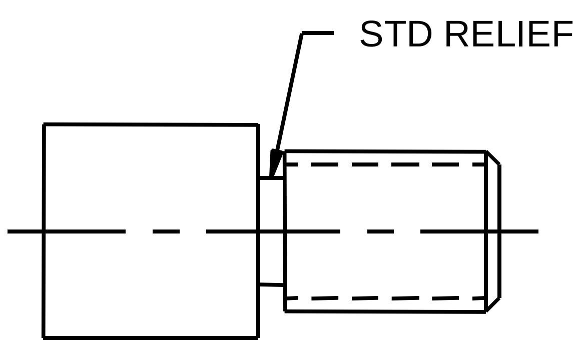
		8		INSERT, THREADED, [.250"-20UNC-2B] X .5 L SST	2500-4AB0500	2
		1		PLATE, 19mm THK	Al 6061-T6	1
QTY REQD			PART OR IDENTIFYING NO.	NONINCLATURE OR DESCRIPTION	MATERIAL OR SPECIFICATION	ITEM NO.

12.6.16 Threaded Relief Specification

The Problem: When a thread relief is dimensioned, it requires inspection.

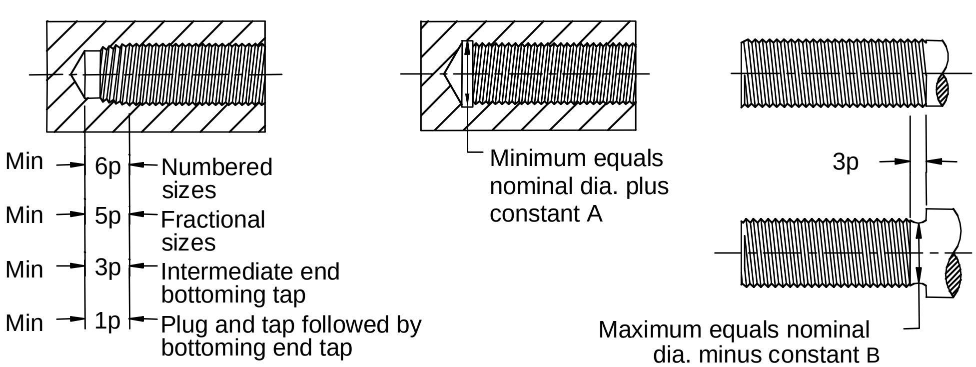


The Solution: If your design will allow a standard relief, just show the graphics without dimensions. For standard thread relief, see subsection 12.6.17, "Standard Thread Relief."



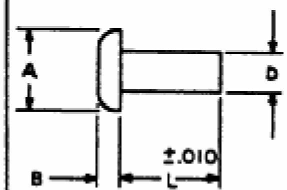
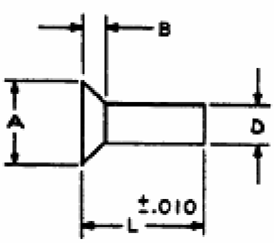
12.6.17 Standard Thread Relief

Threads per inch	Length of relief or allowance beyond full form threads — Pitch Interval							Relief Constant	
	1p	1_p	2p	2_p	3p	5p	6p	Internal A	External B
80	.012	.019	.025	.031	.038	.062	.075	.0052	.0196
72	.014	.021	.028	.035	.042	.069	.083	.0056	.0216
64	.016	.023	.031	.039	.047	.078	.094	.0058	.0241
56	.018	.027	.036	.045	.054	.089	.107	.0066	.0272
48	.021	.031	.042	.052	.062	.104	.125	.0074	.0315
44	.023	.034	.045	.057	.068	.114	.136	.0078	.0341
40	.025	.038	.050	.062	.075	.125	.150	.0084	.0373
36	.028	.042	.056	.069	.083	.139	.167	.0090	.0411
32	.031	.047	.062	.078	.094	.156	.188	.0099	.0460
28	.036	.054	.071	.089	.107	.179	.214	.0114	.0526
24	.042	.062	.083	.104	.125	.208	.250	.0126	.0607
20	.050	.075	.100	.125	.150	.250	.300	.0144	.0722
18	.056	.083	.111	.139	.167	.278	.333	.0162	.0814
16	.062	.094	.125	.156	.188	.312	.375	.0180	.0902
14	.071	.107	.143	.179	.214	.357	.429	.0201	.1026
13	.077	.115	.154	.192	.231	.385	.462	.0215	.1103
12	.083	.125	.167	.208	.250	.417	.500	.0232	.1195
11	.091	.136	.182	.227	.273	.455	.545	.0249	.1299
10	.100	.150	.200	.250	.300	.500	.600	.0272	.1427
9	.111	.167	.222	.278	.333	.556	.667	.0300	.1583
8	.125	.188	.250	.312	.375	.625	.750	.0332	.1776
7	.143	.214	.286	.357	.429	.714	.857	.0376	.2026
6	.167	.250	.333	.417	.500	.833	1.000	.0442	.2367
5	.200	.300	.400	.500	.600	1.000	1.200	.0521	.2830
4 ½	.222	.333	.444	.556	.667	1.111	1.333	.0575	.3141
4	.250	.375	.500	.625	.750	1.250	1.500	.0641	.3528



Extracted from American Standard Drafting Manual, Screw Threads (ANSI Y14.6-1978), with the permissions of the publisher, the American Society of Mechanical Engineers, 29 West 39th Street, New York 18, N.Y.

12.6.18 Standard Inch Rivet Sizes

Rivet Type	Material	D Dia.	A Dia.	B
		.062 +.003 -.001	.125 ±.006	.027 +.010 -.000
UNIVERSAL HEAD AN470AD		.094 +.003 -.001	.187 ±.009	.040 +.010 -.000
		.125 +.003 -.001	.250 ±.012	.054 +.010 -.000
		.156 +.004 -.001	.312 ±.016	.067 +.010 -.000
	2117 AL.	.187 +.004 -.001	.375 ±.019	.080 +.010 -.000
		.062 +.003 -.001	.114 ±.004	.022 (Ref)
100° CSK. HEAD AN426AD		.094 +.003 -.001	.179 ±.004	.036 (Ref)
		.125 +.003 -.001	.225 ±.004	.042 (Ref)
		.156 +.003 -.001	.286 ±.004	.055 (Ref)
		.187 +.003 -.001	.353 ±.004	.070 (Ref)

Rivet Dia.	Length (L) and Dash Numbers								
	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8
1/16	2-2	2-3	2-4	2-5	2-6	2-7	2-8	2-9	2-10
3/32		3-3	3-4	3-5	3-6	3-7	3-8	3-9	3-10
1/8		4-3	4-4	4-5	4-6	4-7	4-8	4-9	4-10
5/32			5-4	5-5	5-6	5-7	5-8	5-9	5-10
3/16				6-5	6-6	6-7	6-8	6-9	6-10

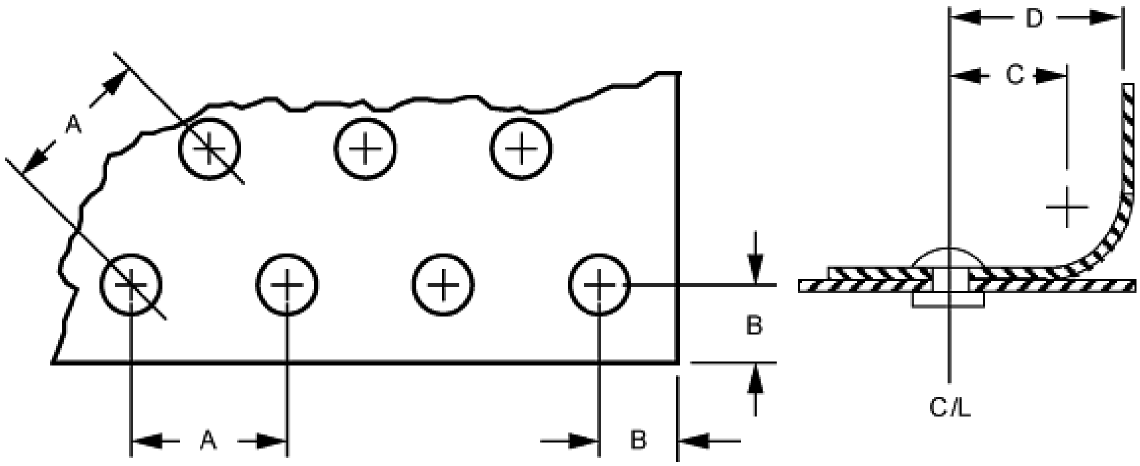
Example: AN470AD 3-5

- AN470AD — Universal Head 2117 Aluminum Rivet
- 3 — 3/32 Rivet Dia.
- 5 — 5/16 Rivet Length

12.6.19 Standard Rivet Head Clearances

The Problem: What clearance should be used for rivet heads when placing rivets?

The Solution: Use the following references to locate rivets.



Rivet Head Clearances

Rivet Diameter (Inches)	Minimum Rivet Pitch (mm)	Minimum Edge Distance (mm)	Minimum Distance From Bend Radius (mm)	Minimum Tool Clearance (mm)
	A	**B**	**C**	**D**
1/16	4.75	3.20	3.20	7.90
3/32	7.15	4.75	4.00	7.90
1/8	9.55	6.35	4.75	7.90
5/32	11.90	7.95	5.60	7.90
3/16	14.30	9.55	6.35	9.55

Locate rivets to accommodate “D” unless the sum of “C” and the bend radius is greater than the minimum tool clearance.

Section 13. Surface Finish

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

13.1 Purpose

This section defines LLNL preferred drafting practices for specifying surface finishes on drawings.

13.2 Applicable Documents

- ANSI/ASME B46.1-2002, "Surface Texture (Surface Roughness, Waviness, and Lay)"
- ANSI/ASME Y14.36M-1996, "Surface Texture Symbols"

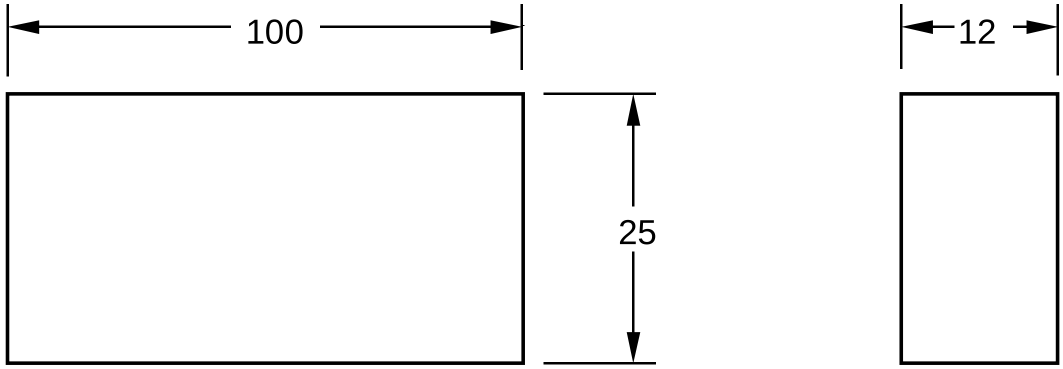
13.3 Problem/Solution Examples

Potential problems and their recommended solutions relating to surface finish practices at LLNL follow.

13.3.1 Surface Finish versus Machining Time

The Problem: Over-specifying a finish on a part will lead to increased fabrication time and increased part cost.

The table below shows the time required to produce the surface finishes on the illustrated part. The material used in this example is steel. (**Note:** It is assumed that all surfaces are finished.)



Surface Finish		Machining Time	Ratio
Inch	Metric		
250	6.3	10 min.	1:1
125	3.2	30 min.	3:1
63	1.6	40 min.	4:1
32	0.8	1 hr. 10 min.	7:1
16	0.4	1 hr. 30 min.	9:1
8	0.2	3 hrs. 30 min.	21:1
4	0.1	6 hrs. 45 min.	40:1
2	0.05	7 hrs. 30 min.	45:1

The Solution: When specifying surface finish on a drawing, give the largest value the design will allow.

13.3.2 Converting Surface Finish from Inch to Metric

The Problem: What are the conversions of inch-based surface finishes to metric?

The Solution: Surface finish units are micrometers and microinches.

Surface Finish	
Inch	**Metric**
500	12.5
250	6.3
125	3.2
63	1.6
32	0.8
16	0.4
8	0.2
4	0.1
2	0.05

13.3.3 Expected Surface Finish for Various Processes

The Problem: What surface finishes can reasonably be expected from various machine processes?

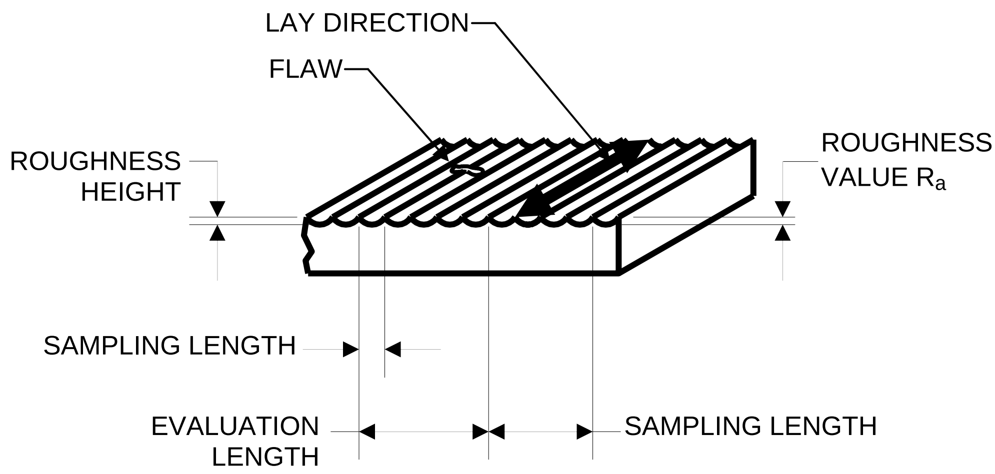
The Solution: The chart below gives surface finishes that can reasonably be expected from various machine processes.

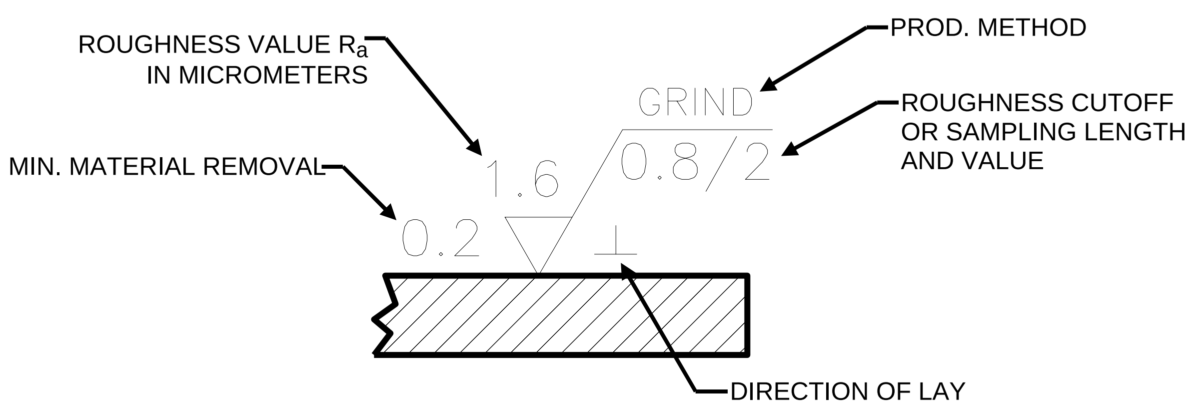
Machine Process	Expected Surface Finish Metric
Flame Cutting	12.5
Sand Casting	12.5
Hot Rolling	12.5
Sawing	3.2
Forging	3.2
Drilling	1.6
Chemical Milling	1.6
Conventional Milling	0.8
Broaching	0.8
Reaming	0.8
Extruding	0.8
Boring, Turning	0.4
Barrel Finishing	0.2
Grinding	0.1
Honing	0.1
Electropolish	0.1
Polishing	0.1
Lapping	0.05

13.3.4 Relation of Symbols to Surface Characteristics

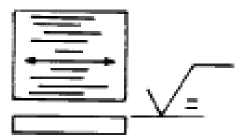
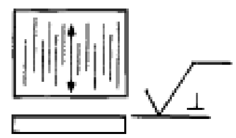
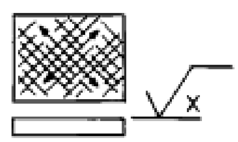
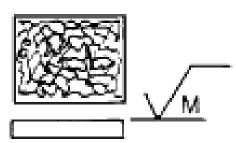
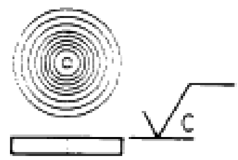
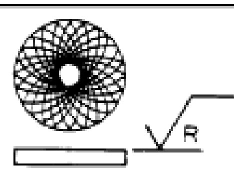
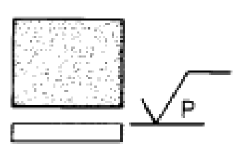
The Problem: What is the relation of symbols to surface characteristics?

The Solution: The following illustration is referenced from ASME B46.1 and ASME Y14.36M.





13.4 Terms and Symbols

Lay symbol	Interpretation	Example showing direction of tool marks
=	Lay parallel to the line representing the surface to which the symbol is applied	
⊥	Lay perpendicular to the line representing the surface to which the symbol is applied	
X	Lay angular in both directions to line representing the surface to which symbol is applied	
M	Lay multidirectional	
C	Lay approximately circular relative to the center of the surface to which the symbol is applied	
R	Lay approximately radial relative to the center of the surface to which the symbol is applied	
P	Pitted, protuberant, porous, or particulate nondirectional lay	

Section 14. Welding Data

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

14.1 Purpose

This section establishes practices and procedures to be followed in the application of standard welding symbols on engineering drawings. Standard welding symbols should be used until familiarity with metric welding symbology can be achieved.

14.2 Applicable Documents

- ANSI Y32.3, "Graphic Symbols for Welding"
- Oberg, Jones, and Horton, *Machinery's Handbook*, Industrial Press Inc., New York

14.3 Welding Symbol Description

The welding symbol indicates the type of weld, location, finish (if required), and any supplemental operations required for a complete welding process. It consists of the following items: reference line, arrowhead, basic weld symbol, dimensions, supplementary symbols, finish symbols, a tail, and reference data.

14.4 General Requirements for Symbols and Notes

Welding symbols should be used to describe the location, size, and type of weld required for joining two or more parts together.

When practical, general notes may be placed on a drawing specifying the necessary data required for the welds. A fillet weld will normally be the same size as the thickness of the smaller of the two parts to be joined.

Finishing of welds, other than cleaning operations, should be indicated by suitable contour and finish symbols.

When the basic weld symbols are inadequate to indicate the desired weld, the weld should be shown by a section or detail view, and a reference to the view should be placed on the welding symbol.

14.5 Significance of Arrow Location

When a joint is depicted by a single line on the drawing, and the arrow is directed to this line, the arrow side of the joint shall be considered the near side.

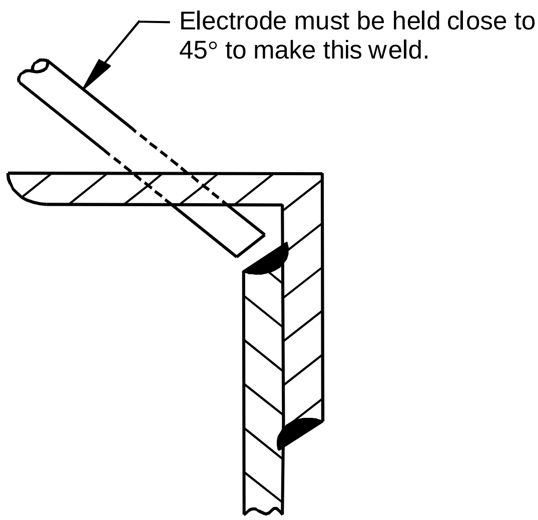
When a joint is depicted as an area parallel to the plane of a projection on the drawing, and the arrow is directed to that area, the arrow-side member of the joint shall be considered the near member of the joint.

14.6 Problem/Solution Examples

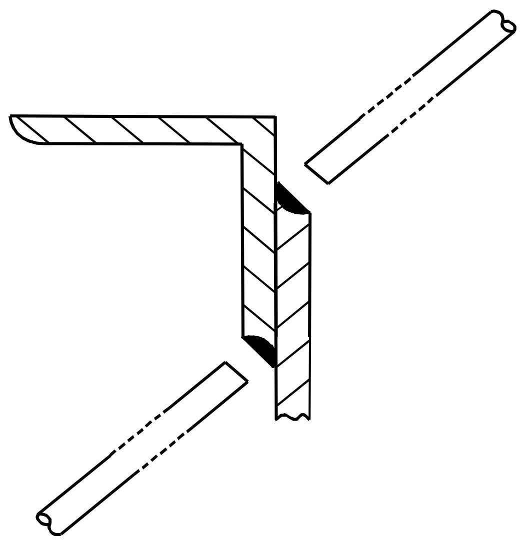
Potential problems and their preferred design solutions relative to welding shop practice at LLNL follow.

14.6.1 Inaccessible Welds

The Problem: Inaccessible weld joint designs must be avoided.



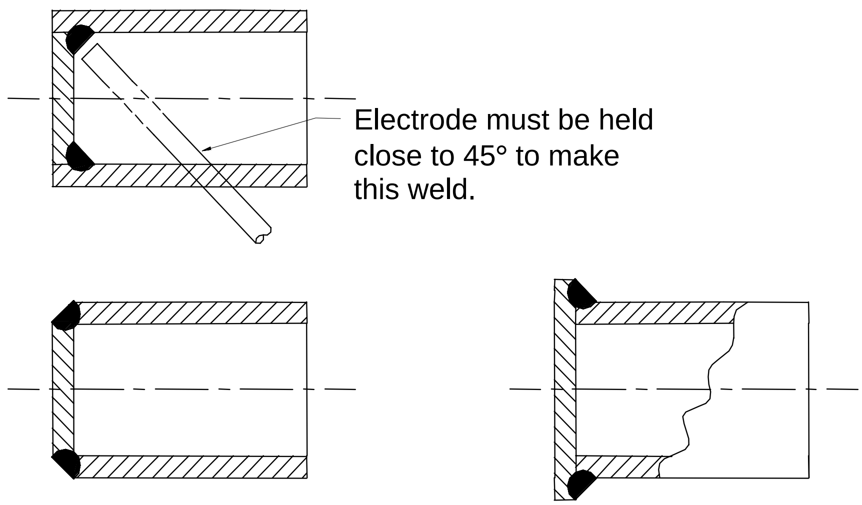
The Solution: Redesign the joint to make room for the welder.



Joint accessibility is only one of many factors that must be examined when designing a weld joint.

Problem

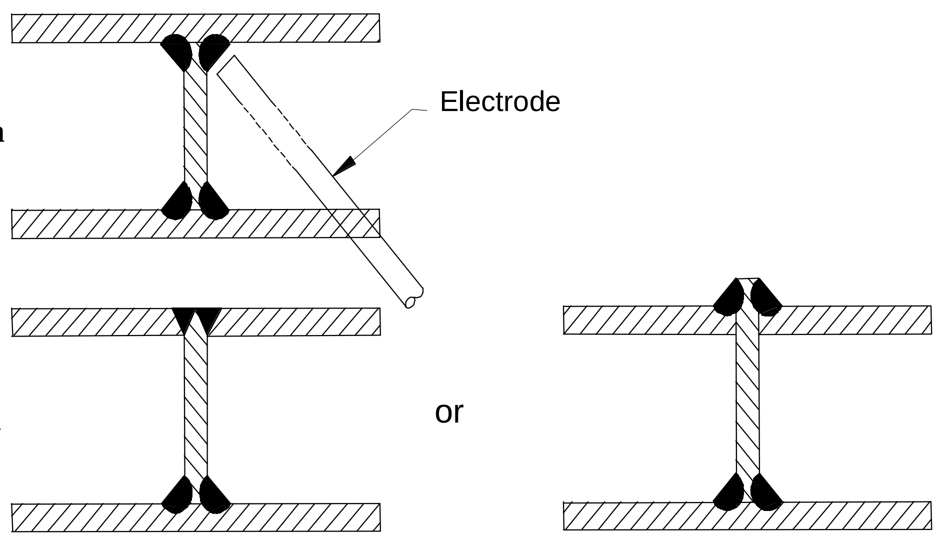
Solution



Consideration must be given to the materials joined, the heat effect of welding, joint preparation, joint penetration, and the required joint strength.

Problem

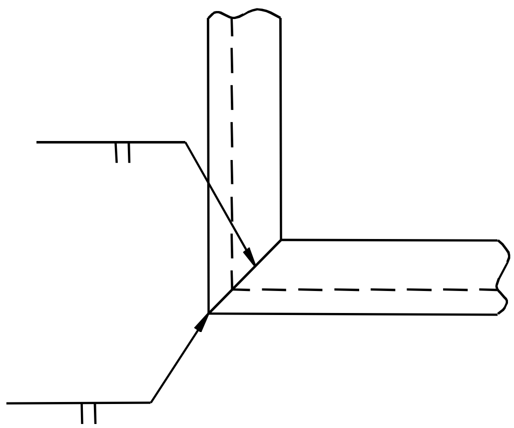
Solution



Consult your welding handbooks and standards for detailed information.

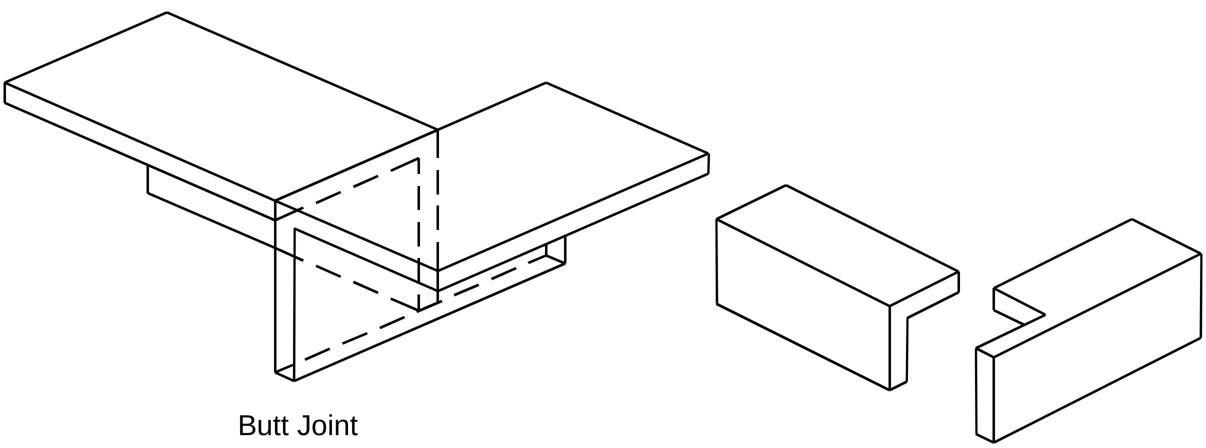
14.6.2 Mitered versus Coped Joint Design

The Problem: A mitered joint is difficult and costly to prepare and requires both pieces to be machined to 45° with relative accuracy for squaring the corner.



Mitered Joint

The Solution: Call for a coped joint that requires a simple cut-off operation to one piece only, or consider a butt design. A coped joint is preferred.



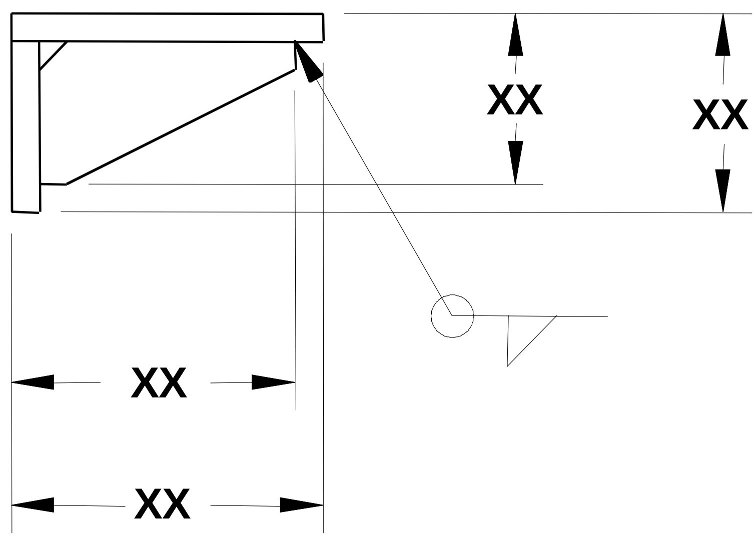
Butt Joint

Coped Joint

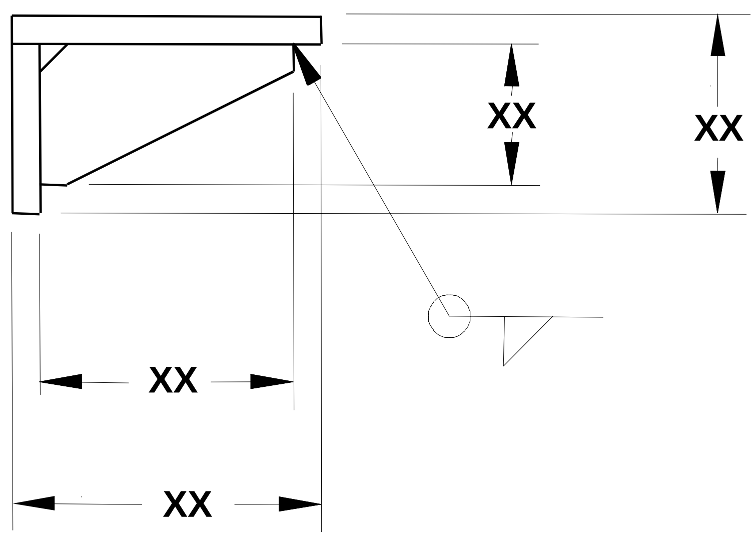
Note: A coped or mitered joint may be noted as vendor's option on drawing.

14.6.3 Weldment Dimensioning

The Problem: When overall dimensions are given on a weldment, the welder must subtract given dimensions to determine piece part sizes.

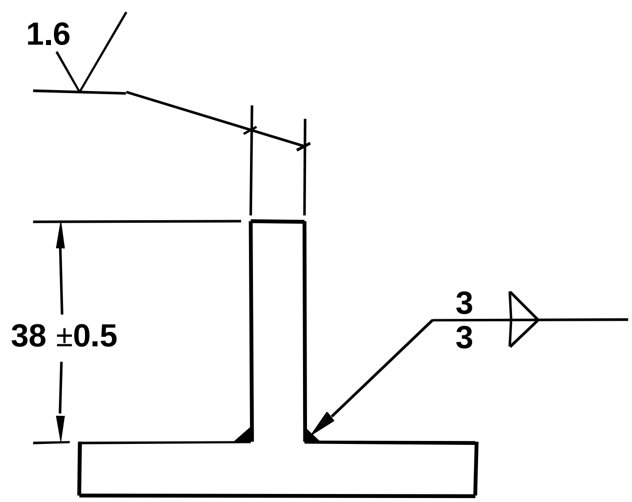


The Solution: When stack-up tolerance allows, give the size of individual parts that must be cut prior to welding.

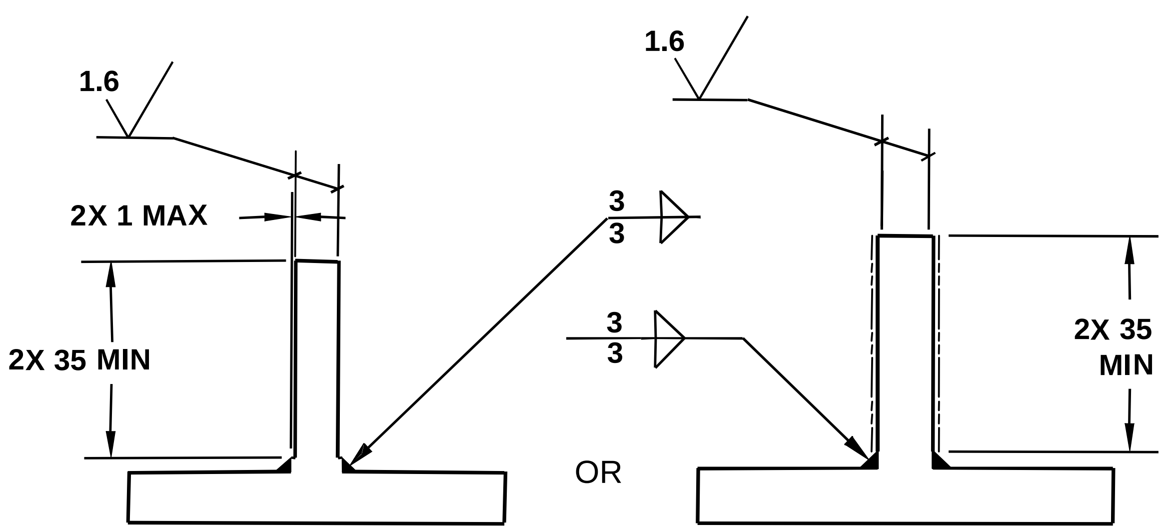


14.6.4 Refinement of Welded Surfaces

The Problem: Welds are located on the surfaces that are to be finished. To satisfy the surface finish requirement, the welds most likely will be damaged or machined off.

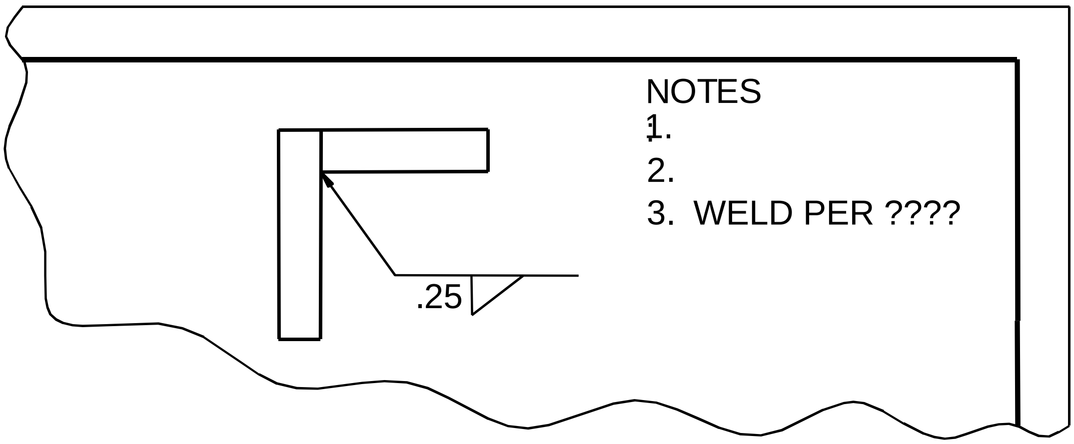


The Solution: Make allowances in the design for the welds when surfaces are to be finished after welding.

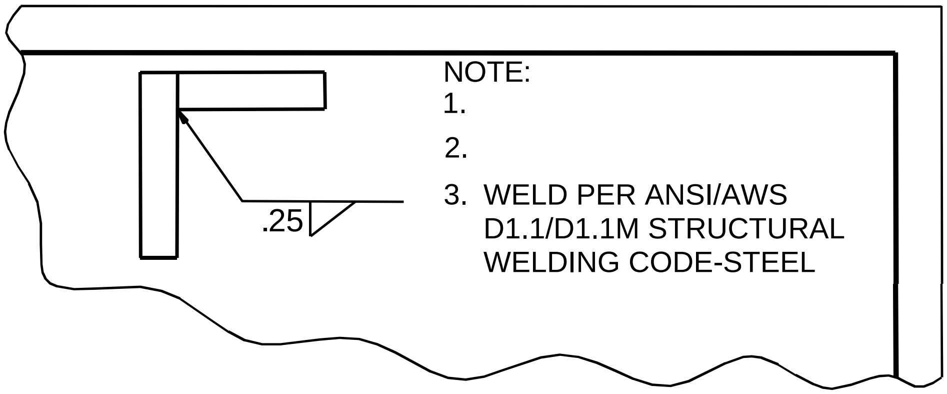


14.6.5 Minimum Weld Specification

The Problem: What minimum weld specification is required on a general type weldment drawing?



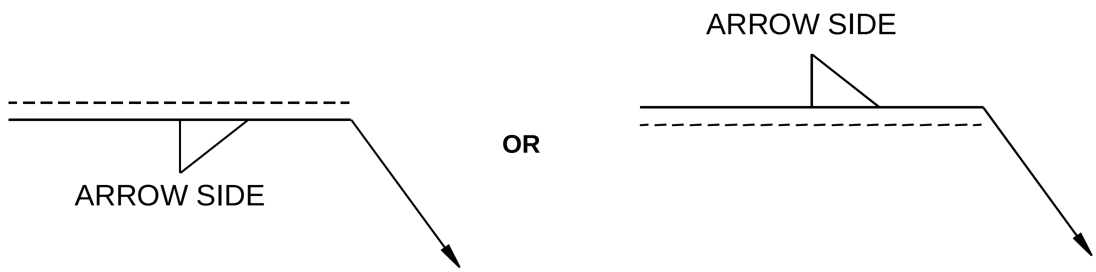
The Solution: Specify one of the ANSI/AWS welding codes. The example shows the specification for structural steel.



See subsection 14.6.7 for a partial listing of ANSI/AWS welding codes.

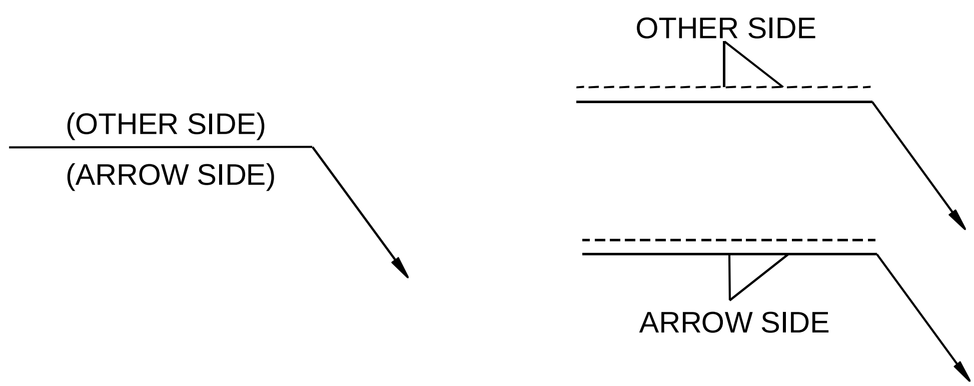
14.6.6 Metric Weld Symbols

The Problem: Metric weld symbols have dual reference lines.



The symbol placement on dashed or solid lines indicates the side of the weld face (near side, far side), and if used may cause confusion.

The Solution: Place the weld symbol according to AWS A2.4-1993 regardless of dashed line location.



See Global Engineering's *Drawing Requirements Manual* Section 14, "Welding Symbology," for a complete description.

14.6.7 ANSI/AWS Welding Codes (Partial Listing)

This is a partial listing of the American Welding Society's welding codes.

Spec. Number	Spec. Name
ANSI/AWS A1.1:2001	Metric Practice for the Welding Industry
ANSI/AWS A2.4:2007	Symbols for Welding and Nondestructive Testing Including Brazing
ANSI/AWS A3.0:2001	Welding Terms and Definitions
ANSI/AWS B1.10:1999	Guide for Nondestructive Examination of Welds
ANSI/AWS B4.0-77	Standard Methods for Mechanical Testing of Welds
ANSI/AWS C5.2-83	Recommended Practices for Plasma Arc Cutting
ANSI/AWS D1.1/D1.1M:2006	Structural Welding Code - Steel
ANSI/AWS D1.2/D1.2M:2003	Structural Welding Code - Aluminum
ANSI/AWS D1.2A-83	Commentary on Structural Welding Code - Aluminum
ANSI/AWS D1.3/D1.3M:2008	Structural Welding Code - Sheet Steel
ANSI/AWS D9.1M/D9.1:2006	Sheet Metal Welding Code
ANSI/AWS D10.4-86	Recommended Practices for Welding Austenitic Chromium Nickel Stainless Steel Piping and Tubing
ANSI/AWS D10.7/D10.7M:2000	Guide for the Gas Shielded Arc Welding of Aluminum and Aluminum Alloy Pipe
ANSI/AWS D10.12M/D10.12:2000	Guide for Welding Mild Steel Pipe
ANSI/AWS D1.4/D1.4M:2005	Structural Welding Code – Reinforcing Steel
ANSI/AWS D1.6/D1.6M:2007	Structural Welding Code – Stainless Steel
ANSI/AWS B4.0M:2000	Standard Methods for Mechanical Testing of Welds
ANSI/AWS D1.9/D1.9M:2007	Structural Welding Code – Titanium
ANSI/AWS D10.6/D10.6M:2006	Recommended Practices for Gas Tungsten ARC Welding of Titanium Piping and Tubing
ANSI/AWS D10.8-96	Recommended Practices for Welding of Chromium-Molybdenum Steel Piping and Tubing
ANSI/AWS D10.3/D10.M:2001	Recommended Practices for the Brazing of Copper Tubing and Fittings for Medical Gas Systems

Note: Design intent should always establish the level of welding specification.

Section 15. Coatings

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Section 16. Casting Data

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Section 17. Forging Data

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Section 18. Facilities

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Section 19. Tooling

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

19.1 Purpose

This section defines LLNL preferred practices for fabrication tooling.

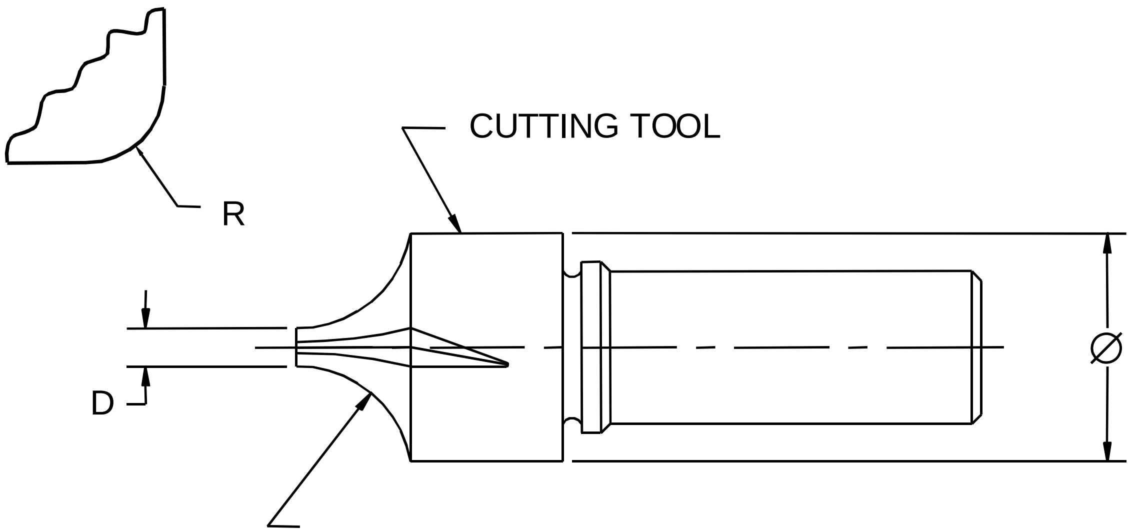
19.2 Applicable Documents

None.

19.3 Problem/Solution Examples

Potential problems and preferred solutions relating to tooling at LLNL follow.

19.3.1 Standard Outside Corner Radius



Use this reference material in the selection of outside corner radius. This allows the machinist to use a standard tool. Be sure to allow for the tool shape.

R ± .0005*			Ø ± .010*			D ± .001*		
Fraction	**Decimal**	**MM**	**Fraction**	**Decimal**	**MM**	**Fraction**	**Decimal**	**MM**
1/16	.06	1.5	7/16	.437	11.09	1/4	.250	6.35
1/32	.09	2.3	1/2	.500	12.70	1/4	.250	6.35
1/8	.12	3.0	5/8	.625	15.87	1/4	.250	6.35
5/32	.16	4.0	3/4	.750	19.05	5/16	.312	7.92
3/16	.19	4.8	7/8	.875	22.23	5/16	.312	7.92
1/4	.25	6.4	1	1.000	25.40	3/8	.375	9.52
5/16	.31	7.9	1 1/8	1.125	28.58	3/8	.375	9.52
3/8	.38	9.7	1 1/4	1.250	31.75	3/8	.375	9.52
7/16	.44	11.2	1 3/8	1.375	34.93	3/8	.375	9.52
1/2	.50	12.7	1 1/2	1.500	38.10	3/8	.375	9.52

* Tolerance is for reference only.
+ Direct metric conversion when rounded.

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Section 20. Packaging Drawings

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Section 21. Sheet Metal

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

21.1 Purpose

This section establishes practices and procedures to be followed in the design and drafting of sheet metal parts and assemblies.

21.2 Applicable Documents

- ANSI Y32.3, "Graphic Symbols for Welding"
- ANSI Y14.5M, "Dimensioning & Tolerancing"
- ANSI B46.1, "Surface Texture"
- LLNL Specification LED 21848, "Machining Tolerances"
- LLNL Specification LED 21849, "Sheet Metal Fabrication–Procedures and Tolerances"
- MIL-STD-100, "Engineering Drawing Practices"

21.3 Definitions

Bending and Bend Radius: The bend radius is the distance to the theoretical center of the arc formed by the inside of a bend (see Figure 21-1).

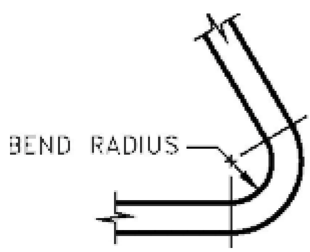


Figure 21-1. Bend radius

21.4 Specifying a Bend Radius

The minimum bend radius is the smallest radius that can be used to form an angle in sheet metal without causing the metal to crack. Some materials may only be bent at right angles. In most cases, metal is bent to a specific bend radius, which is shown by a local or a general note on the drawing. If the bend radius is not specified, it is assumed to be zero. Figure 21-2 illustrates the correct methods of specifying the bend radius. Minimum bend radius information for various aluminum alloys and for carbon and annealed corrosion-resistant steel is provided in Table 21-1.

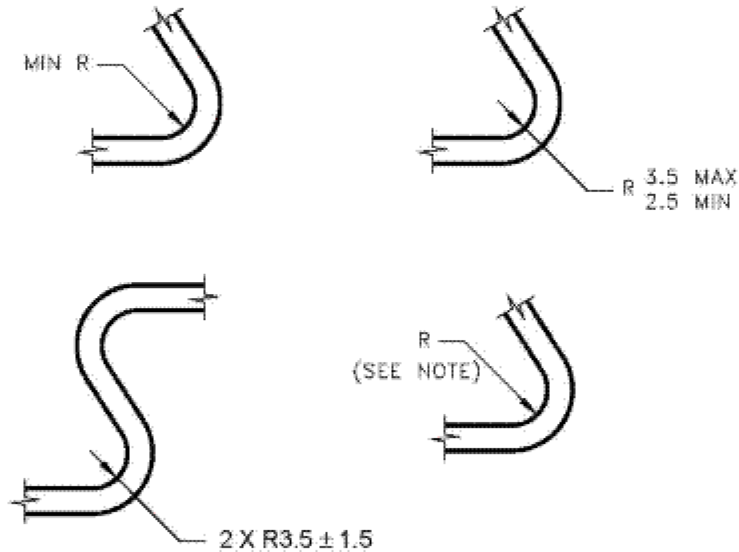


Figure 21-2. Methods of specifying bend radius

21.5 Dimensioning Bends

The mold line is the theoretical intersection of planes extended from the surfaces on each side of a bend. The tangent line is an imaginary line marking the end of the flat surface and the beginning of the bend (see Figure 21-3).

In dimensioning bent sheet metal parts, the following information is required: the distance from the outside mold line to the edge of the material, or to the outside mold line of the next bend; the bend radius; and the angle that the metal is to be bent (see Figure 21-4).

Note: A 90° angle need not be specified.

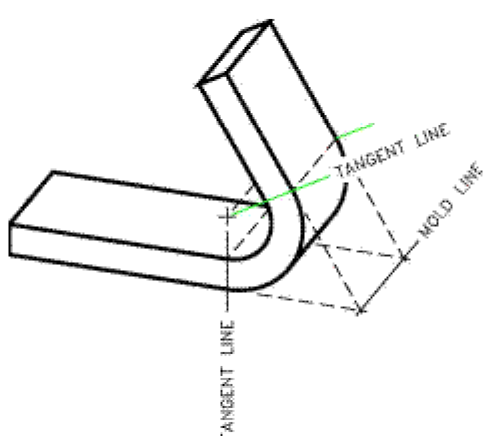


Figure 21-3. Mold line

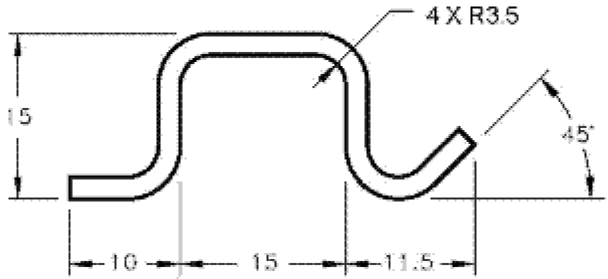


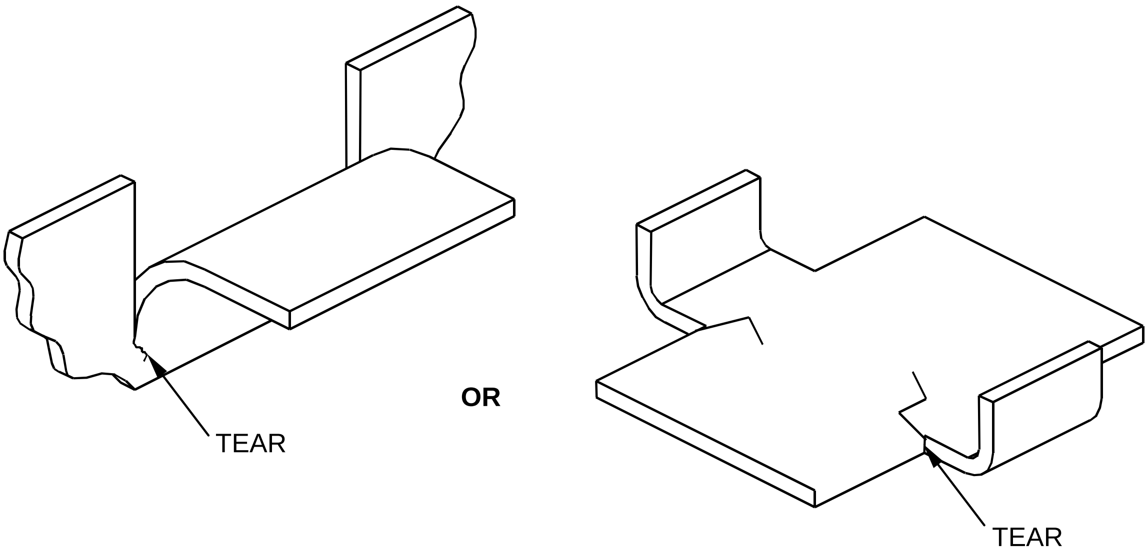
Figure 21-4. Required sheet metal dimensions

21.6 Problem/Solution Examples

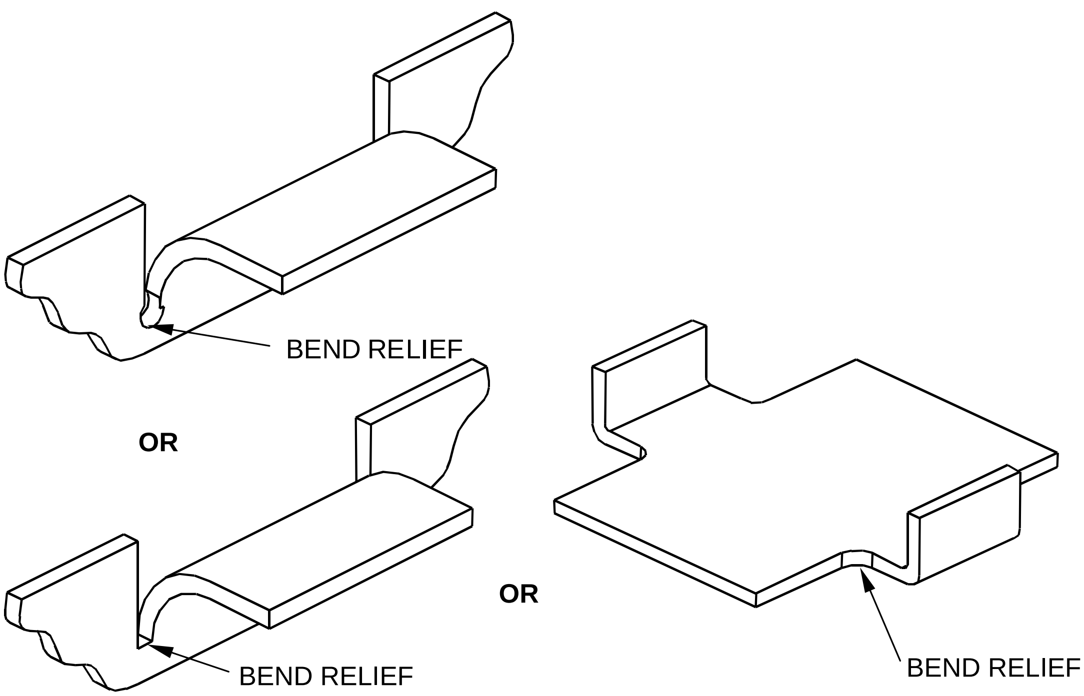
Potential problems and preferred design solutions for machine shop practice at LLNL follow.

21.6.1 Bend Relief

The Problem: No bend relief has been provided in this tab design, resulting in a material tear at the bend.

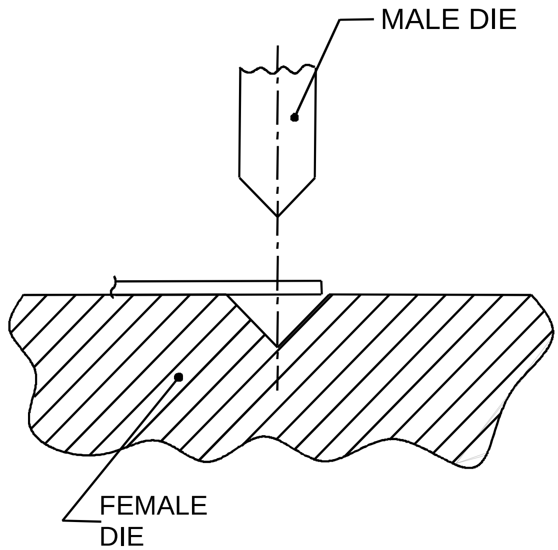


The Solution: Provide for removal of material at or beyond the intersection of the bend lines.

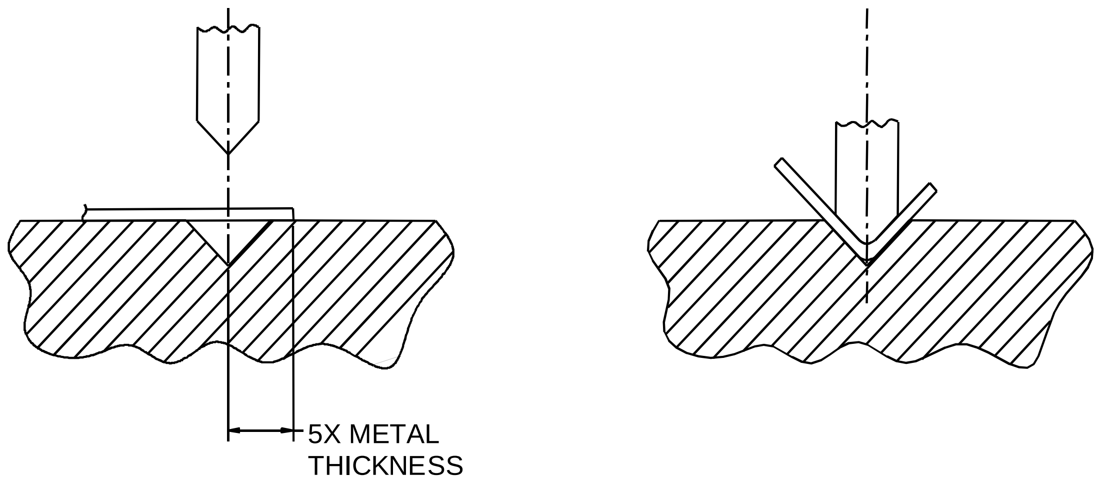


21.6.2 Brake Formed Metal

The Problem: A leg to be bent is too short to function properly with the die.

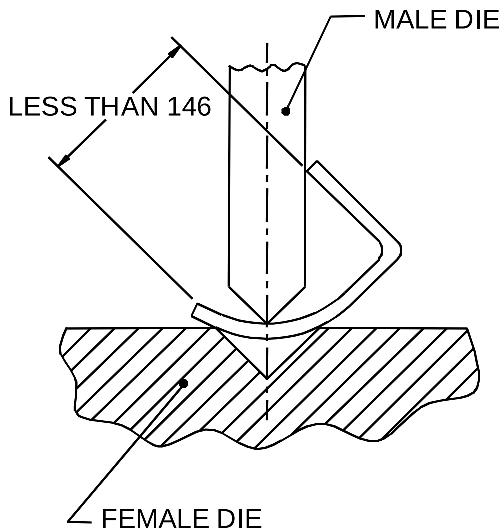


The Solution: If the design permits, make the leg of the bend not less than 5 times the metal thickness.

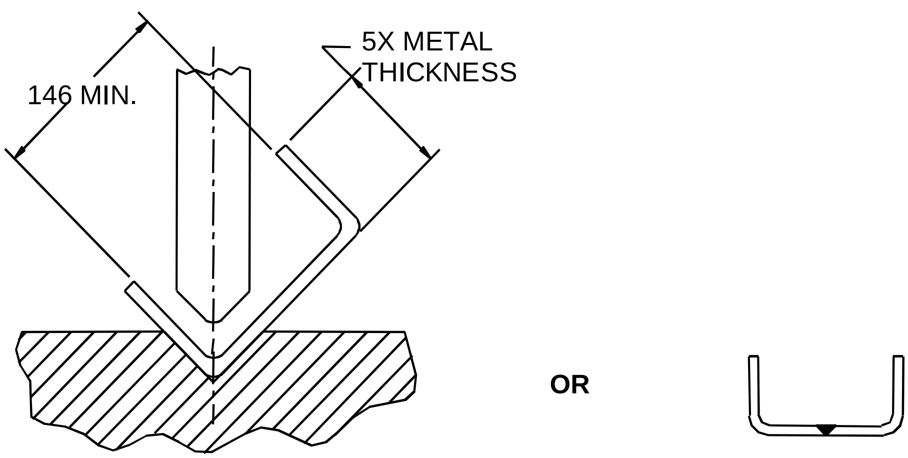


21.6.3 Brake Formed Channel

The Problem: If channel width is designed less than 146 mm, the previously bent leg will interfere with the male die before the second leg can be formed.



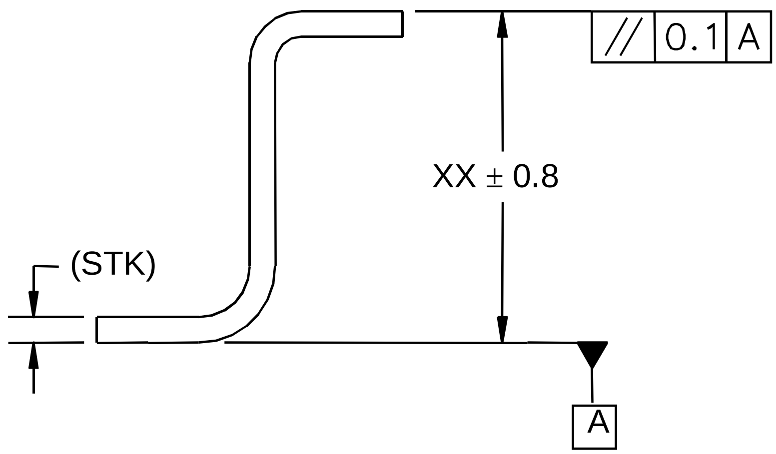
The Solution: If the design permits, design the width of the channel to be a minimum of 146 mm.* Or, if design intent dictates the width to be less than 146 mm, then two parts can be formed and welded in the center.



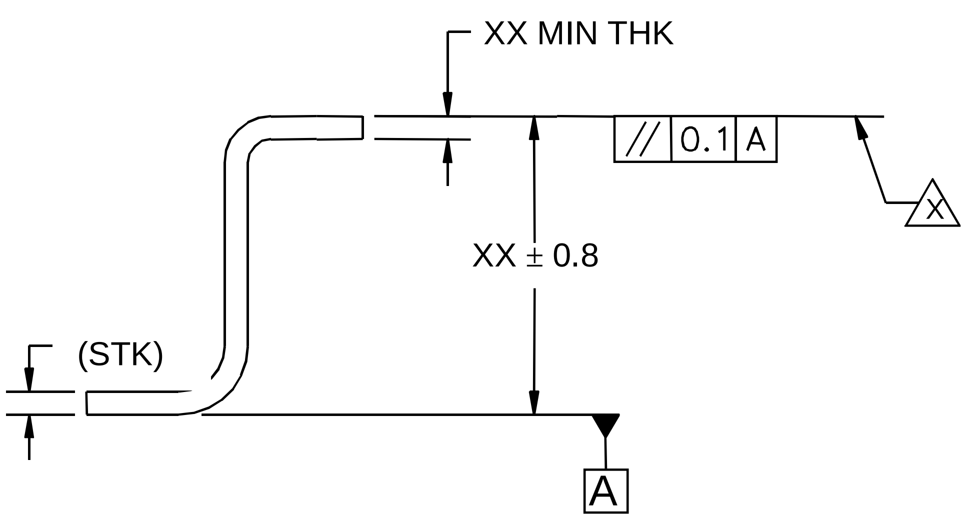
* Per TRED existing tooling.

21.6.4 Machine Option for Formed Metal

The Problem: Parallel surfaces with tight tolerances are difficult to achieve due to rebound.



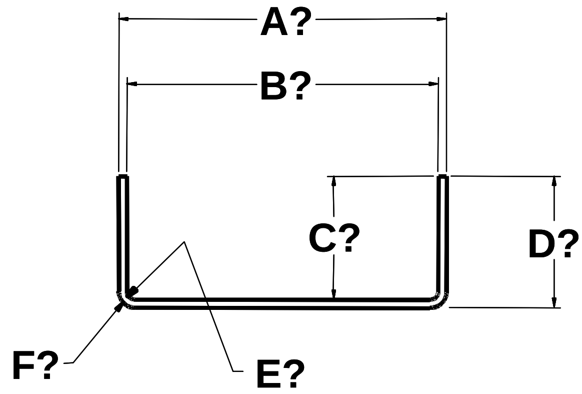
The Solution: Allow machining of the critical surfaces. Specify a minimum thickness.



Machining allowed on surface indicated.

21.6.5 Dimensioning Brake Formed Parts

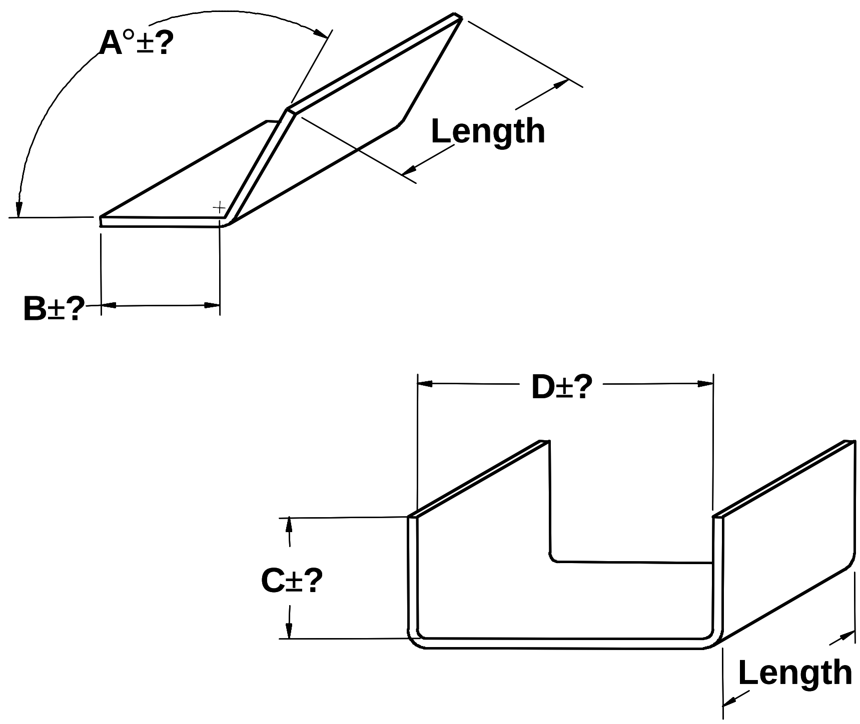
The Problem: Which dimensions are preferred on brake formed parts, assuming no special design constraints?



The Solution: Inside dimensions at “B,” “C,” and “E” are preferred.

21.6.6 Tolerances for Brake Formed Parts

The Problem: With no special design constraints, what are the minimum practical tolerances on sheet metal brake formed parts with no subsequent machining?

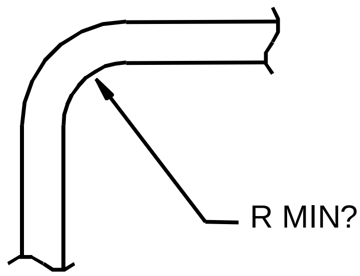


The Solution: For lengths to 2440 mm [96 inches], linear tolerances on “B,” “C,” and “D” dimensions can be held to a minimum of ±1.57 mm [±.062 inches].

For lengths to 914 mm [36 inches], angular tolerances for dimension “A” can be held within ±3° for thickness up to 3.2 mm [.125 inches], and ±5° for thickness above 3.2 mm [.125 inches].

21.6.7 Recommended Minimum Bend Radius for Aluminum

The Problem: Selecting the wrong bend radius for aluminum can cause metal fatigue.



The Solution: Use the bend radius recommended by the Aluminum Association.

Table 21-1. Recommended minimum bend radii for 90-degree cold forming of aluminum* sheet and plate. Extracted from the Aluminum Association, Construction Manual Series, Section 3.

Alloy	Temper	Radii for Various Thicknesses Expressed in Terms of Thickness "t"							
		1/64 in.	1/32 in.	1/16 in.	1/8 in.	3/16 in.	1/4 in.	3/8 in.	1/2 in.
1100	0	0	0	0	0	1/2 t	1 t	1 t	1 1/2 t
	H12	0	0	0	1/2 t	1 t	1 t	1 1/2 t	2 t
	H14	0	0	0	1 t	1 t	1 1/2 t	2 t	2 1/2 t
	H16	0	1/2 t	1 t	1 1/2 t	1 1/2 t	2 1/2 t	3 t	4 t
	H18	1 t	1 t	1 1/2 t	2 1/2 t	3 t	3 1/2 t	4 t	4 1/2 t
5052	0	0	0	0	1/2 t	1 t	1 t	1 1/2 t	1 1/2 t
	H32	0	0	1t	1 1/2 t	1 1/2 t	1 1/2 t	1 1/2 t	2 t
	H34	0	1 t	1 1/2 t	2 t	2 t	2 1/2 t	2 1/2 t	3 t
	H36	1 t	1 t	1 1/2 t	2 1/2 t	3 t	3 1/2 t	4 t	4 1/2 t
	H38	1 t	1 1/2 t	2 1/2 t	3 t	4 t	5 t	5 1/2 t	6 1/2 t
6061	0	0	0	0	1 t	1 t	1 t	1 1/2 t	2 t
	T4	0	0	1 t	1 1/2 t	2 1/2 t	3 t	3 1/2 t	4 t
	T6	1 t	1 t	1 1/2 t	2 1/2 t	3 t	3 1/2 t	4 1/2 t	5 t
7075	0	0	0	1 t	1 t	1 1/2 t	2 1/2 t	3 1/2 t	4 t
	T6	3 t	4 t	5 t	6 t	6 t	8 t	9 t	9 1/2 t

* For sheet copper and bronze, see bend allowance tables in Oberg et al. *Machinery's Handbook* (Industrial Press).

21.6.8 Recommended Minimum Bend Radius for Steel

The Problem: What is the correct bend radius for carbon steel or annealed corrosion-resistant steel?

The Solution: See Table 21-2.

Table 21-2. Sheet metal bend radii

Carbon Steel and Annealed Corrosion-Resistant Steel, 0°–180° Bends	
Material Thickness (in.)	**Minimum Bend Radius (mm)**
.015	0.80
.030	
.041	1.60
.060	
.075	2.40
.090	
.120	3.20
.135	4.75
.188	

Section 22. Electrical and Electronics Drawings

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

22.1 Schematic/Logic Diagram Symbols

22.1.1 Purpose

This section establishes a list of graphic symbols and practices used in electrical and schematic diagrams, and illustrates those used in electrical/electronics schematic diagrams at LLNL.

22.1.2 Applicable Documents

- ANSI Y32.2, “Graphic Symbols for Electrical and Electronics Diagrams”
- ANSI Y32.14, “Graphic Symbols for Logic Diagrams”
- ANSI Y32.16, “Reference Designations for Electrical and Electronics Parts and Equipment”
- ASME Y14.38A-2002, “Abbreviations and Acronyms”
- *Engineering Design Safety Standards Manual,* Part III
  - Section 11.1, “Designing and Fabricating Safe Electrical Equipment”
  - Section 11.3, “Specification for Electrical Equipment Fabrication”

22.1.3 Definitions

Schematic or Elementary Diagram: A schematic or elementary diagram shows, by means of graphic symbols, the electrical connections and functions of a specific circuit arrangement. The schematic diagram facilitates tracing the circuit and its functions without regard to the actual physical size, shape, or location, or the equipment devices or parts.

Single-Line Diagram: A single-line diagram shows, by means of single lines and graphic symbols, the course of an electrical circuit or system, or circuits and the component devices or parts used therein. These diagrams are commonly referred to at LLNL as *one-line diagrams* or *one-line interconnect diagrams*.

22.1.4 Requirements

Schematic diagram symbols should be assigned and used in accordance with this manual and with ANSI Y32.2, unless otherwise specified.

22.1.5 Practices

- Orientation of a symbol on a drawing, including mirror image presentations, does not alter the meaning of the symbol.
- Line width does not affect the meaning of the symbol. In some cases, normal line width may be increased for emphasis.

- A symbol may be drawn to a proportional size appropriate for a particular drawing, depending on the anticipated reduction or enlargement requirements.
- Standard symbols for a terminal (a .100-in. diameter circle) may be added to the connecting lines of any of the graphic symbols. Such added terminal symbols should not be considered as part of the individual graphic symbol as shown in this section.
- For diagram simplification, parts of a symbol for a device, such as a relay or switch, may be separated. If this method is employed, suitable reference designations to show proper correlation of parts must be provided.
- Unless otherwise noted or specified, the angle at which a connecting line is brought to a graphic symbol has no particular significance.
- Symbols used for associated or future parts should be shown by lines composed of short dashes.
- Details of type, properties, or ratings may be added adjacent to any symbol, as required. If used, abbreviations should be in accordance with ASME Y14.38a-2002 or with Section 24 of this manual. Letter combinations used as parts of graphic symbols are not considered abbreviations.
- Schematic layouts should be planned to avoid crowding, long lines, excessive crossovers, and bends. Planning should include the following considerations: sequence of stages, related components, standard layout of common circuits, inputs from the left of the drawing, outputs to the right of the drawing, common lines, and repeated stages.
- Where repeated stages of a circuit exist, the initial stage at the left of the drawing should be shown as typical, with others, in block form only. Letters shall designate appropriate inputs and outputs identifiable from the typical stage.
- Reference designations shall be assigned and used in accordance with ANSI Y32.16 and subsection 22.2, “Reference Designations.” If there is a conflict between these two sources, subsection 22.2 shall be the governing or primary source.

22.1.6 Most-Used Symbols of Electrical and Electronics Components

Use the symbols shown in Figure 22-1 or choose the preferred symbols given in ANSI Y32.2, “Graphic Symbols for Electrical and Electronics Diagrams.” Except as noted, symbols in Figure 22-1 conform to ANSI Y32.2.

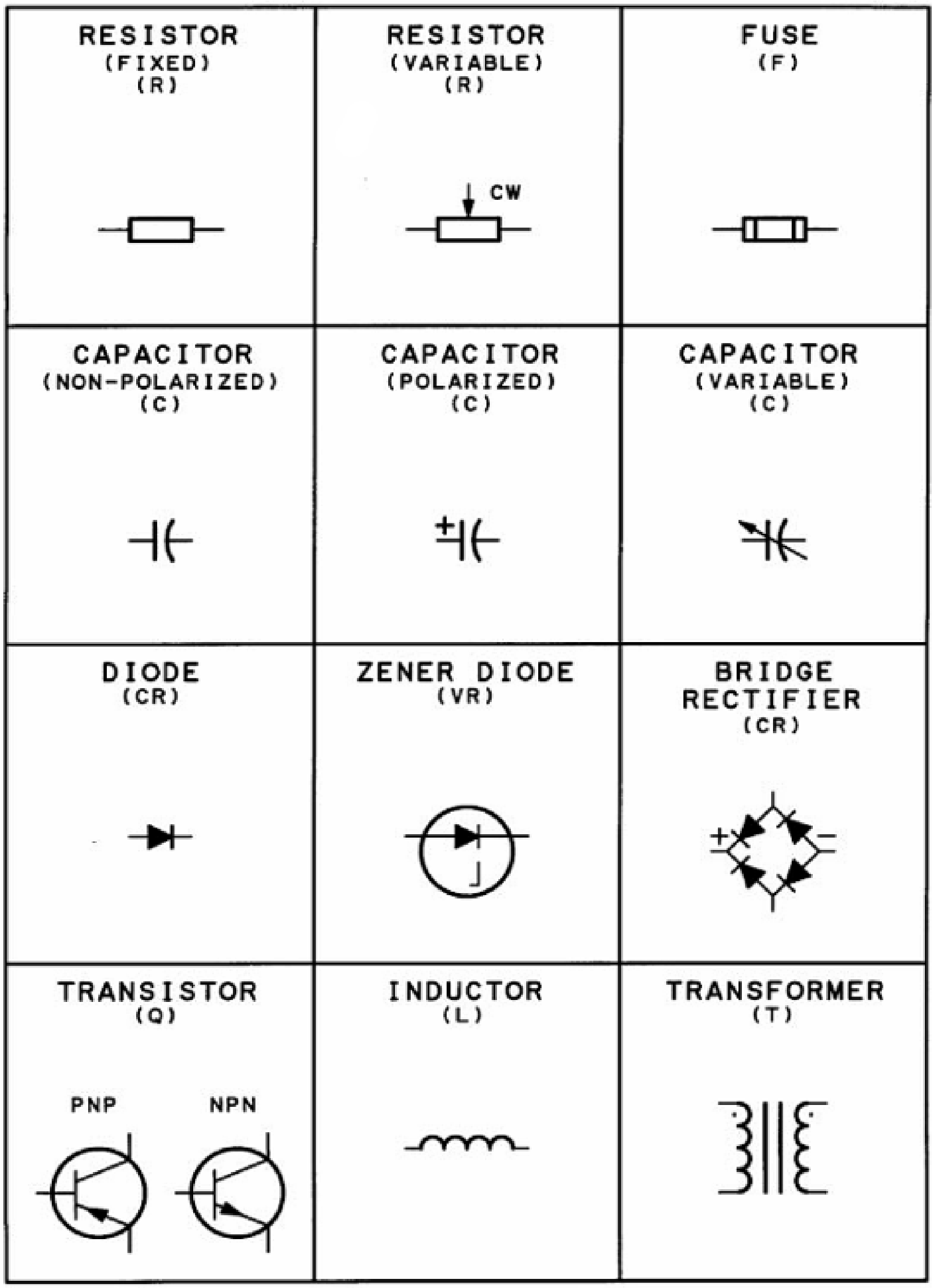


Figure 22-1. Most-used symbols (sheet 1 of 5)

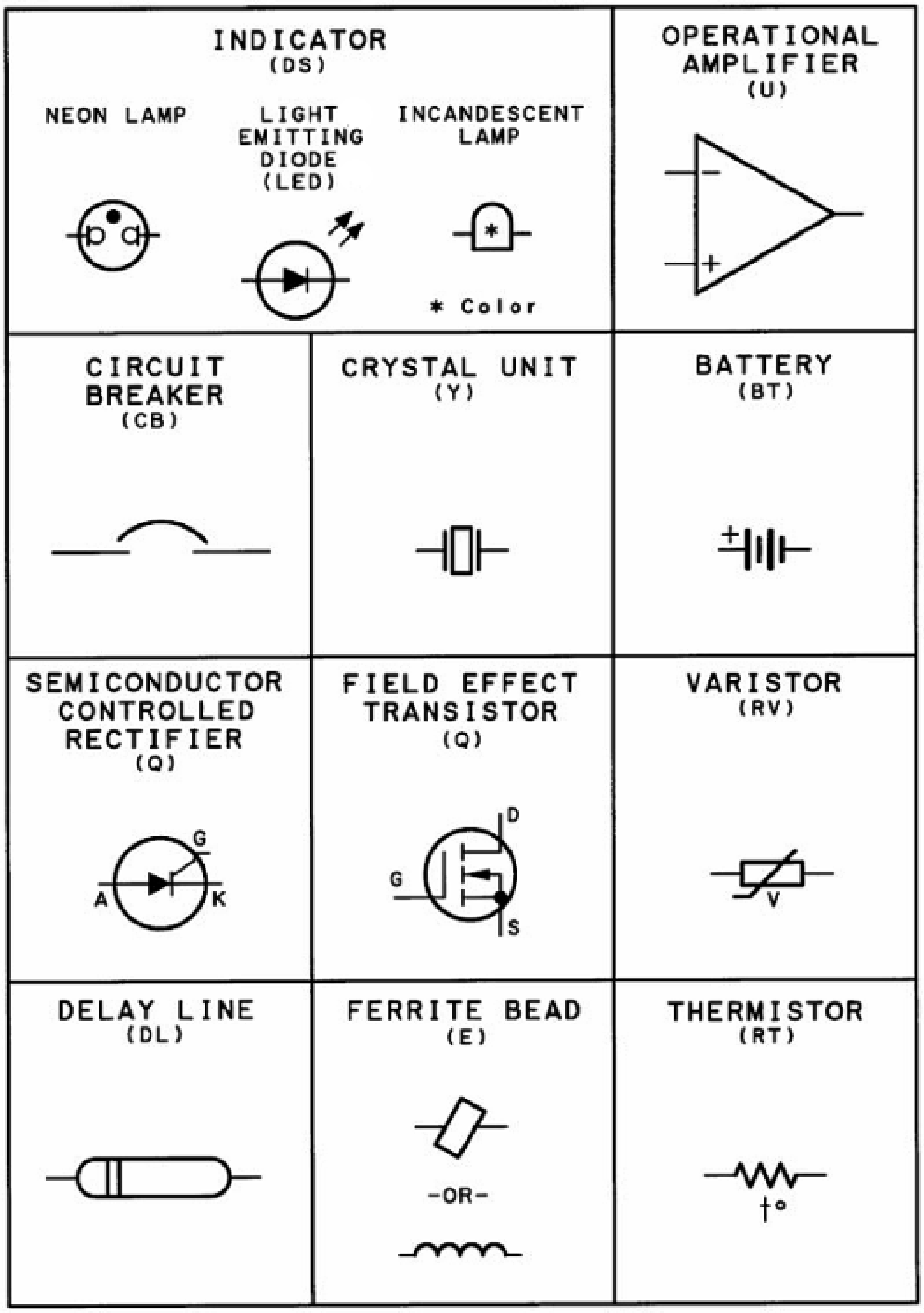
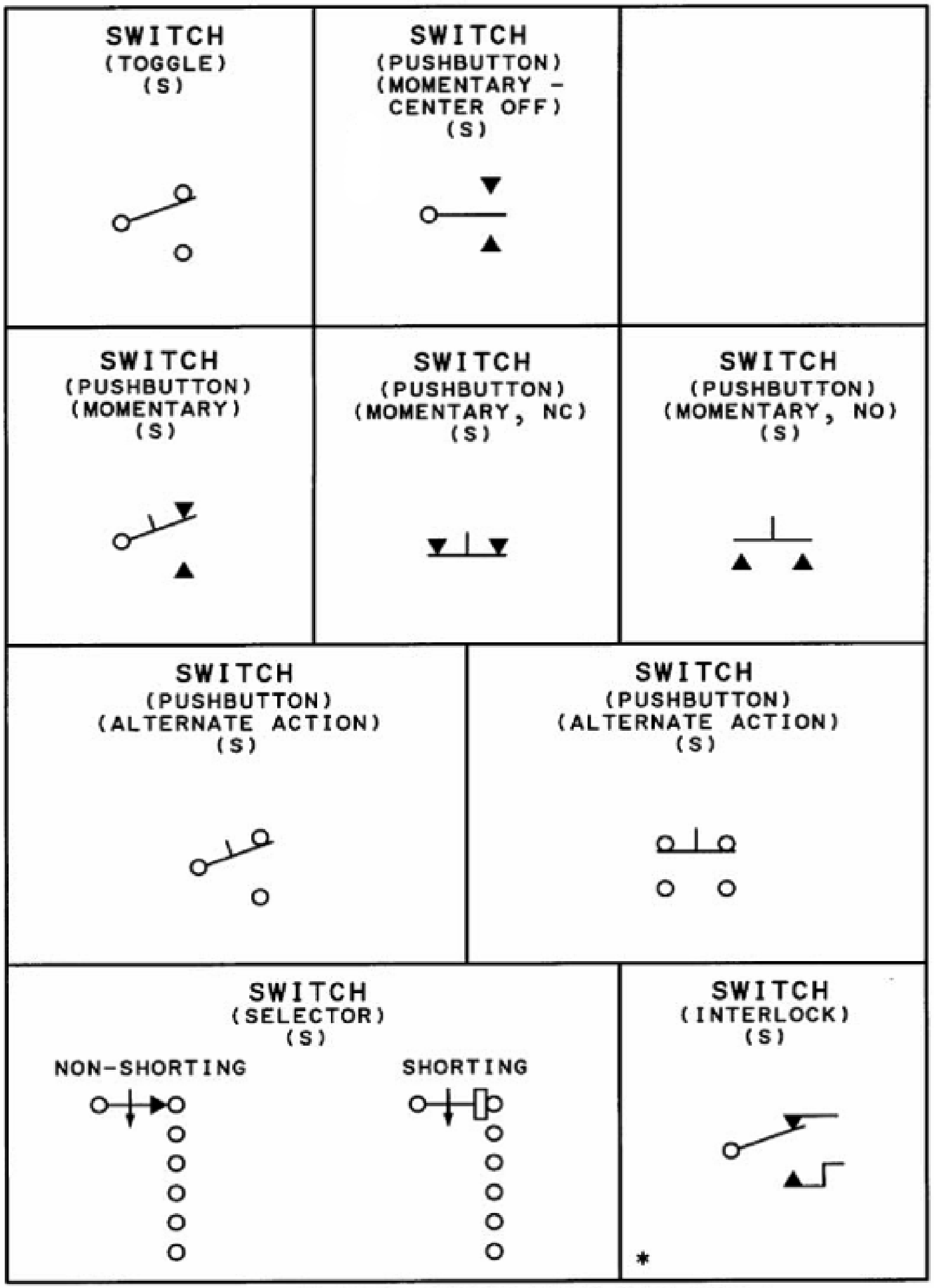
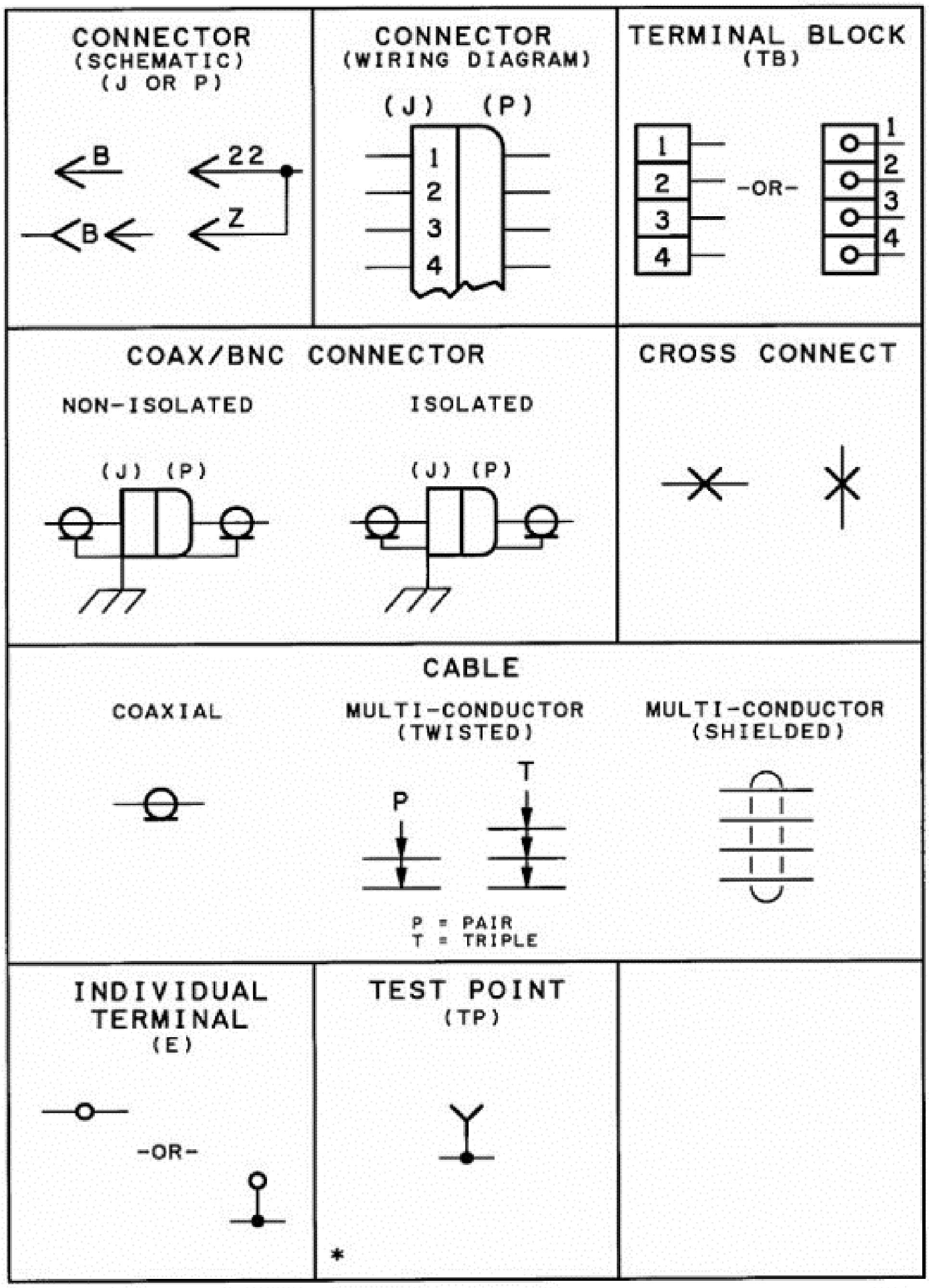


Figure 22-1. Most-used symbols (sheet 2 of 5)



* Symbol shown deviates from ANSI Y32.2.

Figure 22-1. Most-used symbols (sheet 3 of 5)



* Symbol shown deviates from ANSI Y32.2.

Figure 22-1. Most-used symbols (sheet 4 of 5)

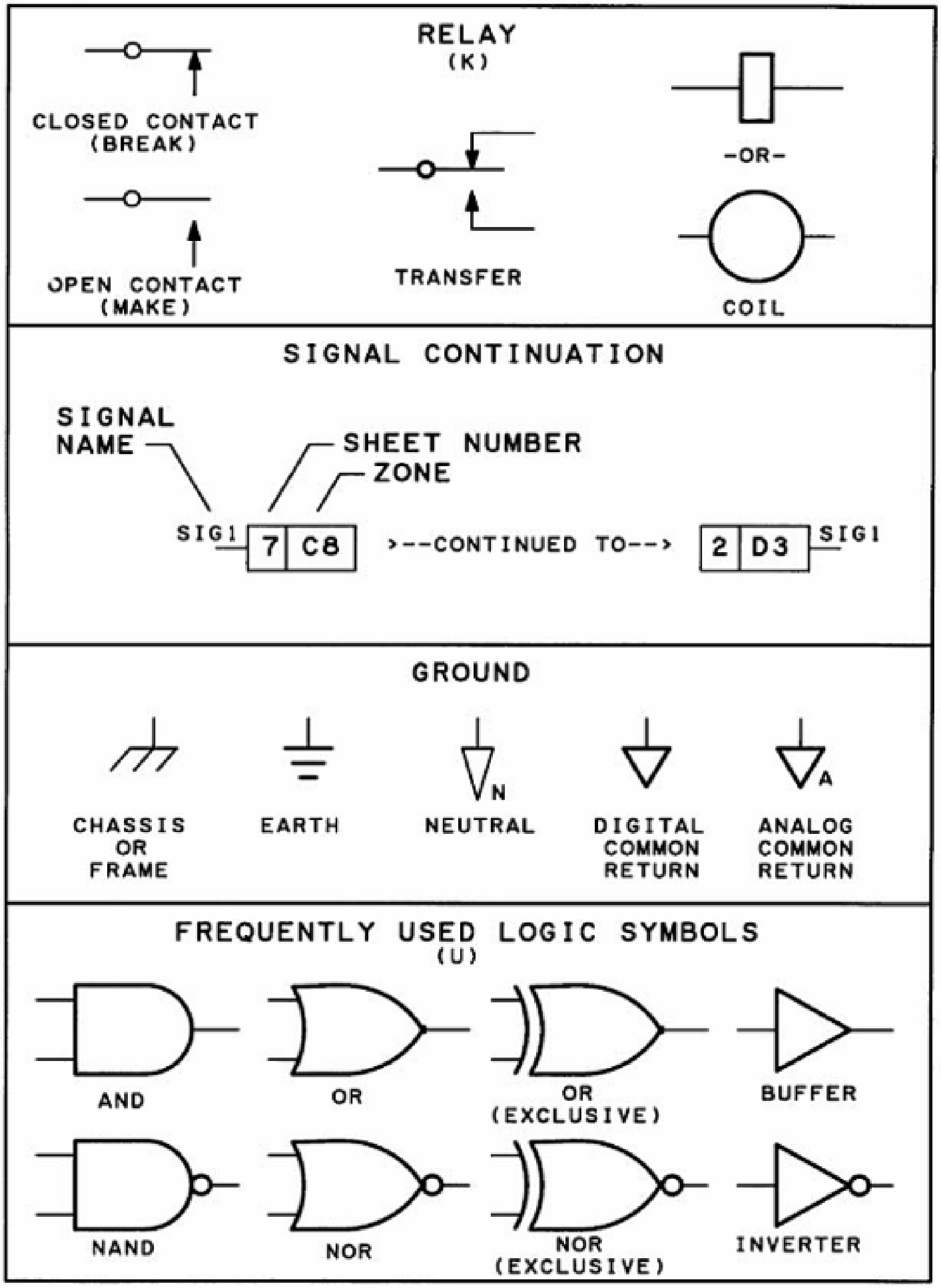


Figure 22-1. Most-used symbols (sheet 5 of 5)

22.2 Reference Designations

22.2.1 Purpose

This section establishes principles governing the formation and application of electrical and electronics reference designations. It also provides a list of designating letters for electrical and electronics parts shown on schematic and wiring diagrams (Tables 22-1 and 22-2).

22.2.2 Applicable Documents

ANSI Y32.16, "Reference Designations for Electrical and Electronics Parts and Equipment"

22.2.3 Definitions

Part: A part is a piece, or pieces joined together, that cannot be disassembled and retain its designed utility. Examples: integrated circuit, resistor, screw, gear, audio transformer.

Subassembly: A subassembly is two or more parts that constitute a portion of an assembly or a unit. Replacement may be made of the subassembly or any of its parts. Examples: IF strip, terminal board with mounted components.

Assembly: An assembly is a combination of parts and subassemblies joined to perform a specific function. Examples: fabricated assembly, audio frequency amplifier.

Unit: A unit is a combination of parts, subassemblies, or assemblies mounted together but capable of independent operation. Examples: electric motor, electronic power supply, electric generator, radio receiver. (**Note:** The size of an item is a consideration in some cases. An electric motor for a clock may be considered as a part, inasmuch as it is not normally subject to disassembly.)

Group: A group is a subdivision of a system. It is a collection of units, assemblies, or subassemblies not capable of performing a complete operational function. Examples: antenna group, indicator group.

Set: A set is a unit or units and necessary assemblies, subassemblies, and parts connected or associated together to perform an operational function. Examples: a radio receiving set or a sound measuring set that includes necessary parts and assemblies, and other items such as cables, microphones, and measuring instruments.

System (Electrical/Electronic): A system is a combination of two or more sets or units, generally physically separated when in operation, and other equipment necessary to perform an operational function. Examples: diagnostic system, pin system, grounding system, telephone system.

Accessory: An accessory is a part, subassembly, or assembly designed for use in conjunction with or to supplement another assembly, unit, or set. Examples: test instrument, shot recording camera, headphones, or emergency power supply.

22.2.4 Reference Designations—Definitions and Requirements

Reference designations are symbols used to identify assemblies, subassemblies, and component parts on schematic diagrams and/or parts lists; for example, “R” for resistor, “C” for capacitor, etc.

Reference designations consist of letter and number combinations. The letter identifies the class to which the part belongs; for example, “B” indicates blower, fan, or motor. The number following the letter identifies the particular component in the drawing; for example, “B1.”

Component terminal numbers are referred to by a dash number added to the basic reference designation; for example, “Note: Connect B1-1 to S1-3 for reversing action.”

On old drawings, particularly “control schematics,” the designations “RE1-1” (relay) and “TK1-1” (time delay) indicate the first set of contacts. On new drawings, “K1S1” and “TD1S1” are now used.

In the case of old control schematics, standard panel components are already wired to terminal strips on the panel. Here, the “TS” point is indicated rather than the component terminal. On new drawings this is shown as “TB”; for example, TB1-1.

For clarity, the drawing may have a brief note explaining the use of dash numbers to indicate terminals and component leads.

Network component element numbering is dependent on the algorithms used by the different CAE software packages. Refer to the appropriate software user’s guide to verify number assignment. One example is R1-A, R1-B, etc.

Table 22-1. Standard reference designations, listed by part name

Part Name	Ref. Des.
Accelerometer	A
Adapter (Waveguide or Connector)	CP
Alarm (Audible)	LS
Amplifier, General	U
Amplifier, Rotating	G
Annunciator (Lighted)	DS
Annunciator (Audible)	LS
Antenna	E
Arrestor, Lighting	E
Artificial Line	Z
Assembly	A
Attenuator (Fixed or Variable)	AT
Audible Signaling Device	LS
Autotransformer	T
Barrier Photocell	BT
Battery	BT
Bell	LS
Bimetallic Strip	E
Blocking Layer Cell	BT
Blower	B
Board, Terminal	TB
Breaker, Circuit	CB
Brush	E
Buzzer	LS
Cable	W
Capacitance Brushing	C
Capacitor	C
Capacitor Network	C
Carbon Block	E
Cavity, Tuned	Z
Cell, Light Sensitive, Photoemissive	BT
Choke	L
Circuit Breaker	CB
Clock	M
Coil, Hybrid	L
Coil, Non-Transformer Type	L
Coil, Telephone, Repeating, Induction	L

Part Name	Ref. Des.
Computer	A
Connector, Plug (mounted on cable)	P
Connector, Receptacle (mounted on bulkhead, wall chassis, or panel)	J
Contractor, Electrical (magnetic)	K
Contractor, Mechanical or Thermal	S
Counter	M
Counterpoise	E
Coupler, Directional	DC
Coupling, Aperture, Loop or Probe	CP
Crystal, Piezoelectric	Y
Crystal Unit	Y
Cutout, Fuse	F
Cutout, Thermal	S
Delay Line	DL
Delay relay, Time	K
Device, Indicating (except meter thermometer, or visual signaling device with lights)	DS
Dial, Circuit Interrupter	S
Diffusion Pump (Vacuum)	DP
Diode, Crystal Breakdown	CR
Diode, Crystal Detector	CR
Diode Network	CR
Diode, Semiconductor	CR
Diode, Zener	VR
Dipole Antenna	E
Disconnecting Device (plug)	P
Disconnecting Device (switch)	S
Discontinuity (coax or waveguide)	Z
Drop	DS
Dynamotor	MG
Electromagnet	L
Electron Tube	V
Equalizer	EQ
Exciter (rotating machine)	G
Fan	B
Ferrite Core	L
Filter	FL
Flasher (circuit interrupter)	DS

Part Name	Ref. Des.
Fuse	F
Fuse Holder	XF
Gap	E
Gage	M
Generator	G
Govern Switch	S
Hall Effect Device	E
Handset	HS
Head, Erasing, Recording, Reproducing	PU
Headset	HT
Hearing Aid	HT
Heater (element for thermostat, oven, etc.)	HR
Heating Lamp	HR
Horn	LS
Hybrid Coil or Junction	HY
Hydraulic Part	HP
Indicator (audible device)	DS
Indicator (light device)	DS
Inductor	L
Instrument	M
Insulator	E
Integrated Circuit	U
Interlock, Electrical	S
Inverter (motor-generator)	MG
Inverter (static, dc to ac)	PS
Jack, Banana	J
Junction, Hybrid	HY
Junction, Tee, Wye, coaxial or waveguide	CP
Key Switch	S
Key, Telegraph	S
Lamp, Ballast	RT
Lamp, Heating	HR
Lamp, Illuminating (also LED's)	DS
Lamp, Pilot	DS
Lamp, Resistance (ballast lamp)	RT
Lamp, Signal	DS
Lamp, Holder, Pilot Light	XDS
Line, Artificial	Z
Line, Delay	DL
Loop Antenna	E
Loudspeaker	LS

Part Name	Ref. Des.
Magnet, Electric	L
Magnet, Permanent	E
Magneto	G
Meter	M
Microphone	MK
Mode Suppressor	FL
Mode Transducer	MT
Modulator	A
Motor	B
Motor-Generator	MG
Network (general)	Z
Oscillator (not oscillator tube)	G
Oscillograph	M
Oscilloscope	M
Part (miscellaneous electrical)	E
Path, Guided Transmission	W
Phototube	V
Pickup (head)	PU
Plug, Connector (movable portion)	P
Potentiometer	R
Power Supply	PS
Prime Mover (rotating, electrical)	B
Protector, Carbon Block, Gap	E
Radio Receiver	RE
Receiver, Telephone (not part of handset)	HT
Receptacle, Connector (stationary portion)	J
Recorder, Elapsed Time	M
Recorder, Sound	A
Rectifier, Crystal or Metallic Diode	CR
Rectifier, Silicon Controlled (SCR)	Q
Reed Relay	K
Regulator, Voltage (not a tube)	U
Regulating Generator	G
Relay or Contactor	K
Repeater (telephone usage)	AR
Reproducer, Sound	PU
Resistive Termination	AT
Resistor	R
Resistor, Variable	R
Resistor, Network	R
Resonator	Z

Part Name	Ref. Des.
Rheostat	R
Ringer, Telephone	LS
Saturable Reactor (ferrite core)	L
SCR	CR
Selenium Cell (rectifier)	CR
Sensor	MT
Shield, Electrical	E
Short	E
Shunt	R
Siren	LS
Slip Ring	SR
Socket, Integrated Circuit	XU
Socket, Pilot Lamp	XDS
Socket, Relay	XK
Socket, Tube	XV
Socket, Transistor	XQ
Solenoid	L
Speaker, Loudspeaker	LS
Strip, Terminal	TS
Subassembly	A
Switch (mechanical or thermal)	S
Synchro	B
Taper, Coaxial or Waveguide	W
Telephone Station	A
Teleprinter	A
Teletypewriter	A
Terminal, Individual	E
Terminal Board	TB
Terminal Strip	TS
Termination, Resistive	AT
Test Block	TB
Test Point (tie point)	TP
Thermistor	RT

Part Name	Ref. Des.
Thermocouple	TC
Thermometer	M
Thermostat	S
Thyristor (SCR)	CR
Tie Point, Wiring	WT
Timer (without contacts)	S
Timer, Time Delay (with switch contacts)	S
Transducer	MT
Transducer, Mode	MT
Transformer	T
Transistor	Q
Transistor, Field Effect, FET	Q
Transistor, Unijunction	Q
Transmission Path	W
Transmitter, Radio	TR
Transmitter, Telephone	MK
Tube, Electron	V
Tuned Cavity	Z
Tuned Circuit	Z
Unijunction Transistor	Q
Vacuum Switch	S
Varistor, Asymmetrical	CR
Varistor, Symmetrical	RV
Vibrator, Indicating	DS
Vibrator, Interrupting	G
Visual Signaling Device (with lights)	DS
Voltage Regulator (tube)	VR
Voltage Regulator (printed circuit)	U
Waveguide	J, P
Waveguide Flange (choke)	J
Waveguide Flange (plain)	P
Winding	L
Wire	W

Table 22-2. Standard reference designations, listed alphabetically

Ref. Des.	Part Names/Descriptions
A	Accelerometer, modulator, recorder unit (sound), telephone station, teleprinter, teletypewriter. Assembly, subassembly (examples: computer, sensor. Includes all other mechanical or electrical assemblies that appear on a schematic diagram and that do no fall under more specific designations.)
AR	Magnetic amplifier, telephone repeater
AT	Attenuator, fixed or variable; resistive termination
B	Blower, fan, motor, prime mover, synchro, and all other equipment that yields a mechanical rotational output.
BT	Battery, barrier photocell, blocking layer cell (photosensitive), photoemssive cell
C	Capacitor, capacitance bushing, capacitance device
CB	Circuit breaker
CP	Coupling (aperture, loop, or probe), adapter (waveguide or connector)
CR	Crystal diode, contact or metallic rectifier, semiconductor diode, diode network, silicon-controlled rectifier, thyristor (SCR), varistor (asymmetrical)
DC	Directional coupler
DL	Delay line
DP	Diffusion pump (vacuum)
DS	Indicating lights, light-emitting diodes (LED's), signal lights, illuminating and pilot lamps, flasher
E	Miscellaneous electrical parts such as an aluminum or electrolytic call, antenna, brush, carbon block, counterpoise, electrical shield, gap, lighting arrestor, magnet, short, individual terminals, contacts, bimetallic strip, hall effect device, and insulator
EQ	Equalizer
F	Fuse, fuse cutout
FL	Filter, mode suppressor
G	Generator, motor generator, converter (rotating machine), exciter (rotating machine), magneto, oscillator (non-tube), rotating amplifier, interrupting vibrator, or any electrical generator that yields an electrical output
HP	Hydraulic part
HR	Heater; element for thermostats, ovens, etc.; heating lamp
HS	Handset
HT	Headset, hearing aid, telephone receiver (not part of handset)
HY	Hybrid coil junction
J	Connector, electrical receptacle (stationary portion of connector), receptacle (mounted on wall, chassis, frame, or relatively fixed device), banana jack, waveguide, waveguide flange (choke), disconnecting device (receptacle)
K	Contactor, relay, reed relay, time-delay relay
L	Choke, inductor, coil winding, saturable reactor, reactor (iron core), ferrite core, solenoid, electromagnet
LS	Loudspeaker, horn, (electrical) speaker; bell buzzer' audible alarm, annunciator or signal device
LT	Annunciator (lighted)
M	Meter, clock, counter, recorder (elapsed time), instrument motor, register, oscillograph, oscilloscope, thermometer, gage

Ref. Des.	Part Names/Descriptions
MG	Dynamotor, motor-generator
MK	Microphone, telephone transmitter
MT	Mode transducer, transducer, sensor
P	Connector plug (mounted to cable or movable device), disconnecting device (plug), test plug, banana plug, waveguide, waveguide flange (plain)
PS	Power supply, inverter (static, non-rotating, dc to ac), complete power supple assembly (except rotating)
PU	Pickup head (erasing, recording, etc.), reproducer (sound)
Q	Transistor, silicon-controlled rectifier (SCR), field-effect transistor (FET)
R	Resistor, shunt, potentiometer, rheostat, variable resistor, resistor network
RE	Radio receiver
RT	Thermistor, ballast lamp or tube, current regulating resistor, thermal resistor
RV	Resistor (voltage sensitive), varistor (symmetrical)
S	Switch-mechanical, thermal, governor, thermostat, key, interlock (safety, electrical), disconnect, vacuum, contactor (manual or thermal), thermal cutout, circuit interrupter dial, telegraph key, timer
SR	Slip ring
T	Transformer, autotransformer
TB	Terminal board, component mounting board, terminal block, test block
TC	Thermocouple
TP	Test point (tie point)
TR	Radio transmitter
TS	Terminal strip
U	Integrated circuit, voltage regulator (non-tube, printed circuit), amplifier (general)
V	Electron tube, photomultiplier tube, phototube, magnetron, klystron, ignition
VR	Voltage regulator electron tube, zener diode
W	Cable, coaxial cable, wire, guided transmission path, taper (coaxial or waveguide)
WT	Wiring tie point
X	Socket (designation of component or device must follow “X” –i.e., XV indicated tube socket, XQ indicates transistor socket, XDS indicates pilot light socket, XF indicates fuse holder
Y	Piezoelectric crystal oscillator, tuning fork resonator, piezoelectric crystal, crystal unit
Z	Artificial line, discontinuity, tuned cavity, network (general), phase shifting network, resonator, tuned circuit

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Section 23. Drawing Change Procedure

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

23.1 Purpose

This section describes the protocol for the initial release of LEA, AAA, and SAA drawings and the revision methodology of drawings associated to parts that have been modified by a sketch or red lined formal or informal drawing.

This section closely aligns with the industry standard *Drawing Requirements Manual* and ASME Y14.35M, "Revision of Engineering Drawings and Associated Documents."

23.2 Applicable Documents

- Global Engineering, *Drawing Requirements Manual*, Tenth Edition, Section 23, "Drawing Change Procedures"
- ASME Y14.35M-1997, "Revision of Engineering Drawings and Associated Documents"

23.3 Initial Release

As of January 2003, the first issuance of a formal or informal drawing requires a unique number with assigned letters –AA as the last two characters of the drawing number. When approved, these letters denote the initial release revision for official use distribution. This unique number is obtained from the Engineering Records Center web site or institutional data management system such as ECMS. (Refer to Engineering Policy 4.1.2, "Conventions for Numbering Engineering Drawings, Documents and Parts.") The initial release revision is identified with uppercase letters in the suffix of the LEA, AAA, or SAA drawing number–for example, LEA03-123456-AA–and is recorded in the revision block with a description of "INITIAL RELEASE." The first change to the drawing is rolled to the next sequenced revision, –AB.

Drawings require that all revision callouts on each sheet of a drawing match the latest revision specified in the revision block. When revisions to a drawing have gone through the "AA" level of allowable revisions then the next revision is –BA through –BY; –CA through –CY; etc. Refer to subsection 23.6, "Legacy Revisions," for previous revision methodologies still used on drawings issued prior to January 2003.

To avoid possible confusion between similar numbers and letters, the letters **I, O, Q, S, X**, and **Z** are never used in the first or second position of any drawing revision issued in 2003 or later. It is acceptable to use the letter "O" in the first position only on drawings issued in 2002 or earlier.

23.4 Revisions

Engineering accepts the simplified method of direct revision for indicating changes on a drawing. This method records all changes/modifications to the original drawing, or digital

CAD data, directly in the revision block on the face of the drawing at the time the change is authorized.

The revision block contains the following minimum information:

- DRAWN BY (OUN signatures or electronically applied)
- CHECKED BY (OUN signatures or electronically applied)
- APPROVED BY and DATE (OUN signatures or electronically applied)
- Description of change(s)
- Zone callout
- Revision symbol on the field of the drawing for each change. The revision symbol is a bold circle (0.50 inch in diameter on a full-size drawing) containing the revision letter.

The use of revision suffix numbers to record multiple same revision changes is an acceptable practice. The suffix number identifies multiple same revision changes on the field of the drawing. The suffix number is recorded in the revision block and the revision balloon found on the face of the drawing. (See Figures 23-1 and 23-2 as examples. Do not interpret any other drafting preferences from these examples.)

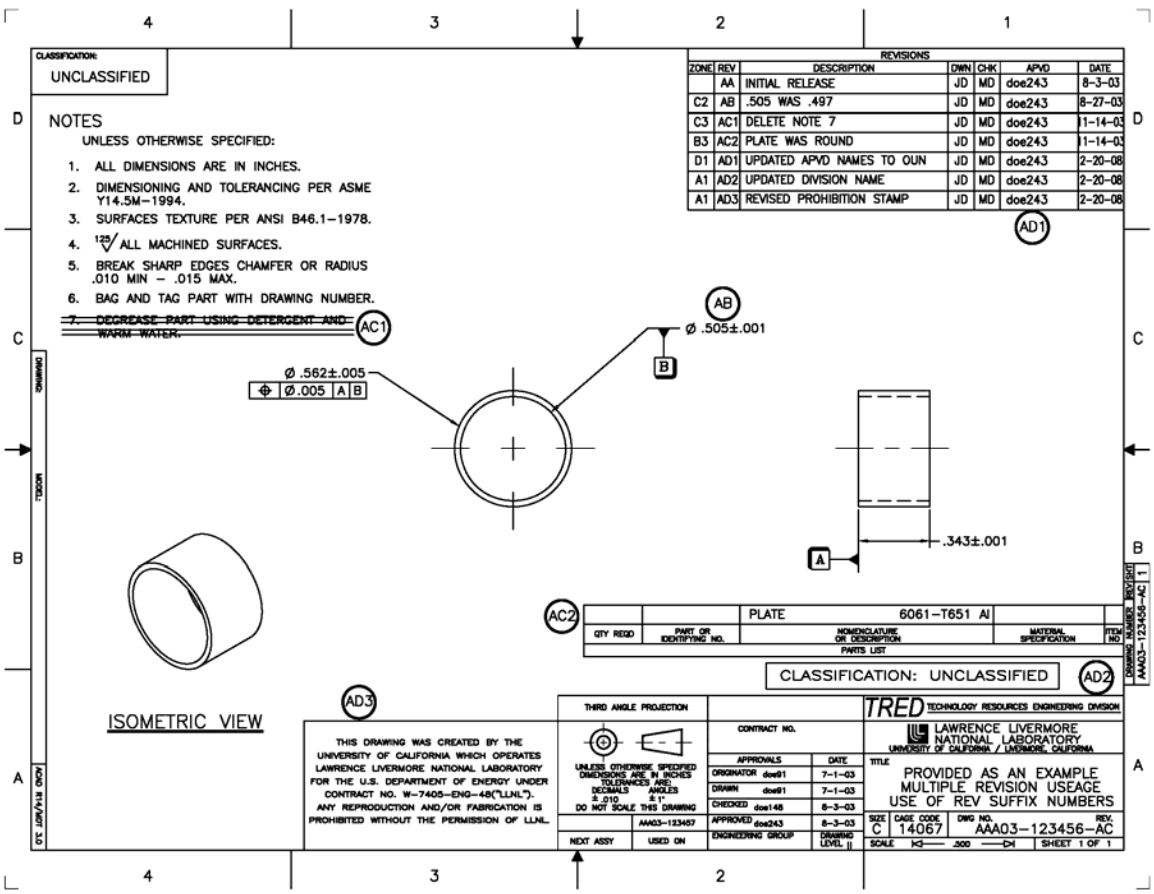

Figure 23-1. Multiple revision usage preferred

REVISIONS						
ZONE	REV	DESCRIPTION	DWN	CHK	APVD	DATE
	AA	INITIAL RELEASE	SILVA11	GILBERT7	RISINGER1	05/01/14
SH1	AB	(1) REMOVED NOTES #11 AND #14 ADDED NOTES #15 AND #16	ALFORD3	GILBERT7	HARSCH2	06/05/02
SH1		(2) RELOCATED DETAIL A				
SH3		(3) ADDED SECTION VIEW F-F ADDED SECTION VIEW G-G				
SH3		(4) ADDED 2X R9.530				
SH2		(5) 2X R.500 MAX WAS .250 ± .015				
SH1	AC	(1) ADDED MISSING DIMENSION	ALFORD3	HARSCH2	HARSCH2	06/07/26
SH2		(2) LIGHT PRESS FIT ASSEMBLY WAS WELDED CONSTRUCTION				
SH1		(3) REMOVED NOTE #9				

Figure 23-2. Multiple revision usage optional

All revisions of released drawings must follow the same review and release process (the Drawn By/Checked By/Approved By process) as the initial release. Revisions shall be reviewed and approved by the same Responsible Design Organization (RDO) that originally reviewed and approved the drawing(s).

In the event another design organization wishes to use an existing drawing, and its associated part or assembly, previously assigned an LEA, AAA, or SAA number, a new drawing is generated by copying the existing drawing, and its associated part or assembly and assigning it a new drawing number. This process is sometimes referred to as “rolling” a part (drawing) number. This process protects the integrity of the original design and provides a method for expediting the creation of a new drawing.

More formal methods of drawing revision and/or configuration management are at the discretion of the program/project that created the drawing. (See “Drawing Change Procedure” in the *Drawing Requirements Manual* for more detailed examples of these formal drawing change procedures.)

23.5 Drawings and Parts, Modified by Redlines

It is sometimes necessary to modify existing parts or make “field changes” to released drawings. The use of sketches or redlined drawings to modify existing parts or released drawings are an informal engineering change order process. Although this practice is discouraged, in preference of the incorporated simplified revision process, it is recognized that circumstances may dictate otherwise. Modifications made in this manner require review and approval by the designated responsible individual, responsible engineer, or design group, for functionality, ES&H concerns, etc.

In either case, sketch or redlined drawing, desired modifications shall be communicated to the designated responsible individual, responsible engineer, or design group for review and approval prior to any modification of the physical component. The decision to incorporate approved modifications into the released drawing is determined by the same group reviewing and approving the modifications.

23.6 Legacy Revisions

The following addresses Engineering's revision procedure for legacy drawings requiring revision control. All drawings first issued in 2002 or earlier should continue with the revision cycle currently in use. For example, if a drawing has an –OH revision and requires a change, the next revision shall be –OJ. Changes continue in this fashion to –OY. The next revision to follow is –PA (next sequenced revision, as the letter P follows the letter O in the alphabet). When dealing with drawings released prior to 2003, always refer to the change block to ascertain the legacy revision methodology.

23.7 Problem/Solution Examples

Problems and their solutions follow, relating to revisions at LLNL.

23.7.1 Drawing Revisions for Reworked Part

The Problem: On drawings of existing parts to be reworked, change blocks seem to take on some troublesome forms, for example:

1. All changes are not listed.
2. "GENERAL REVISION" is used as a change descriptor.

On a part to be reworked, the shop must check each and every dimension just to see what has been changed.

AB	MC	JONESY3	VAXY1	8/4/04	~	GENERAL REVISION
AA	MC	JONESY3	VAXY1	5/20/04	ALL	GENERAL REVISION
LTR	DRW	CHK	APVD	DATE	ZONE	CHANGE

The Solution: If a part is to be reworked, list all changes.

AB3	MC	JONESY3	VAXY1	8/4/04	K16	ADDED NOTE 7
AB2	MC	JONESY3	VAXY1	8/4/04	E10	3.7 WAS 3
AB1	MC	JONESY3	VAXY1	8/4/04	E9	Ø2.2 WAS Ø2
AA2	MC	JONESY3	VAXY1	5/20/04	F13	0.76 WAS 0.5
AA1	MC	JONESY3	VAXY1	5/20/04	D5	0.5 WAS 0.4
LTR	DRW	CHK	APVD	DATE	ZONE	CHANGE

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Section 24. Abbreviations

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

24.1 Purpose

This section contains a list of abbreviations commonly used on drawings. For additional abbreviations, refer to ASME Y14.38A-2002.

24.2 Applicable Documents

- ANSI/IEEE STD 260.1, "Standard Letter Symbols For Units Of Measure"
- IEEE/ASTM SI 10-2002, "American National Standard for Use of the International System of Units (SI): The Modern Metric System"
- ASME Y14.38A-2002, "Abbreviations and Acronyms"

24.3 Form

Periods should not be used with abbreviations unless they are needed to provide clarity and avoid misinterpretation. For example, the abbreviation "ABS" for absolute should not be followed by a period.

On drawings, upper-case letters are to be used for all text except where the use of lower-case letters has been established by long practice.

Note: Abbreviations used in drawing titles should conform to requirements given in Section 8, "Drawing Titles."

24.4 Rules for Use

Abbreviations should be used only when necessary and only when the meanings are unquestionably clear. When there is any doubt concerning the use of an abbreviation, the word should be spelled out.

Abbreviations of word combinations should be used only as such, and should not be separated for use as single-word abbreviations. Single-word abbreviations may be combined, but only if the meaning is clearly retained. For example, milliamperes direct current is represented as mA DC.

The same abbreviation should be used for all tenses, the possessive case, and the singular and plural forms of a given word (e.g., control, controlled, controls, and control's are all abbreviated CONT).

24.5 Color Abbreviations (Base Units)

Color	Abbreviation
Black	BLK
Blue	BLU
Brown	BRN
Green	GRN
Gray	GRY
Orange	ORN
Red	RED
Violet	VIO
White	WHT
Yellow	YEL

24.6 SI Abbreviations (Base Units)

Unit Name	Symbol or Abbreviation	Quantity	Multiples and Submultiples
Ampere	A	electric current	kA, mA, µA, nA, pA
Candela	cd	luminous intensity	
Kelvin	K	thermodynamic-temperature*	mK
Kilogram	kg	mass	Mg, g, mg, µg
Meter	m	length	km, cm, mm, µm, nm
Mole	mol	amount of substance	kmol, mmol, µmol
Second	s	time	ks, ms, µs, ns, ps

* Degree Celsius (ºC) accepted (ºC = ºK–273.15)

24.7 SI Derived Units with Special Names

Unit Name	Symbol or Abbreviation	Quantity	Formula	Multiples and Submultiples
Coulomb	C	electric charge	A•s	kC, mC, µC, nC, pC
Farad	F	electric capacitance	C/V	mF, µF, nF, pF
Henry	H	inductance	Wb/A	mH, µH, nH, pH
Hertz	Hz	frequency	1/s or s^{-1}	THz, GHz, MHz, kHz
Joule	J	energy	N•m	TJ, GJ, MJ, kJ, nJ
Lumen	lm	luminous flux	cd sr	
Lux	lx	illuminance	m^{-2}•cd•sr	
Newton	N	force or weight	m•kg•s^{-2}	MN, KN, mN, µN
Ohm	Ω	electric resistance	V/A	GΩ, MΩ, kΩ, mΩ, µΩ
Pascal	Pa	pressure or stress	N/m^2	kPa
Siemen	S	conductance	A/V	kS, mS, µS, nS
Tesla	T	magnetic flux density	Wb/m^2	mT, µT, nT
Volt	V	electric potential	W/A	MV, kV, mV, µV
Watt	W	power	J/s	TW, GW, MW, kW, mW, µW, nW
Weber	Wb	magnetic flux volume	V•s	

24.8 Selected Abbreviations for Drawings

Term	Abbreviation
acme screw thread	ACME
approximate	APPROX
as required	AR
assembly	ASSY
bend radius	BR
bolt circle	BC
cap screw	CAP SCR
carbon steel	CS
center line	CL
chamfer	CHAM
clockwise	CW
company	CO
continued	CONT
corrosion resistant steel	CRES
counterbore	CBORE

Term	Abbreviation
counterclockwise	CCW
counterdrill	CDRILL
countersink	CSK
cubic centimeters	CC
cubic foot	CUFT
cubic inch	CUIN
cubic meter	CUM
cubic meter(s) per second	m^3/s
cubic millimeter	CUMM
cubic yard	CUYD
curie	Ci
decibel	DB
decibel referred to 1 milliwatt	dBm
decibel referred to 1 volt	dBV
deep	D

Term	Abbreviation
degree Celsius	ºC
degree Fahrenheit	ºF
degree Kelvin	ºK
degree Rankine	ºR
degree(s) (for angle)	…º
density	DENS
department	DEPT
depth	DP
derivative	DERIV
deuteron	d
diameter	DIA
diametral pitch	DP
dimension	DIM
direct current	DC
disintegrations per second	dis/s
dollar	$
double sideband	DSB
dozen	DOZ
drawing	DWG
drawing number	DWG NO
dyne	dyn
efficiency	EFF
electric	ELEC
electrocardiograph	ECG
electroencephalograph	EEG
electromagnetic compatibility	EMC
electromagnetic unit	EMU
electromotive force	EMF
electronic data processing	EDP
electronvolt	eV
electrostatic unit	ESU
elevation	EL
equally spaced	EQLSP
equation	EQ
equivalent	EQUIV
erg	erg
exponent or exponential	EXPNT
external	EXT
extra fine (thread)	EF
extra-high voltage	EHV
extremely high frequency	EHF
extremely low frequency	ELF

Term	Abbreviation
fabricate	FAB
farad	F
feet per minute	FPM
feet per second	FPS
field-effect transistor	FET
figure	FIG
fillister head	FILH
finish all over	FAO
fitting	FTG
flange	FLG
flat head	FLH
foot	FT
foot lambert	fL
foot poundal	ft•pdl
foot pound-force	FTLB
for example	EG
free on board	FOB
frequency	FREQ
frequency modulation	FM
frequency-shift keying	FSK
full width at half maximum	FWHM
gallon(s)	GAL
gallons per minute	GPM
gallons per second	GPS
gauss	G
giga (prefix, 10^9)	G
gigacycle per second	Gc/SEC
gigaelectronvolt	GeV
gigahertz	GHz
gilbert	Gi
gram	G
gram calorie	cal
grams per cubic centimeter	G/CC
grams per liter	G/L
gravity, acceleration of	G
gravity, center of	CG
ground-controlled approach	GCA
henry(s)	H
hertz (cycle per second)	Hz
hexagonal head	HEXHD
hexagonal socket head	HEXSOCH
high	H

Term	Abbreviation
high explosive	HE
high frequency	HF
high voltage	HV
horizontal	HORIZ
horsepower	HP
horsepower-hour	HPHR
hour	HR
hyperbolic cosine	COSH
hyperbolic cotangent	COTH
hyperbolic secant	SECH
hyperbolic sine	SINH
hyperbolic tangent	TANH
in accordance with	IAW
in the place cited	LOCCIT
inch	IN
inches per second	IPS
inch-pound	INLB
inductance	IND
inductance-capacitance	LC
infrared	IR
inside diameter	ID
inside radius	IR
instrument landing system	ILS
intermediate frequency	IF
interrupted continuous wave	ICW
joule	J
joule(s) per degree	DEG
joule(s) per degree Kelvin	J/ºK
keyway	KWY
kilo (prefix, 10^3)	k
kilocalorie	kcal
kilocurie(s)	kCi
kiloelectrovolt	keV
kilogauss	kG
kilogram	kg
kilogram-force	kgf
kilohertz	kHz
kilohm	kΩ
kilojoule	kJ
kilometer	km
kilometer(s) per hour	km/HR
kilometer(s) per second	km/SEC

Term	Abbreviation
kilovolt	kV
kilovoltampere	kVA
kilowatt	kW
kilowatthour	kWh
kinetic energy	KE
laboratory	LAB
lambert	L
left hand	LH
length	LG
liter	L
liter(s) per second	L/SEC
logarithm (common)	LOG
logarithm (natural)	LN
long	L
low frequency	LF
lumen	lm
lumen second	lm•s
lumen(s) per square foot	lm/SQFT
lumen(s) per square meter	lm/SQM
lumen(s) per watt	LPW
lux (lumen(s)/m^2)	lx
machine	MACH
machine screw	MSCR
magnetohydrodynamics	MHD
magnetomotive force	MMF
male pipe thread	MPT
manufacturer	MFR
material	MATL
maximum	MAX
maxwell	Mx
mean free path	MFP
medium frequency	MF
mega (prefix, 10^6)	M
megacurie	MCi
megaelectron volt	MeV
megahertz	MHz
megavolt	MV
megavolt ampere	MVA
megawatt	MW
megawatt-hour	MWh
megohm	MΩ
metal-oxide semiconductor	MOS

Term	Abbreviation
meter (instrument)	MTR
meter (unit)	m
meter-kilogram-second	MKS
micro (prefix, 10^{-6})	µ
microampere	µA
microcoulomb	µC
microcurie	µCi
microfarad	µF
microgram	µG
microhenry	µH
microinch	µIN
micrometer (or micron)	µm
microradian	µRAD
microsecond	µSEC
microsiemens	µS
microvolt	µV
microwatt	µW
mil	MIL
mile	MI
mile(s) per hour	MPH
milli (prefix, 10^{-3})	m
milliampere	mA
millicurie	mCi
milligram	mG
millihenry	mH
millilambert	mL
milliliter	mL
millimeter	mm
millimeter(s) of mercury	mmHg
million volts	MV
millionelectronvolt	MeV
milliradian	mRAD
milliroentgen	mR
millivolt	mV
milliwatt	mW
minimum	MIN
minute (angle)	…’
minute (time)	MIN
model	MOD
modification, modify	MOD
modulated continuous wave	MCW
molecular weight	MOLWT

Term	Abbreviation
month	MO
motor generator	MG
moving target indicator	MTI
nano (prefix, 10^{-9})	n
nanoampere	nA
nanofarad	nF
nanometer	nm
nanosecond	nSEC
nanowatt	nW
National Electric Code	NEC
natural logarithm	LN
nautical mile	NMI
neper	Np
neutron	NTN
newton	N
newton meter	N•m
number	NO
oersted	Oe
ohm	Ω or OHM
ohm centimeter	Ω•cm
optical density	OD
ounce	OZ
outside diameter	OD
outside radius	OR
pan head	PNH
part number	PN
parts per million	PPM
peak-to-peak	PP
per	PER
percent	%
perpendicular	PERP
phase modulation	PM
pico (prefix, 10^{-12})	p
picoampere	pA
picofarad	pF
picosecond	pSEC
picowatt	pW
pitch diameter	PD
place, places	PL
plan position indication	PPI
plated	PLD
post meridian	PM

Term	Abbreviation
pound	LB
poundal	pdl
pound-force	lbf
pound-force foot	LB•FT
pound-force per square inch	PSI
pound-ft	LB•FT
pound-inch	LB•IN
pounds per square inch	PSI
pounds per square inch, absolute	PSIA
pounds per square inch, gage	PSIG
power factor	PF
private branch exchange	PBX
proportional	PROPN
pulse repetition frequency	PRF
pulse repetition rate	PRR
pulse-amplitude modulation	PAM
pulse-code modulation	PCM
pulse-count modulation	PCTM
pulse-duration modulation	PDM
pulse-position modulation	PPM
pulse-time modulation	PTM
pulse-width modulation	PWM
radian	RAD
radio direction finder	RDF
radio frequency	RF
radio frequency interference	RFI
radius	R
reference	REF
relative biological effectiveness	RBE
required	REQD
resistance	R
resistance-capacitance	RC
resistance-inductance-capacitance	RLC
revise	REV
revolutions per minute	RPM
revolutions per second	RPS
right hand	RH
roentgen	R
roentgen equivalent, man	REM
roentgen equivalent, physical	REP
root-mean-square	RMS
round head	RDH

Term	Abbreviation
schedule	SCHED
screw	SCR
secant	SEC
second (angle)	”
second (time)	SEC
section	SECT
set screw	SSCR
short-wave	SW
siemens	S
signal-to-noise ratio	SNR
silicon-controlled-rectifier	SCR
sine	SIN
single sideband	SSB
socket head	SCH
specific gravity	SPGR
specific heat	SPHT
specific volume	SPVOL
specification	SPEC
speed of light	c
spherical	SPHER
spot face	SF
square	SQ
square foot	SQFT
square inch	SQIN
square kilometer	SQKM
square meter	SQm
square millimeter	SQmm
square root of mean square	RMS
square yd	SQYD
stainless steel	SST
standard	STD
standard (conditions of) temperature and pressure	STP
standing-wave ratio	SWR
steel	STL
steradian	SR
stock	STK
subassembly	SUBASSY
superhigh frequency	SHF
symmetrical	SYMM
tangent	TAN
taper pipe thread	NPT
television	TV

Term	Abbreviation
television interference	TVI
temperature	TEMP
tesla	T
that is	IE
thick	THK
thin-film transistor	TFT
thousand	k
thousand circular mils	kcmil
thousand electron volts	keV
thread	THD
through	THRU
tolerance	TOL
transmit-receive	TR
transverse electric	TE
transverse electromagnetic	TEM
transverse magnetic	TM
traveling-wave tube	TWT
typical	TYP
ultrahigh frequency	UHF
ultraviolet	UV
unified coarse thread	UNC
unified extra fine thread	UNEF
unified fine thread	UNF
unified special thread	UNS
unless otherwise specified	UOS
vacuum	VAC
vacuum-tube voltmeter	VTVM
variable-frequency oscillator	VFO

Term	Abbreviation
velocity	VEL
versus	VS
vertical	VERT
very high frequency	VHF
very high frequency omnirange	VOR
very low frequency	VLF
vestigial sideband	VSB
video-frequency	VIDF
volt	V
voltage controlled oscillator	VCO
voltage regulator	VR
voltage standing-wave ratio	VSWR
voltampere	VA
volts per meter	V/m
volume	VOL
volume unit	VU
wall	W
watt	W
watt(s) per steradian	W/SR
watt(s) per steradian-square meter	W/(SR•SQM)
watthour	WH
weber	Wb
weight	WT
wide	W
yard	YD
year	YR

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Section 25. Definitions

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

25.1 Purpose

This section contains a list of acronyms commonly used at LLNL.

25.2 Applicable Documents

- http://physci-r.llnl.gov/sso/r_acronyms.htm
- https://nif-int.llnl.gov/files/pdf/acronyms.pdf

25.3 LLNL Acronyms

ADC	Authorized Derivative Classifier
AIS	Administrative Information Systems
AISSO	Alternate Information Security Systems Officer
AM	Assurance Manager
ARO	Assurance Review Office
ASCI	Accelerated Strategic Computing Initiative
ASCII	American Standard Code for Information Interchange
BBRP	Biology & Biotechnology Research Directorate
BS	Business Services
CAS	Classified Administrative Specialist
CIO	Chief Information Officer
CMS	Chemistry and Materials Science
CL	Classification Office
CSP	Computer Security Plan
DNT	Defense and Nuclear Technologies Directorate
DOD	Department of Defense
DOE	Department of Energy
DOT	Department of Transportation
DTED	Defense Technologies Engineering Division
EODD	Employee and Organization Development Division
EPA	Environmental Protection Agency
EPD	Environmental Protection Department
ETD	Engineering Technologies Division
FN	Foreign National
FPOC	Facility Point of Contact
FTO	Foreign Travel Office
FTS	Foreign Travel System
FSP	Facility Safety Plan
FTE	Full Time Employee
FY	Fiscal Year
GAO	Government Accounting Office

GUI	Graphical User Interface
HAR	Hazard Analysis Report
HCD	Hazards Control Department
HEPA	High-Efficiency Particulate Air Filter
H&S	Health & Safety
H&SM	Health & Safety Manual
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HWM	Hazardous Waste Management
HVAC	Heating, Ventilation and Air Conditioning
IC	Incident Commander
IH	Industrial Hygiene
IS	Information Systems
IT	Information Technology
ISM	Integrated Safety Management
ISSO	Information Systems Security Officer
IWS	Integration Work Sheet
LAN	Local Area Network
LANL	Los Alamos National Laboratory
LEDO	Laboratory Emergency Duty Officer
LLC	Limited Liability Corporation
LLNL	Lawrence Livermore National Laboratory
LLNS	Lawrence Livermore National Security
LSEO	Laser Systems Engineering & Operations Division
MOU	Memorandum of Understanding
MSDS	Material Safety Data Sheet
NAI	Nonproliferation, Arms Control and International Security
NFPA	National Fire Protection Association
NIF	National Ignition Facility
NNSA	National Nuclear Security Administration
NSED	National Security Engineering Division
OAK	DOE Oakland Operations Office
OIS	Office of Investigative Services
OISSO	Organizational Information Systems Security Officer
OSHA	Occupational Safety and Health Administration
OSP	Operational Safety Plan
OUO	Official Use Only
PAO	Public Affairs Office
Ph	Online Personnel Directory
POC	Point of Contact
P&AT	Physics & Advanced Technologies
PWS	Procurement Work Sheets
QA	Quality Assurance
R&D	Research & Development
SAR	Safety Analysis Report

SCR	Facility Hazard Screening Report
SLO	Supplemental Labor
SND	Systems and Network Department
SSR	Sensitive Subject Review
SUI	Sensitive Unclassified Information
TRED	Technology Resources Engineering Division
TRR	Technical Release Representative
UC	University of California
UCNI	Unclassified Controlled Nuclear Information
URL	Uniform Resource Locator
VTS	Visitor Tracking System
WAA	Waste Accumulation Area
WAN	Wide Area Network
WFO	Work for Others
WMD	Weapons of Mass Destruction
WSS	Work Smart Standards

25.4 NIF Acronyms

A/D	analog to digital
	assembly/disassembly
AA	automatic alignment
AAAP	advanced acquisition or assistance plan
AAFEP	Automatic Alignment Front-End Processor
AC	alternating current
ACC	access control computer
ACD	advanced conceptual design
ACDR	Advanced Conceptual Design Report
ACE	American Controls Engineering
ACIS	Attribute Capture and Information System
ACS	Access Control System
ACWP	Actual Cost of Work Performed
AD	Associate Director
ADP	automated data processing
AE	Architectural Engineering (Division)
	Acquisition Executive
AEC	Atomic Energy Commission
AFM	atomic force microscope
AGEX	aboveground experimental
AGV	automated self-guided vehicle
AHF	Advanced Hydrotest Facility
AHJ	Authority Having Jurisdiction
AHU	air-handling unit
AI	Authorizing Individual
AIC	assembly, installation, and commissioning
AIM	Area Integration Manager

AIR	Assembly, Installation, and Refurbishment
AISC	American Institute of Steel Construction
AIT	Area Integration Team
ALARA	as low as reasonably achievable
ALS	Advanced Light Source
	alignment light source
AM	amplitude modulation
	area manager
AMC	amplifier cavity
AMP	assembly and maintenance processing
	amplifier module prototype
AMPLAB	Amplifier Module Prototype Laboratory
AMS	Aerosol Monitoring System
ANL	Argonne National Laboratory
ANSI	American National Standards Institute
APE	Associate Project Engineer
APE/L	Associate Project Engineer/Leader
APL	Associate Program Leader
	Associate Project Leader
	assembly point leader
APM	Associate Project Manager
APS	American Physical Society
AQCR	Air Quality Control Region
AR	anti-reflection
ARC	air recirculation chamber
	Advanced Radiography Capability
ARG	argon
ARO	assembly, refurbishment, and operation
	Assurance Review Office
ARS	Advanced Radiation Source
ASBO	active shock break-out diagnostic
ASCI	Accelerated Strategic Computing Initiative
ASE	amplified spontaneous emission
ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineers
ASME	American Society of Mechanical Engineers
ATM	asychronous transfer mode
ATP	acceptance test procedure
AVLIS	Atomic Vapor Laser Isotope Separation
AWE	Atomic Weapons Establishment
AWG	arbitrary waveform generator
AWID	Automatic Window Inspection System (NASA)
B or Bu	bundle
BA	Budget Authority
	booster amplifier
BAAQMD	Bay Area Air Quality Management District
BAC	Budget at Complete

BATSAMP	bottom-access, transfer-service for assembly and maintenance processing
BAU	basic assembly unit
BC	beam control
BCCB	Baseline Change Control Board
BCLD	beam control and laser diagnostics
BCP	Baseline Change Proposal
	best current practice
BCS	Beam Control System
BCWP	Budgeted Cost of Work Performed
BCWS	Budgeted Cost of Work Scheduled
BD	beam dump (insertable shutter between RM enclosure and SY)
BDA	beam-defining aperture
BDP	beam diagnostic processors
BDDS	Beam Delivery and Diagnostics System
BE	beampath enclosure
BEBA	beyond evaluation basis accident
BEEF	Big Explosives Experimental Facility
BEIR	Biological Effects of Ionizing Radiation (Committee)
BIOS	basic input output system
BIS	Beampath Infrastructure System
BITM	BIS Integration Team Manager
BL	bottom loading
BLDS	bottom-loading delivery system
BLIP	beamline integrated performance
BLOP	beamline optic performance
BLU	bottom-loading universal (canister)
BNLA	Bechtel Nevada Los Alamos
BNSB	Bechtel Nevada Santa Barbara
BO	Budget Outlay
BOM	Bill of Materials
BRS	back-reflection sensor
BSCR	Budget/Schedule Change Request
BSG	beam sampling grating
BSM	beam shaping module
BSU	basic switch unit
BSW	beam sampling window (attached to SF-4)
BTB	beam to beam
BTBD	bang-time and burn duration
BTR	Budget Transfer Request
BTS	Beam Transport System
C	cluster
C/M	control monitor
CA	compressed air
	controlled area
CAA	Clean Air Act
CAD	computer-aided design

CADD	computer-aided design and drafting
CAL	calorimeter
CAL-OSHA	California Occupational Safety and Health Administration
CAM	Controls Activation Manager
	Cost Account Manager
CAP	Cost Account Plan
	Control Account Plan
CATS	Crystal Alignment Test System
CAVE	Crystal Alignment and Verification Equipment
	Converter Assembly Verification Equipment
CB	Capacitor Bay
CBSC	California Building Standards Code
CBT	computer-based training
CC	critical chain
CCA	common component architecture
CCB	Configuration Control Board
	Change Control Board
CCC	Change Control Coordinator
CCD	closed-circuit detector
	charge-coupled device
CCE	Contra Costa Electric
CCI	Cleveland Crystals, Inc.
CCL	Control Center Leader
CCP	clean construction protocol
	Cleanliness Control Plan
CCR	California Code of Regulations
	chamber center reference
	classified computer room
	configuration control requirement
CCRS	Chamber Center Reference System
CCS	change control system
CCT	change control threshold
CD	Critical Decision
CDA	clean, dry air
CDIN	Classified Distributed Information Network
CDL	California Digital Library
CDPO	Classified Document Project Office
CDR	Conceptual Design Report
	Comprehensive Design Review
CDRL	Contract Data Requirements List
CEA	Commissariat a L'Energie Atomique
CEDE	committed effective dose equivalent
CEL-V	Centre d'Etude de Limeil – Valenton
CEO	Chief Executive Officer
CEP	Controls Engineering Plan
CEPE	controlled-environment process enclosure

CEQ	Council on Environmental Quality
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	Conventional Facility
CF/CM	Conventional Facilities Construction Management
CFC	chlorofluorocarbons
CFD	computational fluid dynamics
CFF	Contained Firing Facility
CFM	cubic feet per meter
CFO	Chief Financial Officer
CFM	cubic feet per minute
CFQ	clear-fused quartz
CFR	Code of Federal Regulations
CFS	continuous filtration system (for crystal growth tanks)
CHAINOP	chain optimization
CHW	chilled water
CIAC	Computer Incident Advisory Capability
CI I	Construction Industry Institute
CIM	conditioning, initiation, and mitigation
CIVS	Chamber Interior Viewing System
CLOT	Clean Large Optic Transport
CM	Construction Manager
	Configuration Management
CMMS	Computerized Maintenance Management System
CMP	Configuration Management Plan
CMT	Construction Management Team
CMU	concrete masonry unit
CNC	condensation nucleus counter
CNM	control network monument
CO	Cassegrain optic
	Commissioning and Operations
COB	crystal on bottom
COMS	Crystal Orientation Measurement System
CORBA	Common Object Request Broker Architecture
CORI	coaxial reference interferometer
CORR	Contractor Operational Readiness Review
COTR	Contracting Officer's Technical Representative
COTS	commercial off the shelf
CP	continuous polisher (same as a ring polisher)
CPAF	cost plus award fee
CPFF	cost plus fixed fee
CPI	cost performance index
CPIF	cost plus incentive fee
CPM	Critical Path Method
CPP	continuous phase plate
CPU	central processing unit
CR	Control Room

CRADA	Cooperative Research and Development Agreement
CREM	Classified Removable Electronic Media
CRO	Change Request Order
CS&T	core science and technology
CSC	computer software components
CSF	cavity spatial filter
CSF-A	CSF-alignment tower
CSF-D	CSF-diagnostic tower
CSG	color separation grating
CSO	Construction Safety Officer
CSP	Construction Safety Program
	Construction Subcontract Package
CSTP	Core Science and Technology Plan
CTBT	Comprehensive Test Ban Treaty
CTM	cryogenic target mount
CTP	commissioning test procedure
CTR	Cost Transfer Request
	Contingency Transfer Request
	Contract Technical Representative
CTS	Cross-Timing System
	Cryogenic Target System
Cu	curie
CV	cost variance
CVD	chemical vapor deposition
CVI	C virtual instruments
CVS	Cleanliness Verification System
CW	continuous wave
CWA	Clean Water Act
D_2TS	Deuterium Test System
D&D	decontamination and decommissioning
D/A	digital to analog
DAD	Deputy Associate Director
DAPE	Deputy Associate Project Engineer
DARHT	Dual Axis Radiographic Hydrodynamic Test (Facility)
DAS	Data Acquisition System
DBA	Design Basis Accidents
DBB	Design Basis Book
DBE	Design Basis Earthquake
DBFL	design basis flood
DBR	Distributed Bragg Reflector
DBS	diagnostic beamsplitter
DBW	design basis wind
DC	device controller
	diagnostic controller
	dc direct current
DCC	Document Control Center

DCI	diagnostic controls integration
DCO	Directed Change Order
DCP	Diagnostic Communication Protocol
DDC	direct digital control
DDI	direct-drive ignition
DDL	Deputy Division Leader
DDS	Disposable Debris Shield
DEC	Digital Equipment Corporation
DefTrack	deficiency tracking (Laser Program's ES&H database)
DEIS	Draft Environmental Impact Statement
DFB	distributed feedback (laser)
DFM	deformable mirror
	Diamond Flycutting Machine
D-GDP	deuterated polymer
DIM	Diagnostic Instrument Manipulator
DIMU, DIM-U	DIM utilities
DJO	digital job order
DKDP	deuterated potassium dihydrogen phosphate
DL	Division Leader
DM	deformable mirror
DM1 & 2	Diagnostic Mezzanine Levels 1 and 2
DMS	Damage Mapping System
DNT	Defense and Nuclear Technologies
DOE	Department of Energy
DOE/DP	Department of Energy – Defense Programs
DOE/GC	Department of Energy – General Council
DOE/HQ	Department of Energy – Headquarters
DOE/OAK	Department of Energy – Oakland Operations Office
DOE/ORO	Department of Energy – Oak Ridge Operations
DOE/RFP	Department of Energy – Rocky Flats Plant
DOF	degrees of freedom
DOFAST	Diffractive Optic Full Aperture System Test
DOI	Department of the Interior
DOJ	Department of Justice
DOP	diffractive optics plate
DOT	Department of Transportation
DP	Defense Programs
DPP	distributed phase plate
DPEIS	Draft Programmatic Environmental Impact Statement
DPSSL	diode-pumped solid-state laser
DRB	Design Review Board
DRC	design requirements and criteria
	Directorate Review Committee
DS	debris shield
DSA	Documented Safety Analysis
DSCS	Debris Shield Cleaning System

DSTC	debris shield transportation cart (phase 1–manual, phase 2–remote)
DSWA	Defense Special Weapons Agency
DT	deuterium-tritium
DTC	diagnostic transportation cart
DTRA	Defense Threat Reduction Agency
DU	depleted uranium
DVB	divinylbenzene
DW	demineralized water
DWTL	Daily Work Team Leader
EA	environmental assessment
EAC	Estimate at Complete
EBA	evaluation basis accident
EBIT	electron-beam ion trap
EBM	energy balance module
EBOM	Engineering Bill of Materials
ECMS	Enterprise Configuration Management System
ECO	Engineering Change Order
ECR	Engineering Change Request
ECR/O	Engineering Change Request/Order
EDAX	energy-dispersive x-ray analysis
EDM	electronic distance measurement
	electron discharge machining
EEO	Equal Employment Opportunity
EESN	Electronic Engineering Safety Note
EFC	Experimental Facilities Commissioning
EIFS	Exterior Insulation and Finish System
EIS	Environmental Impact Statement
ELID	electrolytic in-situ dressing
EM	DOE Office of the Assistant Secretary for Environmental Management
EMC	Emergency Management Center
EMD	Emergency Management Division
EMI	electromagnetic interference
EMP	electromagnetic pulse
EOL	end of life
EOS	equation of state
EPA	Environmental Protection Agency
EPAC	Experimental Planning Advisory Committee
EPD	Environmental Protection Department
EPS	Environmental Protection System
ERC	Engineering Records Center
ERD	Environmental Restoration Division
	entity relationship diagram
ERP	Enterprise Resource Planning
ES	Engineering Service
ESD	electrostatic device
ES&H	Environmental Safety and Health

ESAAB	Energy System Acquisition Advisory Board
ESM	Engineering Services Manager
ETC	Estimate To Complete
EUVL	extreme ultraviolet lithography
EVM	Earned Value Milestone
EVMS	Earned Value Management System
F&I	Facility and Infrastructure
FABS	Full-Aperture Backscatter System
FACA	Federal Advisory Committee Act
FAM	Field Area Manager
FAR	Federal Acquisition Regulations
FAU	frame assembly unit
FCOM	Facility Commissioning, Operations, and Management
FDDI	fiber-distributed data interconnect
	fiber-distributed data interface
FDR	Final Design Review
FEA	finite element analysis
FED	front-end diagnostic
FEIS	Final Environmental Impact Statement
FEIST	Front-End Integrated System Test
FEM	facility environmental monitor
FEP	front-end processor
FET	field-effect transistor
FF	far field
FFL	final-focus lens
FFLEX	filter fluorescer
FHLE	frame-handling lift effector
FI	fast ignitor
	fast ignition
FIB	focused ion beam
FIR	finite impulse response
FIT	facility timing transmitter
FL	focus lens
FLAIR	a failure database
FLIP	facility laser integrated planning
FLO	Final Optics, Large Optics, and Optics Assembly Building
FM	fiscal month
	frequency modulation
	Field Manager
FMEA	failure modes and effects analysis
FOA	Final Optics Assembly
FOC	final optics chamber
	final optics cell
	final optics cassette
FODI	Final Optics Damage Inspection (system)
FONSI	finding of no significant impact

FOS	Final Optic System
FOV	field of view
FPEIS	Final Programmatic Environmental Impact Statement
FPOC	Facility Point of Contact
FR	Federal Register
FR/PC	Functional Requirements/Primary Criteria
FS	fused silica
FSAR	Final Safety Analysis Report
FSC	Federal Supply Classification
FSD	Functional System Description
FSP	Facility Safety Procedure
FTE	full-time equivalent
FTT	facility timing transmitter
FWHM	full-width at half maximum
FWTC	First wall transportation cart
FXI	Framing X-ray Imager
FXR	Flash X-Ray (Facility)
FV	flow valve
FY	fiscal year
FYNSP	Future-Years Nuclear Security Program
GA	General Atomics
GAO	General Accounting Office
GB	gigabyte
GC	General Council
GDP	glow discharge polymer
GDWS	general decontamination workstation
GFCI	ground fault circuit interrupter
GFE	government-furnished equipment
GFM	ground fault monitor
GFRC	graphite fiber-reinforced carbon
GHz	gigahertz
GISO	General Industry Safety Orders
GL	Group Leader
GPIB	general-purpose interface bus
GPS	Global Positioning System
GRS	gamma x-ray spectrometer
GSA	General Services Administration
GSCP	Generic Streak Camera Platform
GUI	graphical user interface
GVD	group velocity dispersion
GW	gigawatts
GXD	Gated X-ray Detector
GXI	Gated X-ray Imager
HA	humid air
HAPL	high-average-power laser
HAP	hazardous air pollutants

HAR	Hazard Analysis Report
HASAP	Hazard Assessment Safety Action Plan
HCD	Hazards Control Department
HCS	Hazard Communication Standard
HDOS	hydrogen deuteride
HE	high explosives
He	helium
HEDES	High Energy Density Experimental Science (name of program)
	high-energy-density experimental science (lc if general term)
HEDP	High Energy Density Physics (name of a program)
	high-energy-density physics (lc if general term)
HEDSP	High Energy Density Stockpile Physics (name of program)
	high-energy-density stockpile physics (lc if general term)
HEL	Hugoniot elastic limit
HELSTF	High-Energy Laser System Test Facility
HENEX	(a special x-ray survey spectrometer)
HEPA	high-efficiency particulate air (filter)
HEPPF	High Explosive Pulsed Power Facility
HEPW	high-energy petawatt
HEU	highly enriched uranium
HEXRI	High-Energy X-ray Imager
HF	hydrogen flouride
HI	hazard index
HLW	high-level waste
HPCC	Hensel Phelps Construction Company
HQ	hazard quotient
	headquarters
HR	high reflective
HSD	Health Services Department
HV	high voltage
HVAC	heating, ventilation, and air conditioning
HVPS	high-voltage power supply
HWM	Hazardous Waste Management (division)
HYD	hydraulic (system)
I/O	input/output
IBE	interstage beam enclosure
IBOM	Interim Bill of Materials
IC	integrated control
	integrated circuit
ICC	integrated computer control
ICCS	Integrated Computer Control System
ICD	Interface Control Document
ICE	independent cost estimate
ICF	inertial confinement fusion
ICFAC	Inertial Confinement Fusion Advisory Committee
ICP	inductively coupled plasma

ICRP	International Commission on Radiological Protection
ICS	Industrial Controls System
ICST	Industrial Complex Short-Term (model)
ICUIL	International Committee on Ultrahigh Intensity Lasers
ID	internal diameter
IDI	indirect-drive ignition
IDL	Image Diagnostic Language
IEEE	Institute of Electrical and Electronics Engineers
IET	Integrated Experimental Team
IFE	inertial fusion energy
IFF	Internal Fusion Technology
IGES	International Graphics Exchange Standard
IH	industrial hygiene
IHS	information handling systems
IIPP	Injury and Illness Prevention Program
IL	intensity-path length
	input laser
ILE	Institute of Laser Engineering (Japan)
ILS	Injection Laser System
IMI	Integration Management and Installation
INEEL	Idaho National Engineering and Environmental Laboratory
INEL	Idaho National Engineering Laboratory
IO	integrated optical
IOM	integrated optics module
IP	Internet Protocol
	Implementation plan
IPA	isopropyl alcohol or isopropanol
IPAT	Independent Project Assessment Team
IPM	In Place Machining Corp.
IPRB	Integrated Product Review Board
IPS	Integrated Project Schedule
IPT	Integrated Product Team
IPTL	Integrated Product Team Leader
IQ	installation qualification
IR	infrared
IRP	integrated resource planning
IS	input sensor
ISDF	interstage docking frame
ISE	interstage enclosure
I-SITE	in situ interferometric test equipment
ISMS	Integrated Safety Management System
ISP	input sensor package
ISS	Integrated Safety System
IT	Information Technology
I-TIC	ignition target inserter and cryostat
ITR	Institutional Training Requirement

ITS	Integrated Timing System
	Issue Tracking System
ITT	independent test team
IUPAP	International Union of Pure and Applied Physics
IWO	Integrated Work Order
IWS	Integration Work Sheet
JISP	Java Indexed Serialized Package
JEDI	joule energy delivery injection
JFE	Jacobs-furnished equipment
JFI	Jacobs Facilities, Inc.
JHA	Job Hazards Analysis
JISP	Java-Induced Serialized Package
JIT	just in time
JMN	justification of mission need
JOWOG	joint working group
JPL	Jet Propulsion Laboratory
JTP	Java Technology Pilot
K	Kelvin (measure of temperature)
K-25	K-25 Site, Oak Ridge Reservation
KCP	Kansas City Plant
KD	Key Decision
KD*P	deuterated potassium dihydrogen phosphate
KDP	potassium dihydrogen phosphate
kJ	kilojoule
KPP	kinoform phase plate
KSLOC	kilo source line of code
LADS	Large Aperture Diagnostic System
LAN	local area network
LANL	Los Alamos National Laboratory
LANSA	Large Area Neutron Scattering Array
LANSCE	Los Alamos Neutron Science Center
LAR	liquid argon
LAT	laser assembly training
LRU	Assembly Transporter
LAVS	LRU Alignment Verification System
LB	laser bay
LBTS	Laser Bay Transporter System
LBTSS	Laser and Beam Transport Structural Support System
LC1–3	Laser Bay Core Level 1–3
LCS	Layering and Characterization System
LCW	low-conductivity water
LDG	laser diagnostics
LDM	Lower Diagnostic Mezzanine
LDS	laser diagnostics subsystem
LE	Lead Engineer
LEH	laser entrance hole

LEOT	Laser and Electronic Optics Technician
LEP	Laser Equipment Production
LES	Laser Experimental Systems
LFC	large format camera
LG	laser glass
LGDT	laser glass damage tester
LGIS	Laser Glass Inspection System
LI	lower injection
LIL	Ligne d'Integration Laser
	Laser Integration Laboratory (France)
LIMI	Laser Integration Management Individual
LLE	Laboratory for Laser Energetics
LLIX	LLNL telephone exchange
LLNL	Lawrence Livermore National Laboratory
LLRW	low-level radioactive waste
LLSN	Livermore Laboratory Safety Note
LLW	low-level waste
LM	laser mirror
LMF	Laboratory Microfusion Facility
	Lower Mirror Floor
LMJ	Laser MegaJoule (France)
LMOT	Laser Materials and Optics Technology
LMPPC	large mechanical parts precision cleaner
LMXRB	low-mass x-ray binaries
LoCoS	Location Component and State (tracking system)
LODI	Laser Optic Damage Inspection (System)
LOIS	Lightweight Orbiting Imaging System
	Large Optics Inspection System
LOS	line of site
LOTO	lockout/tagout
LOTS	Lens Optical Test System
LPAS	Laser Point Alignment System
LPI	laser–plasma interaction
LPMS	Lawrence Livermore National Laboratory Performance Measurement System
LPOM	Laser Performance Operations Model
LRM	Labor Relations Manager
LRU	line replaceable unit
LSC	line safety code
LSED	Laser Science and Engineering Design
LTAB	Laser and Target Area Building
LTE	local thermodynamic equilibrium
LTRAIN	Livermore Training Records and Information Network
LULI	Laboratoire Utilisation des Lasers Intenses (France)
MA	main amplifier
M&O	Maintenance and Operations
MACF	main amplifier cooling fan

MAP	Mitigation Action Plan
MB	megabyte
MBOM	Manufacturing Bill of Material
MCC	Monroe Community College (Rochester, NY)
MCD	Model Control Drawing
MCP	microchannel plate
MCPIGS	microchannel plate intensified grazing incidence spectrograph
MCP-PMT	microchannel plate photomultiplier tube
MDML	Metrology Data Management Language
MDMS	Metrology Data Management System
MDS	main debris shield
MEITO	Mechanical Engineering Internal Transfer Opportunities
MEL	Mechanical Engineering Letter
MESM	Main Energy Storage Module
MESN	Mechanical Engineering Safety Note
MFE	magnetic fusion energy
MIL	SPEC military specification
MIL	STD military standard
MJ	megajoule
MLC	Most Likely Cost
MLS	Main Laser System
MLSSI	main laser shot sequence integration
MOD	Ministry of Defense (British)
MOPA	master oscillator power amplifier
MOR	Master Oscillator Room
MOSFET	metal-oxide semiconductor field-effect transistor
MPA	multipass amplifier
MPH	miles per hour
MPR	Management Prestart Review
MRB	Material Review Board
MRF	magnetorheological finishing
MRI	Manufacturing Rework Instructions
MRP	Manufacturing Resource Plan
MRS	magnetic recoil spectrometer
MRT	Milestone Reporting Tool
MS	Mission Support
MSA	major systems acquisition
	multisegment amplifier
MSDS	Material Safety Data Sheet
MSL	mean sea level
MTA	Master Task Agreement
MTC	master timing controller
MTP	Master Test Plan
MTV	maintenance and transport vehicle
MXI	Monochromatic X-ray Imager
MS&T	Material Science and Technology

NA or N/A	not applicable
NAAQS	National Ambient Air Quality Standards
NARA	National Archives and Records Administration
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NAVOO	Nevada Operations Office
NBI	Near-Backscatter Imager
NCAM	neutron coded-aperture microscope
NCCB	NIC Change Control Board
NCO	NIF classified operations
NCR	Nonconformance Report
NCRP	National Council on Radiation Protection
NCTS	NIF Cryogenic Target System
Nd	neodymium
NDBI	Nielsen Dillingham Builders Incorporated
NEL	NIF Early Light
NEPA	National Environmental Policy Act
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NEUMA	neutron multiplying assembly
NF	near field
NFP	neutron flight path
NFPA	National Fire Protection Association
NGMS	Neutron and Gamma Monitoring System
NI	neutron imaging
NIC	National Ignition Campaign
NIF	National Ignition Facility
NIF	IS NIF Information Systems
NIF	IT NIF Information Technology
NIPS	NIF Image Processing System
NIST	National Institute of Standards and Technology
NLTE	nonlocal thermodynamic equilibrium
NLVF	North Las Vegas Facility
NNDP	NIF National Diagnostic Program
NNSA	National Nuclear Security Administration
NODI	NEL Optics Damage Inspection (system)
NOI	Notice of Intent
NOID	New Optic Insertion Device
NOPAS	Nonopposed Port Alignment System
NPAC	NIF Policy Advisory Committee
NPAM	neutron-penumbral aperture imaging detector
NPDES	National Pollutant Discharge Elimination System
NPGO	NIF Program General Operating (expense)
NPL	National Priorities List
NPG	ICF/NIF Program Funding
NPO	NIF Project Office
NPR	Nuclear Posture Review

NPS	NIF Planning System
NPSSP	NIF Project Site Safety Plan
NPT	Nuclear Nonproliferation Treaty
NRC	Nuclear Regulatory Commission
NRDC	Natural Resources Defense Council
NRHP	National Register of Historic Places
NRL	Naval Research Laboratory
NRS	UG National Radiation Science User Group
NS	neutron spectrometer
ns	nanosecond
NSC	National Safety Council
NSD	NIF Shot Director
NSF	National Science Foundation
NSO	NIF Site Operations
NTOF or nTOF	neutron time of flight
NTP	Notice to Proceed
NTS	Nevada Test Site
NUSO	National User Support Office
NVR	nonvolatile residue
NWET	Nuclear Weapons Effects Testing
NWBS	NIF Work Breakdown Structure
NWSM	Nuclear Weapon Stockpile Memorandum
NWSP	Nuclear Weapon Stockpile Plan
NYD	neutron yield diagnostic
NYH	Neutron Yield Diagnostic System – High
NYL	Neutron Yield Diagnostic System – Low
OAK	Oakland Operations Office
OCA	Optical Corporation of America
OCATS	Optical Coating Adsorption Test System
OCIP	Owner Controlled Insurance Program
OCLI	Optical Coating Laboratory Inc.
OD	outside diameter
ODC	optical device controller
OECM	Office of Engineering and Construction Management
OFES	Office of Fusion Energy Science
OJT	on-the-job training
OM	Operations Manager
OMBE	Office of management, Budget, and Evaluation
ONIF	Office of the NIF (DOE)
OPAS	Opposed Port Alignment System
OPC	Other Project Cost
OPD	optical path difference
OPDL	Optics Processing and Development Laboratory
OPEX	operating expense
OPG	optical pulse generation
OPL	Optics Processing Laboratory

OPRDA	Optics Processing Research and Development Area
OPSEC	operation security
OQ	operational qualification
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations
ORR	Operational Readiness Review
Oak	Ridge Reservation
OS	output sensor
OSECS	Operations Special Equipment Control System
OSHA	Occupational Safety and Health Administration
OSL	Optical Sciences Laser
OSP	Operational Safety Procedure
	output sensor package
OSR	Operational Safety Requirement
OSS	optical support structure
OTP	operational test procedure
	Operational Test Plan
OTR	Operational Training Requirements
P&ID	piping and instrumentation diagram
P&M	Procurement and Materiel
PA	power amplifier
PABTS	Preamplifier Beam Transport System
PACE	Plant and Capital Equipment
PACF	power amplifier cooling fan
PAM	preamplifier module
PAMMA	Preamplifier Module Maintenance Area
PAMS	poly alpha-methylstyrene
PASS	preamplifier support structure
PAT	Physics and Advanced Technologies
PBFA II	Particle Beam Fusion Accelerator
PBRS	portable back-reflection sensor
PBT	performance-based training
PC	personal computer
	Project Controls
PC/FR	Primary Criteria and Functional Requirements
PCA	Pockels cell assembly
PCB	polychlorinated biphenyls
PCC	Precision Components Corporation
PCD	photoconductive detector
PCM	Project Control Manual
	Project Control Manager
PCMS	Power Conditioning Module System
PCP	Project Control Procedure
PCR	Project Control Representative
PCS	Power Conditioning System
PCU	power conditioning unit

PD	precision diagnostics
PDAD	production data analysis and display
PD/PH	peak detector/track and hold system
PDD	Presidential Decision Directive
PDM	Product Data Management
	Pitt-Des Moines Steel
PDMS	Project Database Management System
PDR	Preliminary Design Review
PDS	Precision Diagnostic System
	product data structure
PEIS	Programmatic Environmental Impact Statement
PEP	Project Execution Plan
PEPC	plasma electrode Pockels cell
PEPS	Personnel and Environmental Protection Systems
PETG	polyethylene terephthalate glycol (plastic material used for optical storage containers)
PFN	pulse-forming network
PFV	primary focus vessel
PG	process gas
PGA	peak ground acceleration
PH	pinhole
PHA	Preliminary Hazards Analysis
PHERMEX	Pulsed High Energy Radiation Machine Emitting X-Rays (Facility)
PHOM	phase homogeneity (a method of homogeneity testing)
PI	Physics International Corp.
PII	plasma-induced incoherence
PIC	particle in cell
PICS	Problem Identification and Correction System
PILC	pre-ionization lamp current (or check)
PIM	Process Integration Manager
PIPT	Production Integrated Product Team
PL	Program Leader
	public law
PLA	Project Labor Agreement
PLC	programmable logic controller
PM	Program Manager
	precision mirror
	photo multiplier
PMC	Part Master Catalog
PMN	lead magnesium niobate
PMP	Project Management Plan
	Process Materials and Procedures
PO	Project Office
POC	Point of Contact
PODI	PDS Optics Damage Inspection (system)
POL	polarizer
ppb	parts-per-billion

PPBES	Planning, Programming, Budgeting, and Execution/Evaluation System
PPE	personal protective equipment
	pulsed-power electronics
PPG	plasma pulse generator (for the PEPC)
ppm	parts-per-million
PPMP	Pollution Prevention and Waste Minimization Plan
PQP	Project Quality Plan
PR	Procurement
PRC	Program Review Committee
PS	polarization smoothing
PSA	Project Specific Analysis
PSAR	Preliminary Safety Analysis Report
PSBO	Passive Shock Breakout (a diagnostic)
PSD	power spectral density
PSF	precision survey feature
PTP	Performance Test Plan
P-V	peak to valley
PVA	polyvinyl alcohol
PVC	polyvinyl chloride
PW	petawatt
	process water
PZ	polarizing (fiber)
Q	quad
QA	quality assurance
QAE	Quality Assurance Engineer
QAP	Quality Assurance Plan
QAPP	Quality Assurance Program Plan
QBRS	quad back-reflection sensor
QC	quality control
QCM	Quality Construction Manager
QED	quantum electrodynamics
QMU	quantification of margins and uncertainty
Q- level	Quality Assurance level
Qual Card	qualification card
R&D	research and development
RA	Resource Analyst
R	egenerative amplifier
RAL	Rutherford Appleton Laboratory
RAM	random access memory
	reliability, availability, maintainability
RBD	reliability block diagram
RC	reinforced concrete
RCCB	Rebaselining Change Control Board
RCRA	Resource Conservation and Recovery Act
RD&T	research, development, and testing
REL	release elastic limit

REQ	requirements
RF	radio frequency
	reference flat
RFI	radio frequency interference
	Request for Information
RFL	reverse focus lens (final focus lens, part of FOC)
RFP	Request for Proposal
RFQ	Request for Quote
RGA	residual-gas analizer
RHWM	Radioactive and Hazardous Waste Management
RI	Responsible Individual
RIE	reactive ion etching
RIMS	Regional Input-Output Modeling System
RISC	reduced instruction set chip
RM	roving mirror
RMDA	roving mirror diagnostic assembly
RMDE	roving mirror diagnostic enclosure
RMDS	Roving Mirror Diagnostics System
RMP	Risk Management Plan
RMS	root mean square
	Requirements Management System
ROD	Record of Decision
ROI	region of influence
ROLI	relay optics lower injection
ROSI	Raytheon Optical Systems Incorporated
RP	relay plane
ring	polisher
RP0	relay plane zero
RPOM	roving pick-off mirror
RPP	random phase plate
RQ	requirement quality
RSMS	Remote Sensor Monitoring System
RT	Rayleigh–Taylor
RTD	remote temperature device
RTNS	rotating target neutron source
S&PRB	Safety and Performance Review Board
SA	Subcontract Administrator
synthetic air	SAAR Supervisor’s Accident Analysis Report
SAGEM	(a French optical company)
SAH	synthetic air, high pressure
SAR	Safety Analysis Report
SARA	Superfund Amendments and Reauthorization Act
SBS	stimulated Brillouin scattering
SBBS	Science-Based Stockpile Stewardship
SC	streak camera
SCAP	self-constricted asset pool

SCL	sequence command language
SCR	Software Change Request
SCSI	Small Computer Systems Interface
SD	shield doors
	Shot Director
SDD	software design documents
SDR	system design requirement
SDS	Spectral Dispersion System
SDWA	Safe Drinking Water Act
SE	Systems Engineering
	synthesis engineering
	special equipment
SEAB	Secretary of Energy Advisory Board
SEC	Software Engineering Computer
SEG	Special Equipment Group
SEIS	Supplemental Environmental Impact Statement
SEM	scanning electron microscopy
SEMP	System Engineering Management Plan
SF	spatial filter
SFC	spatial filter center (vessel)
SFDB	spatial filter diagnostic beam (assembly station)
SFFS	streaked flat-field spectrometer
SFLC	spatial filter lens cell (assembly station)
SFT	spatial filter tower
SFV	spatial filter vacuum
SGT	Schott Glass Technologies, Inc.
SHCS	socket-head cap screw
SHG	single-harmonic generation
SHP	Self-Help Program
SHPO	State Historic Preservation Officer
SI	system integration
SIDE	Side-Illuminated Damage Evaluation
Si-GDP	silicon-doped glow discharge polymer
SIM	six-inch manipulator
SIS	Safety Interlock System
SL	side loading
SLAC	Stanford Linear Accelerator Center
SLM	standard liters per minute
	spatial light modulator
SLO	Supplemental Labor Office
SLOC	source lines of code
SM	sphere mapper
SME	Safety Management Evaluation
	subject matter expert
SMH	structure-mounted hardware
SMIF	Standard Mechanical Interface

SMPPC	small mechanical parts precision cleaner
SMR	standardized mortality ratio
SNL	Sandia National Laboratories
SNL-Alb.	Sandia National Laboratory, Albuquerque
SOLID	Schlieren (On-line Imaging of Damage)
SOP	Streaked Optical Pyrometer
SOR	Safety Observation Report
SOS	Small Optical Systems
SOW	Statement of Work
S-P	Spectra-Physics Corp.
SPA	Safe Plan of Action
SPCC	Spill Prevention and Countermeasures Control
SPG	switch pulse generator (for the PEPC)
SPI	Schedule Performance Index
SPIE	International Society for Optical Engineering
SPLAT	Short-Pulse Laser Applications and Technology
SPMP	Software Project Management Plan
SQAP	Software Quality Assurance Plan
SQL	Structured Query Language
SREP	Shot Rate Enhancement Program
SRRS	stimulated rotational Ramon scattering
SRS	stimulated Raman scattering
	Software Requirements Specification
	Savannah River Site
SSC	structures, systems, and components
	systems, subsystems, and components
	streaked slit camera
SSD	smoothing by spectral dispersion
SSDR	Software Subsystem Design Requirements
	Subsystem Design Requirements
SSH	security shell
SSHCL	Solid State Heat Capacity Laser
SSMP	Stockpile Stewardship and Management Program
SSP	Stockpile Stewardship Program
SSS	shot services subsystem
SST (also SSt)	stainless steel
SSTD	single-shot transient digitizer
START	Strategic Arms Reduction Talks
STC	sound transmission class
STD	standard
STEP	Standard Translation Exchange Process
STOps	shot-time operations
STP	Software Test Plan
SV	schedule variance
SVT	Sverdrup Technology
SW	switch window

SWEIS	Sitewide Environmental Impact Statement
SW/SPEIS	Site-Wide Environmental Impact Statement and Supplemental Stockpile Stewardship and Management Programmatic Environmental Impact Statement
SWO	Stop Work Order
SWPPP	Storm Water Pollution Prevention Plan
SWR	Stop Work Release
SXD	Streaked X-ray Detector
SXD-B	SXD Backup
SXI	Static X-ray Imager
SXPD	Soft X-ray Power Diagnostic
SXRI	Soft X-ray Imager
SXSS	Soft X-ray Power Diagnostic
SY	switchyard
T-1	T minus 1: closed-loop wavefront control up to 1 second before shot
T&H	transport and handling
T&P	Training and Procedures (Group)
TA	technical area
	Target Area
TA	DAS Target Area Data Acquisition System
TAB	Target Area Building
TAC	target area coordinator
TALIS	target and laser interaction
TAO	target area operator
TARPOS	Target Positioner
TAS	Target Alignment System
	Target Alignment Sensor
TASPOS	Target Alignment Sensor Positioner
TASS	target area structural support
TASTOps	target area shot-time operations
TB	Target Bay
TBA	target base assembly
TBD	to be determined
TBSS	Target Bay Service System
TC	Target Chamber
TCC	Target Chamber Center
TCE	Target Chamber environment
TCO	transport canister operator
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TCR	target chamber robot
TCSS	Target Chamber Service System
TCVW	target chamber vacuum window
TD	target diagnostics
TDC	Target Diagnostic Chamber
TDR	time delay reflectometer
TDS	target digital subsystem

TE	test equipment
TEC	total estimated cost
TEM	transmission electron microscopy
TES	Target Experimental Systems
TF	transmission flat
TGA	thermogravimetric analysis
THG	third harmonic generation
THGC	third harmonic generator crystal (part of FOC)
TIC	target inserter and cryostat
TIMS	twelve-inch manipulators
TIP	Target Ignition Physics
TL	top loading
	task leader
TLD	thermoluminescent dosimeter
TLV/TWA	threshold limit value/time-weighted average
TMCC	Tritium Monitoring and Contamination Control
TMP	Technical Management Plan
TOM	transport optical mount
TOPS	Total Online Procurement System
TP	test plan
TPC	total project cost
TPIP	Transition Period Implementation Plan
TPS	Tritium Processing System
TRC	Total Recordable Case
TRR	test readiness review
	Technical Release Representative
TRU	transuranic
TRXI	Time-Resolved X-ray Imaging System
TRXS	Time-Resolved X-ray Spectrometer
TSA	Task Safety Analysis
TSCA	Toxic Substances Control Act
TSF	transport spatial filter
	TeraScale Facility
TSFD	Transport Spatial Filter Diagnostics
TSP	total suspended particulates
TTC	ThermoTrex Corporation
TTS	tower test station
TTW	through the wall
TV	television
TW	terawatts
TWTT	two-way time-transfer technique
UBC	Uniform Building Code
UC	University of California
UCMP	University of California Museum of Paleontology
UCR	unclassified computer room
UCRL	University of California Report Listing

UDM	Upper Diagnostic Mezzanine
UFE	University-Funded Equipment
UFGOE	university-funded government-owned equipment
UGT	underground testing
UHMW	ultra-high molecular weight
UI	upper IOM
UL	Underwriters Laboratory
ULO	ultralow outgassing
ULOLT	Universal Large Optics Lifting Tool
ULPA	Ultralow Particle Air (filter)
UMF	Upper Mirror Floor
UNSCEAR	United Nations Scientific Committee on Radiological Protection
UPS	uninterruptible power source
UR/LLE	University of Rochester/Laboratory for Laser Energetics
USFWS	U.S. Fish and Wildlife Service
UTA	unresolved transition array
UV	ultraviolet
VAC	vacuum
	Variance at Complete
VBL	virtual beamline
VDC	voltage direct current
VDT	video display terminal
VE	value engineering
VISAR	Velocity Interferometer System for Any Reflector
VIV	vacuum isolation valve
VME	Versa Module Europe
VOC	volatile organic compound
VRT	vacuum relay telescope
VTC	video teleconference
VW	vacuum window (laser entrance window of IOM)
W	watts
WAP	Work Authorization Point
WAVS	Wavefront Alignment Verification System
WBS	Work Breakdown Structure
WC	work center
WCC	Work Control Center
WCO	Work Control Officer
WCS	Wavefront Control System
WETF	Weapons Engineering Tritium Facility
WFC	wavefront controls
WFL	wedge focus lens
WIPP	Waste Isolation Pilot Plant
WMS	Waste Management Systems
WNR	Weapon Neutron Research (facility - LANL)
WPA	work package agreement
WS	workstation

WZ	War Zone
XRD	x-ray diode
XPS	x-ray photoelectron spectroscopy
XRF	x-ray fluorescence
XRFC	x-ray fluorescence camera
XSSC	x-ray streaked slit camera
XUV	extreme ultraviolet
Y	yield
Y-12	Y-12 Plant, Oak Ridge Reservation
YN	yttrium nitride
	neutron yield

Section 26. Reference Data

Section Revision History

Release Date	Author	Revision
March 2008	EP2 Drafting Committee	Revision AA: Initial release of Engineering Drafting Manual, Volume 2.

Contents

26.1 Metric Design

26.1.1 Purpose

This subsection will familiarize drafting design personnel with metric practices.

26.1.2 Applicable Documents

- ASME Y14.5M-1994, “Dimensioning and Tolerancing”
- IEEE/ASTM SI 10–2002, “American National Standard for Use of the International System of Units (SI): The Modern Metric System”
- ISO 1000, “SI Units and Recommendations for the Use of Their Multiples and of Other Certain Units”
- Oberg, Jones, and Horton, *Machinery’s Handbook*, Industrial Press Inc., New York

26.1.3 SI Units of Measure (Base Units)

SI units of measure (base units) are as follows:

Common Measure	SI Unit	SI Symbol
length	meter	m
mass	kilogram	kg
time	second	s
electric current	ampere	A
thermodynamic temperature	Kelvin	K
amount of substance	mole	mol
luminous intensity	candela	cd

26.1.4 Dimensions and Tolerances

Engineering recommends but does not require using ASME Y14.5M-1994 for Level-1 LEA and AAA drawings.

Engineering *requires* adherence to ASME Y14.5M-1994 for Level-2 and -3 LEA and AAA drawings.

There are now three revision years on record for ANSI Y14.5M: ANSI Y14.5-1973, ANSI Y14.5M-1982, and ASME Y14.5M-1994. On any drawing, the entire drawing, and all subsequent revisions of it, shall conform to the same standard revision (year), and all drawings must state the year of the standard that applies.

The following is an example of reference on the face of the drawing:

DIMENSIONING AND TOLERANCING IN ACCORDANCE WITH ASME Y14.5M-1994

The millimeter (mm) shall be the unit of measure for all drawings. The following should be observed when dimensioning drawings:

- ASME Y14.5M-1994 follows the SI metric convention that trailing zeros are omitted and instead are implied: e.g., 25.5 is 25.500000->; 25 is 25.00000->.
- Where the dimension is less that one millimeter, a zero precedes the decimal point (e.g., 0.95).
- Where the dimension is a whole number, neither the decimal point nor a zero is shown (e.g., 25).
- Where the dimension exceeds a whole number by a decimal fraction of one millimeter, the last digit to the right of the decimal point is not followed by a zero (e.g., 11.5).
- When a dimension requires two digits to the right of the decimal point, it is recommended (unless a more precision measurement is required) that the last digit be rounded to zero (in which case it should be left blank) or to 5. Example: 25.45 or 25.4 (0.05 mm is equal to 0.00196 inch).

26.1.5 Threaded Holes and Fasteners

Metric threads are the preferred threads to be used on drawings, unless the design requires the use of English threads. Refer to Section 12, “Threads & Fasteners.”

26.1.6 Components and Hardware Selection

It is preferred that metric-sized components and materials be used on all newly designed equipment when feasible. When components and hardware parts are not available in metric, it is acceptable to specify inch-sized material or components.

26.1.7 Temperature Conversion Table

To use the temperature conversion table (Table 25-1), look for the temperature reading in the middle column. If the reading is in degrees Celsius, the Fahrenheit equivalent is given in the right-hand column. If the reading is in degrees Fahrenheit, the Celsius equivalent is given in the left-hand column.

26.1.8 Common Metric Equivalents and Conversions

Table 25-2 lists common metric equivalents and conversions.

Table 25-1. Temperature conversion

-80 to 34			35 to 77			78 to 290		
°C		°F	°C		°F	°C		°F
-62	-80	-112	1.7	35	95.0	25.6	78	172.4
-57	-70	-94	2.2	36	96.8	26.1	79	174.2
-51	-60	-76	2.8	37	98.6	26.7	80	176.0
-46	-50	-58	3.3	38	100.4	27.2	81	177.8
-40	-40	-40	3.9	39	102.2	27.8	82	179.6
-34	-30	-22	4.4	40	104.0	28.3	83	181.4
-29	-20	-4	5.0	41	105.8	28.9	84	183.2
-23	-10	14	5.6	42	107.6	29.4	85	185.0
-17.8	0	32	6.1	43	109.4	30.0	86	186.8
-17.2	1	33.8	6.7	44	111.2	30.6	87	188.6
-16.7	2	35.6	7.2	45	113.0	31.1	88	190.4
-16.1	3	37.4	7.8	46	114.8	31.7	89	192.2
-15.6	4	39.2	8.3	47	116.6	32.2	90	194.0
-15.0	5	41.0	8.9	48	118.4	32.8	91	195.8
-14.4	6	42.8	9.4	49	120.2	33.3	92	197.6
-13.9	7	44.6	10.0	50	122.0	33.9	93	199.4
-13.3	8	46.4	10.6	51	123.8	34.4	94	201.2
-12.8	9	48.2	11.1	52	125.6	35.0	95	203.0
-12.2	10	50.0	11.7	53	127.4	35.6	96	204.8
-11.7	11	51.8	12.2	54	129.2	36.1	97	206.6
-11.1	12	53.6	12.8	55	131.0	36.7	98	208.4
-10.6	13	55.4	13.3	56	132.8	37.2	99	210.2
-10.0	14	57.2	13.9	57	134.6	37.8	100	212.0
-9.4	15	59.0	14.4	58	136.4	43	110	230.8
-8.9	16	60.8	15.0	59	138.2	49	120	248.8
-8.3	17	62.6	15.6	60	140.0	54	130	266.8
-7.8	18	64.4	16.1	61	141.8	60	140	284.8
-7.2	19	66.2	16.7	62	143.6	66	150	302.8
-6.7	20	68.0	17.2	63	145.4	71	160	320.8
-6.1	21	69.8	17.8	64	147.2	77	170	338.8
-5.6	22	71.6	18.3	65	149.0	82	180	356.8
-5.0	23	73.4	18.9	66	150.8	88	190	374.8
-4.4	24	75.2	19.4	67	152.6	93	200	392.8
-3.9	25	77.0	20.0	68	154.4	99	210	410.8
-3.3	26	78.8	20.6	69	156.2	100	212	413.6
-2.8	27	80.6	21.1	70	158.0	104	220	428.8
-2.2	28	82.4	21.7	71	159.8	110	230	446.8
-1.7	29	84.2	22.2	72	161.6	116	240	464.8
-1.1	30	86.0	22.8	73	163.4	121	250	482.8
-0.6	31	87.8	23.3	74	165.2	127	260	500.8
0.0	32	89.6	23.9	75	167.0	132	270	518.8
0.6	33	91.4	24.4	76	168.8	138	280	536.8
1.1	34	93.2	25.0	77	170.6	143	290	554

Table 25-2. Common metric equivalents and conversions

Approximate Common Equivalents	Conversion Accurate to Parts Per Million
1 inch .... 25 millimeters	inches x 25.4• .... millimeters
1 foot .... 0.3 meter	feet x 0.3048• .... meters
1 yard .... 0.9 meter	yards x 0.9144• .... meters
1 mile .... 1.6 kilometers	miles x 1.60934 .... kilometers
1 square inch .... 6.5 square centimeters	square inches x 6.4516• .... square centimeters
1 square foot .... 0.09 square meter	square feet x 0.929030 .... square meters
1 square yard .... 0.8 square meter	square yards x 0.836127 .... square meters
1 acre .... 0.4 hectare†	acres x 0.404686 .... hectares
1 cubic inch .... 16 cubic centimeters	cubic inches x 16.3871 .... cubic centimeters
1 cubic foot .... 0.03 cubic meter	cubic feet x 0.0283168 .... cubic meters
1 cubic yard .... 0.8 cubic meter	cubic yards x 0.764555 .... cubic meters
1 quart (lq) .... 1 liter†	quarts (lq) x 0.946353 .... liters
1 gallon .... 0.004 cubic meter	gallons x 0.00378541 .... cubic meters
1 ounce (avdp) .... 28 grams	ounces (avdp) x 283495 .... grams
1 pound (avdp) .... 0.45 kilogram	pounds (avdp) x 0.453592 .... kilograms
1 horsepower .... 0.75 kilowatt	horsepower x 0.745700 .... kilowatts
1 millimeter .... 0.04 inch	millimeters x 0.0393701 .... inches
1 meter .... 3.3 feet	meters x 3.28084 .... feet
1 meter .... 1.1 yards	meters x 1.09361 .... yards
1 kilometer .... 0.6 mile	kilometers x 0.621371 .... miles
1 square centimeter .... 0.16 square inch	square centimeters x 0.155000 .... square inches
1 square meter .... 11 square feet	square meters x 10.7639 .... square feet
1 square meter .... 1.2 square yards	square meters x 1.19599 .... square yards
1 hectare† .... 2.5 acres	hectares x 2.47105 .... acres
1 cubic centimeter .... 0.06 cubic inch	cubic centimeters x 0.0610237 .... cubic inches
1 cubic meter .... 35 cubic feet	cubic meters x 35.3147 .... cubic feet
1 cubic meter .... 1.3 cubic yards	cubic meters x 1.30795 .... cubic yards
1 liter† .... 1 quart (lq)	liters x 1.05669 .... quarts (lq)
1 cubic meter .... 250 gallons	cubic meters x 264.172 .... gallons
1 gram .... 0.035 ounces (avdp)	grams x 0.0352740 .... ounces (avdp)
1 kilogram .... 2.2 pounds (avdp)	kilograms x 2.20462 .... pounds (avdp)
1 kilowatt .... 1.3 horsepower	kilowatts x 1.34102 .... horsepower
† Common term not used in SI. • Exact.	

26.2 Ergonomics

26.2.1 Purpose

This section provides some guidance on ergonomic limits and configurations for design applications.

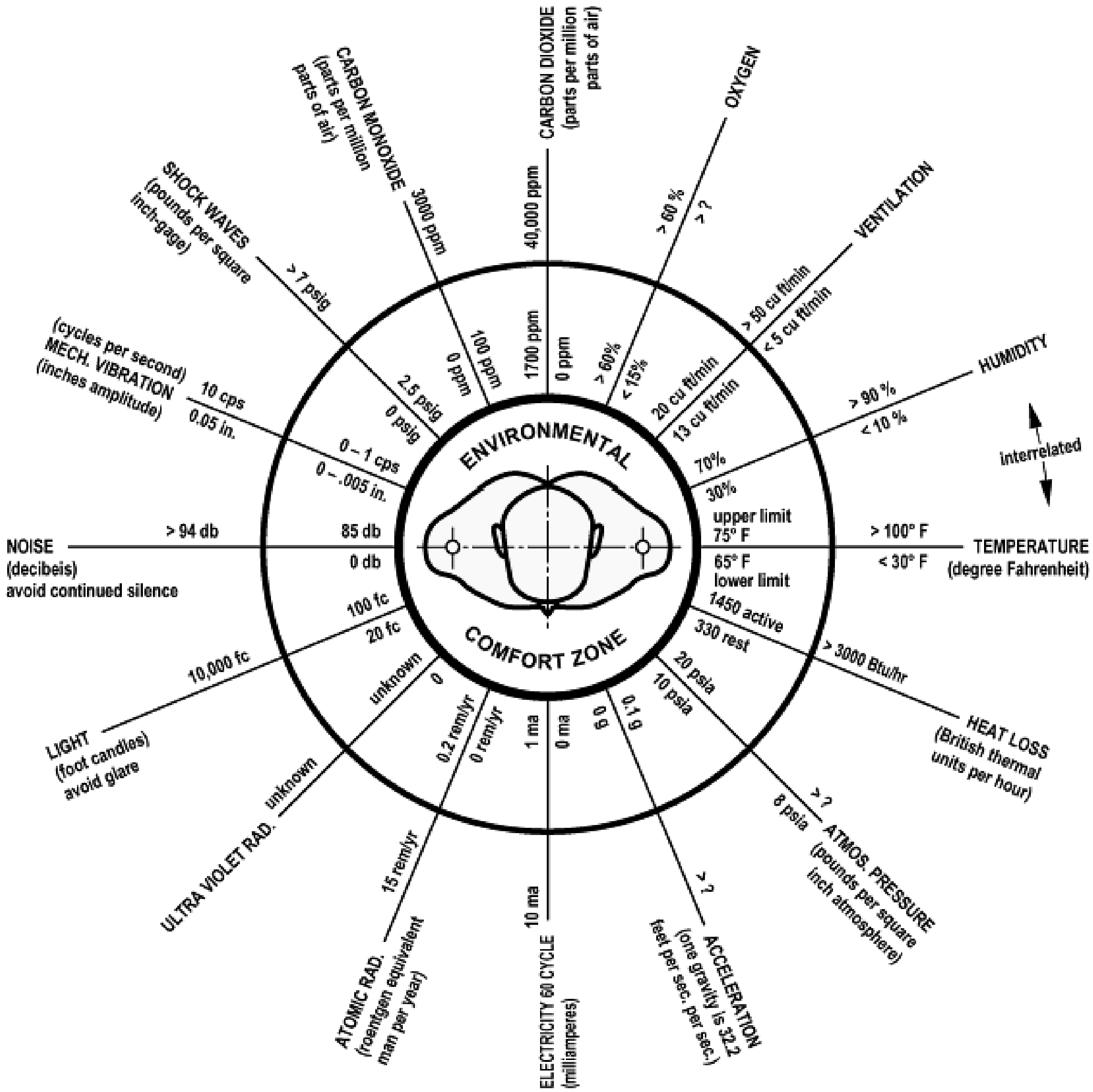
26.2.2 Applicable Documents

- Panero, J. and Zelnick, M., *Human Dimension & Interior Space: A Source Book of Design Reference Standards*, Whitney Library of Design, New York, 1979.

26.2.3 Ergonomic Charts

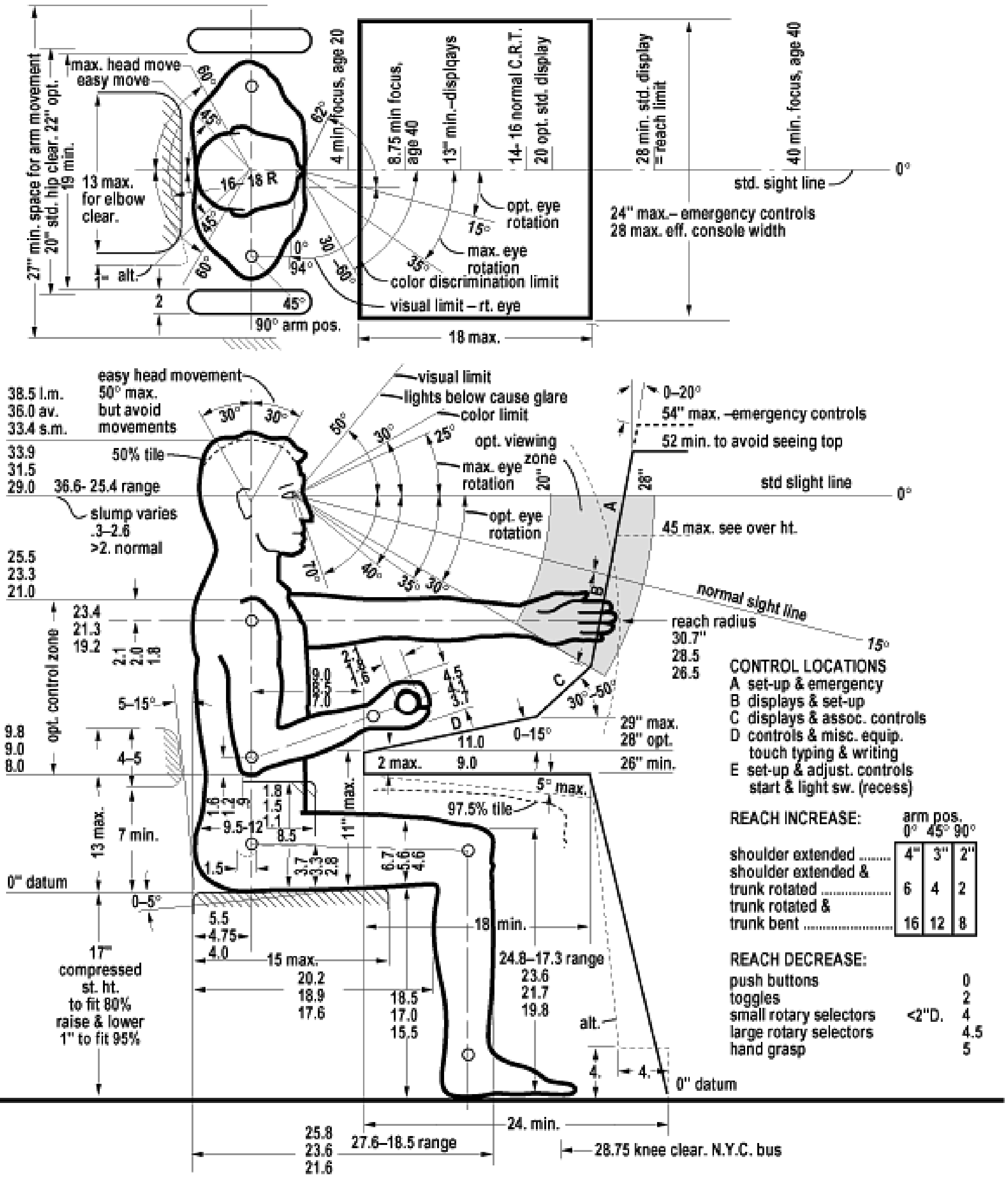
The following charts provide general ergonomic reference data.

26.2.3.1 Human Factors – Environmental Limits

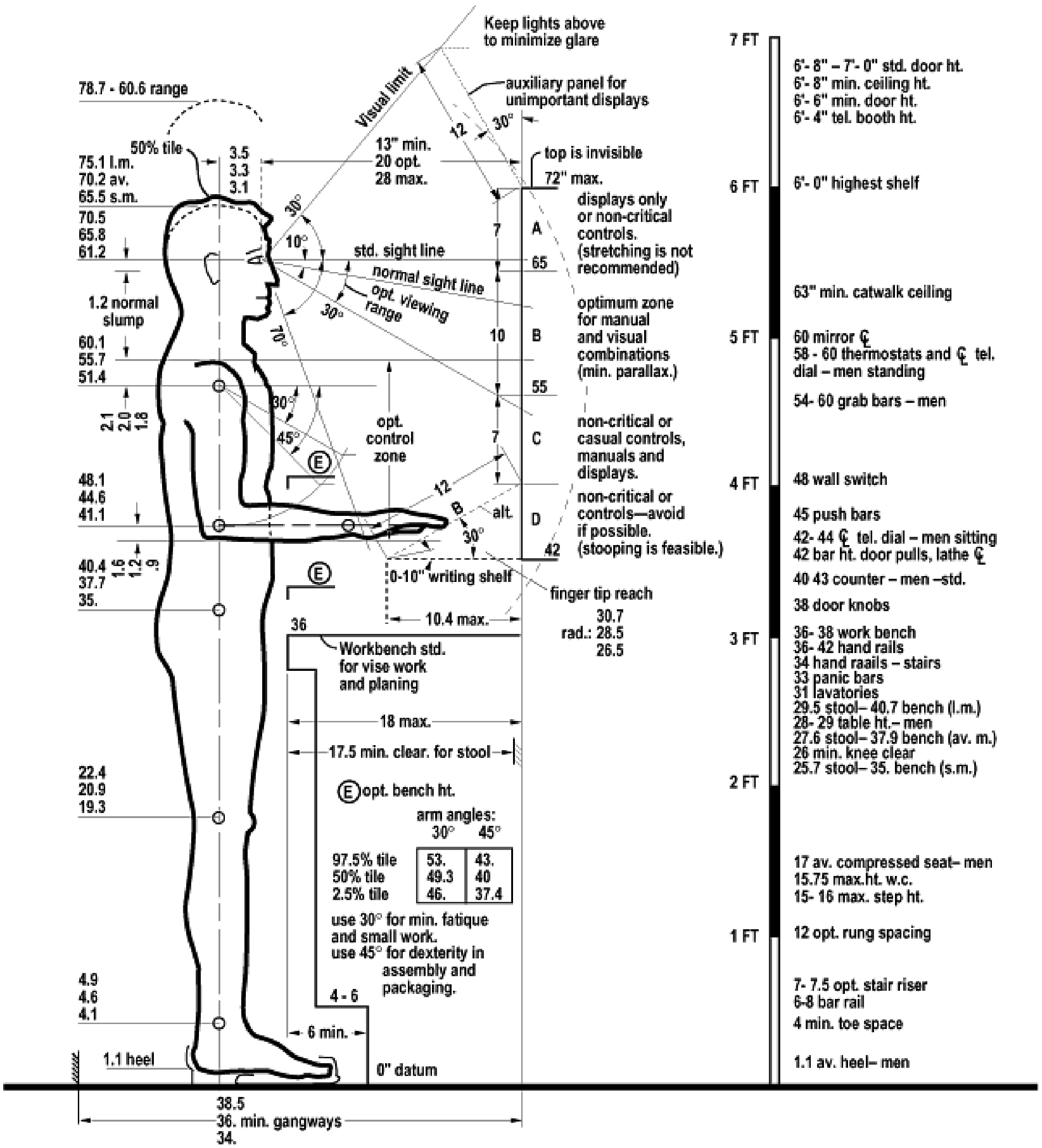


The band between the circles indicates the zone from comfort to the tolerance limits. Outside this limit great discomfort or physiological harm is encountered. Other factors not shown and to be considered are: infrared radiation, ultrasonic vibrations, noxious gases, dust, pollen, chemicals, and fungi.

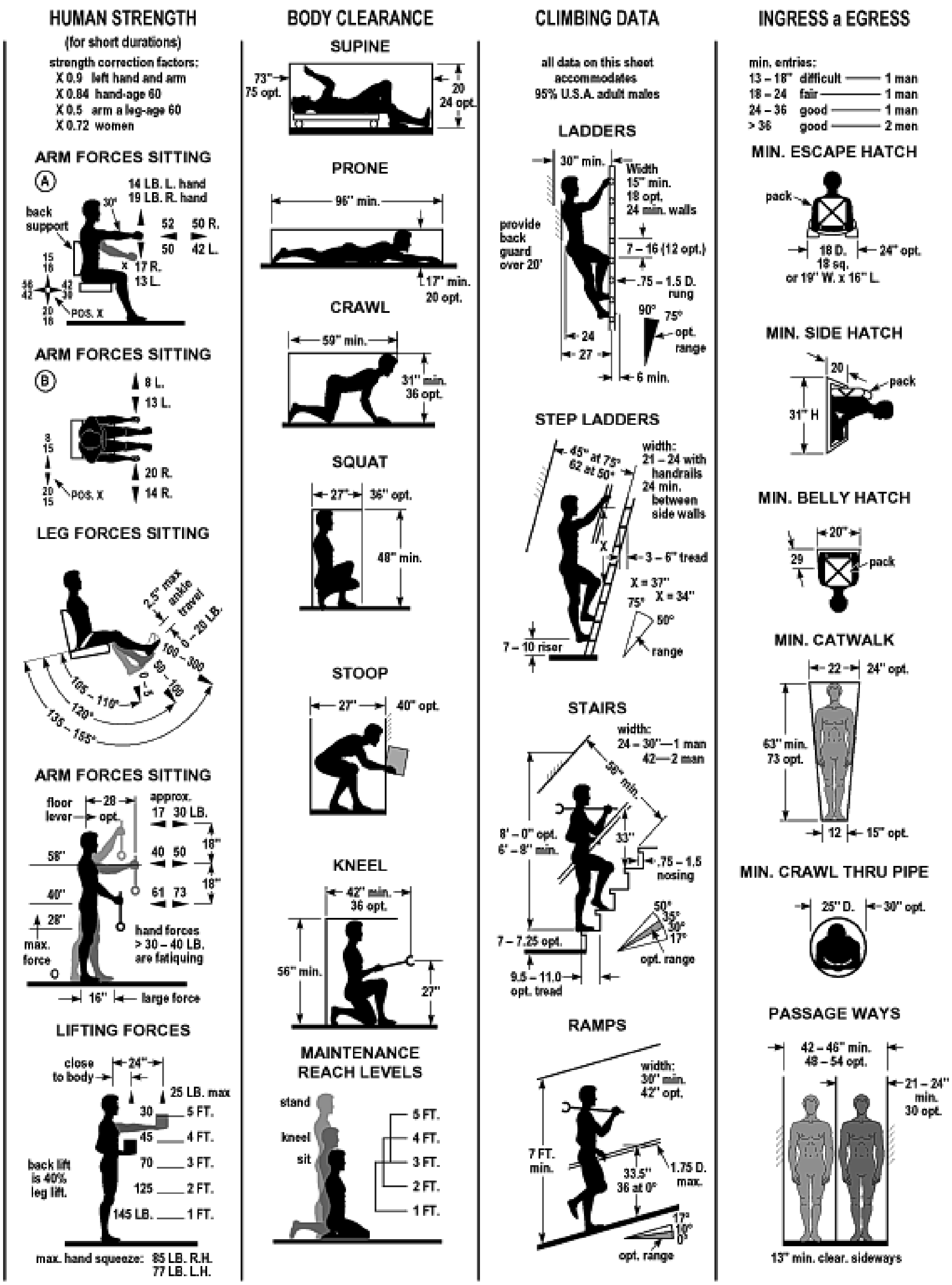
26.2.3.2 Anthropometric Data – Adult Male Seated at Console



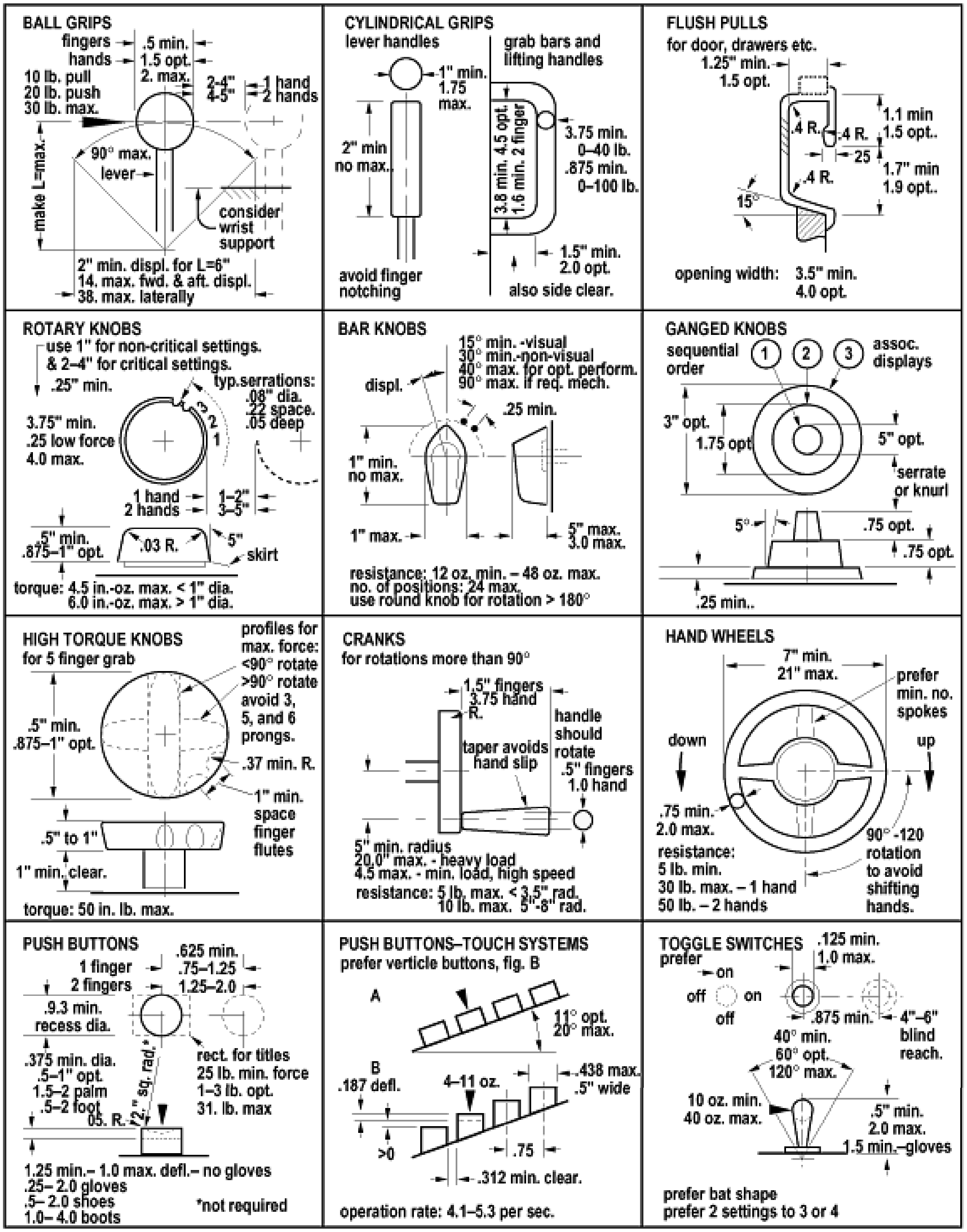
26.2.3.3 Anthropometric Data – Adult Male Standing at Control Board

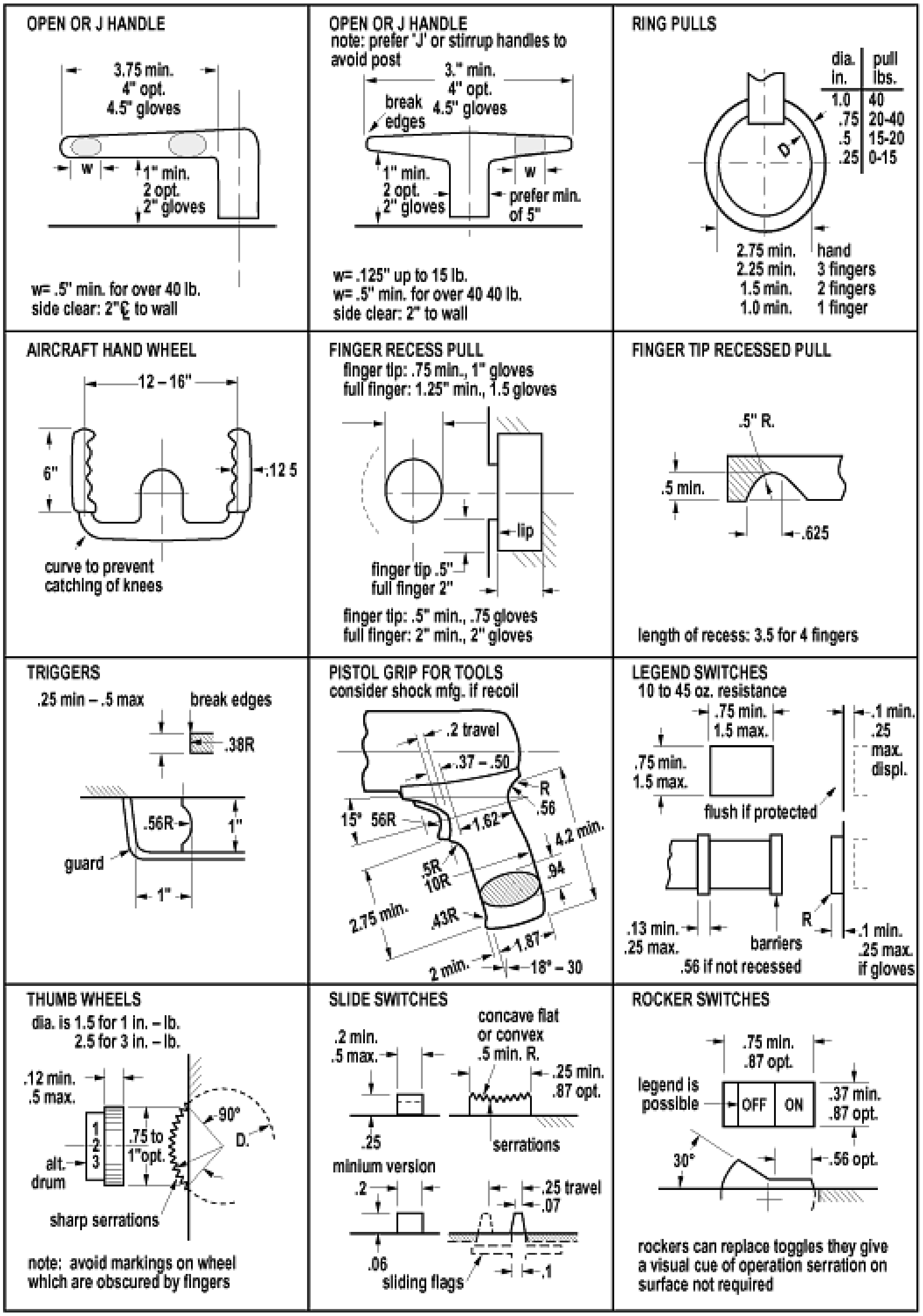


26.2.3.4 Human Strength, Body Clearances, Etc.

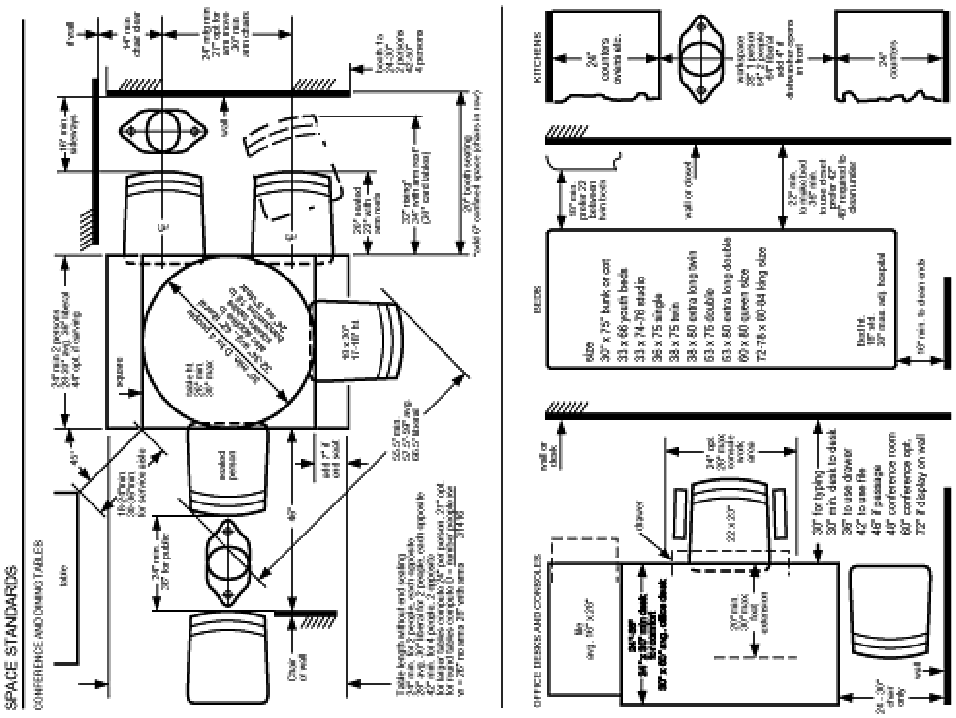


26.2.3.5 Basic Control Data




OPEN OR J HANDLE
3.75 min.
4" opt.
4.5" gloves
w
1" min.
2 opt.
2" gloves
w= .5" min. for over 40 lb.
side clear: 2"℄ to wall
OPEN OR J HANDLE
note: prefer 'J' or stirrup handles to avoid post
3." min.
4" opt.
4.5" gloves
break edges
1" min.
2 opt.
2" gloves
w
prefer min. of 5"
w= .125" up to 15 lb.
w= .5" min. for over 40 40 lb.
side clear: 2" to wall
RING PULLS
dia. in.
pull lbs.
1.0 40
.75 20-40
.5 15-20
.25 0-15
D
2.75 min. hand
2.25 min. 3 fingers
1.5 min. 2 fingers
1.0 min. 1 finger
AIRCRAFT HAND WHEEL
12 – 16"
6"
.12 5
curve to prevent catching of knees
FINGER RECESS PULL
finger tip: .75 min., 1" gloves
full finger: 1.25" min., 1.5 gloves
lip
finger tip .5"
full finger 2"
finger tip: .5" min., .75 gloves
full finger: 2" min., 2" gloves
FINGER TIP RECESSED PULL
.5" R.
.5 min.
.625
length of recess: 3.5 for 4 fingers
TRIGGERS
.25 min – .5 max
break edges
.38R
.56R
1"
guard
1"
PISTOL GRIP FOR TOOLS
consider shock mfg. if recoil
.2 travel
.37 – .50
R .56
15° 56R
1.62
4.2 min.
.5R
10R
.94
2.75 min.
.43R
1.87
2 min.
18° – 30
LEGEND SWITCHES
10 to 45 oz. resistance
.75 min.
1.5 max.
.1 min.
.25 max. displ.
.75 min.
1.5 max.
flush if protected
R
.13 min.
.25 max.
barriers
.56 if not recessed
.1 min.
.25 max. if gloves
THUMB WHEELS
dia. is 1.5 for 1 in. – lb.
2.5 for 3 in. – lb.
.12 min.
.5 max.
90°
.75 to 1"opt.
D.
alt. drum
sharp serrations
note: avoid markings on wheel which are obscured by fingers
SLIDE SWITCHES
concave flat or convex
.2 min.
.5 max.
.5 min. R.
.25 min.
.87 opt.
.25
serrations
minium version
.2
.25 travel
.07
.06
sliding flags
.1
ROCKER SWITCHES
.75 min.
.87 opt.
legend is possible
OFF ON
.37 min.
.87 opt.
30°
.56 opt.
rockers can replace toggles they give a visual cue of operation serration on surface not required

26.2.3.6 Space and Access Standards



ACCESS OPENINGS

*INDICATES DESCRIPTION APPLIES TO DATA TABULATED BELOW

HANDS				
	empty hand held flat	* bare 4 x 2.25"	* work gloves 5 x 3"	* arctic gloves 6.5 x 4"
	min. to wrist	3.5 sq.	5.5 sq.	6.0 sq.
	" " "	3.75 D	5.75 D	6.25 D
	clenched hand	3.5 x 5	4.5 x 6	7 x 6.5
	" " "	5. D	6. D	6.5 D
	inserting 1" object to wrist	3.75 D	6. D	7. D
	using pliers screw driver	5.2 x 4.5 4.2 x 4.6	—	—
	one hand passing object	L = 4" A+B=1.75	L = 6" A+B=2.5	L = 6.5" A+B=2.5
.75 reach	two hands straight ahead reach = 6 – 25"	H = 4 add for vision	H = 6 add for vision	H = 6.5 add for vision
ARMS				
	arm to elbow	—	* clothed 4.5" D	* arctic 7." D
	" " "	—	4.5 sq.	7. sq.
	arm to shoulder	—	5. D	8.5 D
	" " "	—	6. sq.	8.5 sq.
FINGERS				
	one finger	* bare 1.25" D	* gloves 1.5" D	* arctic 7" D
	recessed push button	0.93 D	—	—
	twist access eg. hold screw	2. D	2.5" D	—
FOOT				
	access to pedal	bare 4.3 x 11.5	avg. shoe 4.7 x 12.7	arctic boot 6.3 x 15.3
HEAD				
	head passage	bare 9.3"	military helmet 11.5"	work helmet 12.5"

BODY				
	manhole	work clothes 22.8	—	space suit 36" D
	crawl thru pipe	*min. avg. clothes 25" I.D.	prefer 30" I.D.	arctic clothes 32" I.D.
	ceiling and floor hatch	18" D	22" D	32" D
	" "	18 sq.	22 sq.	32 sq.
	wall hatch	18 x 15	22 x 20	32 x 24
	side hatch incl. pack	20 x 32	—	—
	belly hatch incl. pack	20 x 29	—	—
	crawl thru	20 x 31	22 x 36	30 x 38
	prone access	22.8 x 17	30 x 20	30 x 24
	catwalk	22" H = 63 12	24" H = 73 15	32" H = 75 15
	normal pass / pass sideways	22 x 76 / 13 x 76	30 x 80 / 15 x 80	30 x 80 / 19 x 80
	pressure hatch	20 x 44 A = 16" to floor	26 x 66 A = 10" to floor	—
	head bent / head erect	20 to 24 x 60 / 20 to 24 x 70	30 x 70 / 30 x 80 to 84	30 x 70 / 30 x 80 to 84
	two men facing each other	30 x 76	36 x 80 to 84	36 x 80 to 84
	two men passing abreast	42 x 76	54 x 80 to 84	60 x 80 to 84

26.3 Shop Arithmetic

26.3.1 Purpose

This subsection provides some arithmetic references and relationships to aid in design.

26.3.2 Applicable Documents

- Oberg, Jones, and Horton, *Machinery's Handbook*, Industrial Press Inc., New York

26.3.3 Reference Rules and Trigonometric Relationships

Charts follow relating to various arithmetic relationships.

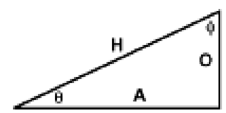
26.3.3.1 Reference Rules

To Find Circumference	Multiply diameter by 3.1416
To Find Diameter	Multiply circumference by 0.3183
To Find Radius	Multiply circumference by 0.15915
To Find Side of an Inscribed Square	Multiply diameter by 0.7071 Multiply circumference by 0.2251
To Find Side of an Equal Triangle	Multiply diameter by 0.8862 Multiply circumference by 0.2821
Square	A side multiplied by 1.4142 equals diameter of its circumscribing circle. A side multiplied by 4.443 equals circumference of its circumscribing circle A side multiplied by 1.128 equals diameter of an equal circle. A side multiplied by 3.547 equals circumference of an equal circle
To Find the Area of a Circle	Multiply circumference by one quarter of the diameter. Or, multiply the diameter by the diameter by 0.7854. Or, multiply the circumference by the circumference by 0.7958. Or, multiply the radius by the radius by 3.1416.
To Find the Surface of a Sphere or Globe	Multiply the diameter by the circumference. Or, multiply the square of diameter by 3.1416. Or, multiply four times the square of radius by 3.1416.
To Find the Volume of a Sphere	Multiply the cube of diameter by 0.5236.
To Find the Cubic Content of a Cone	Multiply the area of the base by 1/3 the altitude.
To Find the Area of a Triangle	Multiply the base by 1/2 the perpendicular height.
To Find the Area of a Rectangle	Multiply the length by the width.

Reference Equivalents	• Doubling the diameter of a circle increases its area four times. • Doubling the diameter of a pipe increases its capacity four times. • Tripling the diameter of a circle increases its area nine times. • A gallon of water (U.S. Standard) weighs 8 1/3 lbs. and contains 231 cubic inches. • A cubic foot of water contains 7 1/2 gallons, 1728 cubic inches, and weighs 62 1/2 lbs. • To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434. • The drag on a flat plate normal to the wind is equal to 32 lbs. per square foot at 100 m.p.h. • The drag and lift due to the air forces on a body increase as the square of the speed. • The measurements made in a machine shop are usually taken in inches or fractional parts of an inch. Most of the precision tools in the shop read in thousandths of an inch. The usual graduations on a scale are in 64ths, 32nds, 16ths, and 8ths of an inch. • To change a fraction to a decimal, divide the numerator by the denominator. For example, in changing 3/16 to a decimal, 3÷16 = .1875.

26.3.3.2 Trigonometric Relationships

Trigonometric Relationships



In any right triangle, if we let

θ = the acute angle formed by the hypotenuse and the base leg,

ϕ = the acute angle formed by the hypotenuse and the altitude leg,

H = the hypotenuse,

A = the side adjacent θ and opposite ϕ,

O = the side opposite θ and adjacent ϕ,

then sine of θ = $\sin\theta = \frac{O}{H}$

cosine of θ = $\cos\theta = \frac{A}{H}$

tangent of θ = $\tan\theta = \frac{O}{A}$

cosecant of θ = $\csc\theta = \frac{H}{O}$

secant of θ = $\sec\theta = \frac{H}{A}$

cotangent of θ = $\cot\theta = \frac{A}{O}$

also

$\sin\theta = \cos\phi$ $\quad \csc\theta = \sec\phi$

$\cos\theta = \sin\phi$ $\quad \sec\theta = \csc\phi$

$\tan\theta = \cot\phi$ $\quad \cot\theta = \tan\phi$

and

$\frac{1}{\sin\theta} = \csc\theta$ $\quad \frac{1}{\csc\theta} = \sin\theta$

$\frac{1}{\cos\theta} = \sec\theta$ $\quad \frac{1}{\sec\theta} = \cos\theta$

$\frac{1}{\tan\theta} = \cot\theta$ $\quad \frac{1}{\cot\theta} = \tan\theta$

The expression "arc sin" indicates, "the angle whose sine is" . . .; likewise arc tan indicates, "the angle whose tangent is" . . . etc. See formulas in table below.

Known Values	Formulas for Determining Unknown Values of . . .				
	A	*O*	*H*	θ	ϕ
A & O			$\sqrt{A^2 + O^2}$	arc tan $\frac{O}{A}$	arc tan $\frac{A}{O}$
A & H		$\sqrt{H^2 - A^2}$		arc cos $\frac{A}{H}$	arc sin $\frac{A}{H}$
A & θ		*A* tan θ	$\frac{A}{\cos\theta}$		90° – θ
A & ϕ		$\frac{A}{\tan\phi}$	$\frac{A}{\sin\phi}$	90° – ϕ	
O & H	$\sqrt{H^2 - O^2}$			arc sin $\frac{O}{H}$	arc cos $\frac{O}{H}$
O & θ	$\frac{O}{\tan\theta}$		$\frac{O}{\sin\theta}$		90° – θ
O & ϕ	*O* tan ϕ		$\frac{O}{\cos\phi}$	90° – ϕ	
H & θ	H cos θ	*H* sin θ			90° – θ
H & ϕ	*H* sin ϕ	*H* cos ϕ		90° – ϕ	

Numerical Relations of Angle Functions

Angle	Sin	Cos	Tan
0°	.0000	1.000	.0000
1	.0175	.9998	.0175
2	.0349	.9994	.0349
3	.0523	.9986	.0524
4	.0698	.9976	.0699
5	.0872	.9962	.0875
6	.1045	.9945	.1051
7	.1219	.9925	.1228
8	.1392	.9903	.1405
9	.1564	.9877	.1584
10	.1736	.9848	.1763
11	.1908	.9816	.1944
12	.2079	.9781	.2126
13	.2250	.9744	.2309
14	.2419	.9703	.2493
15	.2588	.9659	.2679
16	.2756	.9613	.2867
17	.2924	.9563	.3057
18	.3090	.9511	.3249
19	.3256	.9455	.3443
20	.3420	.9397	.3640
21	.3584	.9336	.3839
22	.3746	.9272	.4040
23	.3907	.9205	.4245
24	.4067	.9135	.4452
25	.4226	.9063	.4663
26	.4384	.8988	.4877
27	.4540	.8910	.5095
28	.4695	.8829	.5317
29	.4848	.8746	.5543
30	.5000	.8660	.5774
31	.5150	.8572	.6009
32	.5299	.8480	.6249
33	.5446	.8387	.6494
34	.5592	.8290	.6745
35	.5736	.8192	.7002
36	.5878	.8090	.7265
37	.6018	.7986	.7536
38	.6157	.7880	.7813
39	.6293	.7771	.8098
40	.6428	.7660	.8391
41	.6561	.7547	.8693
42	.6691	.7431	.9004
43	.6820	.7314	.9325
44	.6947	.7193	.9657

Angle	Sin	Cos	Tan
45°	.7071	.7071	1.0000
46	.7193	.6947	1.0355
47	.7314	.6820	1.0724
48	.7431	.6691	1.1106
49	.7547	.6561	1.1504
50	.7660	.6428	1.1918
51	.7771	.6293	1.2349
52	.7880	.6157	1.2799
53	.7986	.6018	1.3270
54	.8090	.5878	1.3764
55	.8192	.5736	1.4281
56	.8290	.5592	1.4826
57	.8387	.5446	1.5399
58	.8480	.5299	1.6003
59	.8572	.5150	1.6643
60	.8660	.5000	1.7321
61	.8746	.4848	1.8040
62	.8829	.4695	1.8807
63	.8910	.4540	1.9626
64	.8988	.4384	2.0503
65	.9063	.4226	2.1445
66	.9135	.4067	2.2460
67	.9205	.3907	2.3559
68	.9272	.3746	2.4751
69	.9336	.3584	2.6051
70	.9397	.3420	2.7475
71	.9455	.3256	2.9042
72	.9511	.3090	3.0777
73	.9563	.2924	3.2709
74	.9613	.2756	3.4874
75	.9659	.2588	3.7321
76	.9703	.2419	4.0108
77	.9744	.2250	4.3315
78	.9781	.2079	4.7046
79	.9816	.1908	5.1446
80	.9848	.1736	5.6713
81	.9877	.1564	6.3138
82	.9903	.1392	7.1154
83	.9925	.1219	8.1443
84	.9945	.1045	9.5144
85	.9962	.0872	11.43
86	.9976	.0698	14.30
87	.9986	.0523	19.08
88	.9994	.0349	28.64
89	.9998	.0175	57.29

26.4 Machine Shop Practices

26.4.1 Purpose

This section defines LLNL-preferred design solutions applicable to LLNL-specific machine shop practices.

26.4.2 Applicable Documents

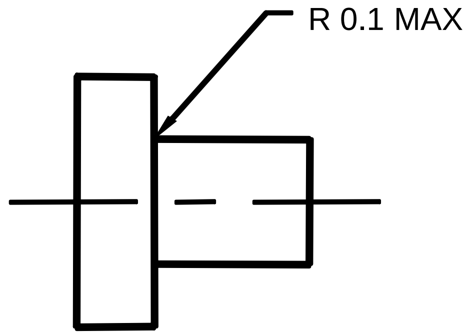
None.

26.4.3 Problem-Solution Examples

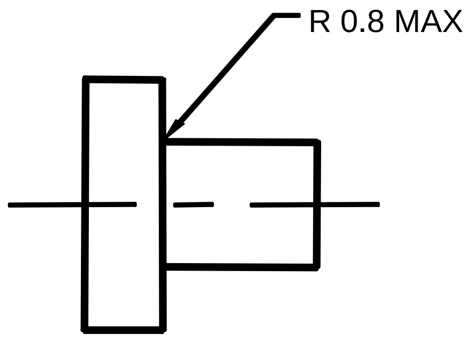
Problems with their solutions follow to illustrate preferred design solutions for machine shop practice at LLNL.

26.4.3.1 Standard Tool Radius

The Problem: When fillet radii are specified in nonstandard sizes, tools must be ground or setups changed to make final cuts.



The Solution: If your design allows, use a standard tool radius.

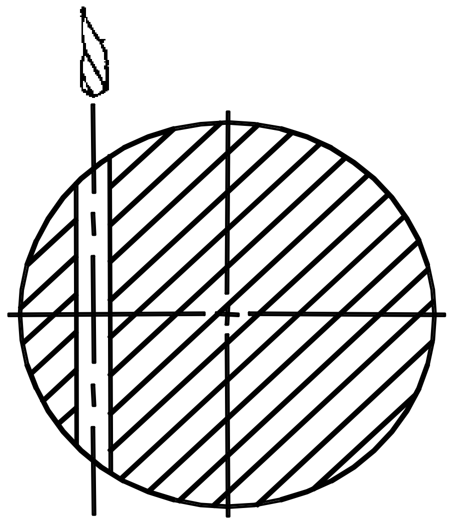


Preferred Callout for Standard Tool Radius	Standard Tool Radius (in inches)	
R <0.13 (Special Grind) R 0.13 MAX R 0.3 MAX R 0.6 MAX R 0.8 MAX	R <.005 (Special Grind) R .005 R .010 R .020 R .030	**Standard Tool Radius Grinds**
R 0.5 MAX R 0.8 MAX R 1.2 MAX R 1.6 MAX R 2.4 MAX	R .016 R .032 R .047 R .063 R .094	**Standard Carbide Insert Radius**

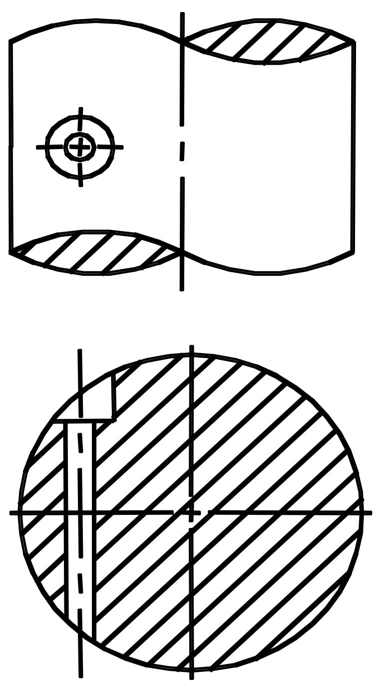
Note: Use the largest standard tool radius permissible in your design.

26.4.3.2 Irregular Surface Drilling

The Problem: Drilling on an irregular surface is always difficult. The drill tends to "walk" or wander.

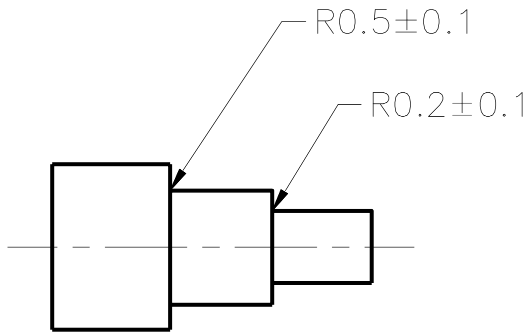


The Solution: A spot face for singular holes or step for multiple holes at the point of entry helps the drill locate the hole precisely.

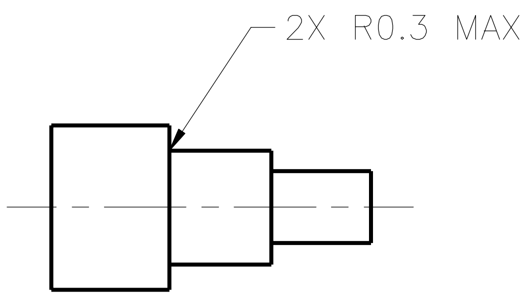


26.4.3.3 Consistent Radii

The Problem: Changing tool radii requires two tools, each ground to a specified radius.

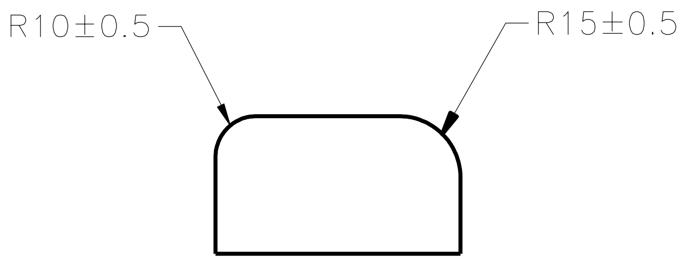


The Solution: If design allows, standardize on radii to reduce the number of operations required.

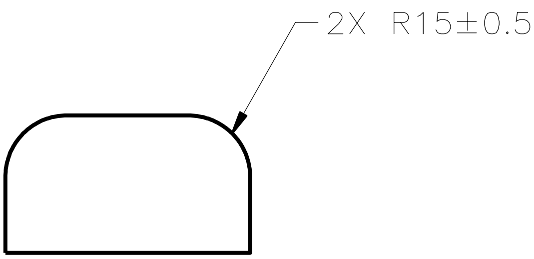


Note: See the table in subsection 26.4.3.1 for standard radii.

The Problem: Different outside radii require changing the cutter.



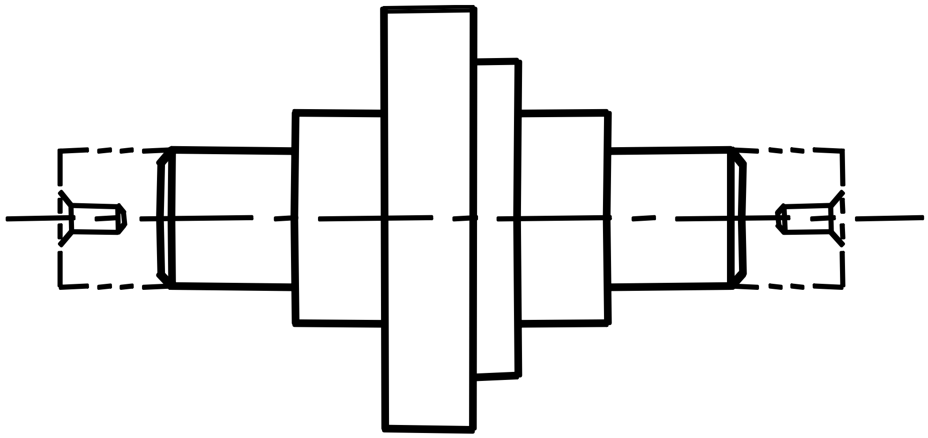
The Solution: If design allows, standardize on radii to reduce the number of tool changes required.



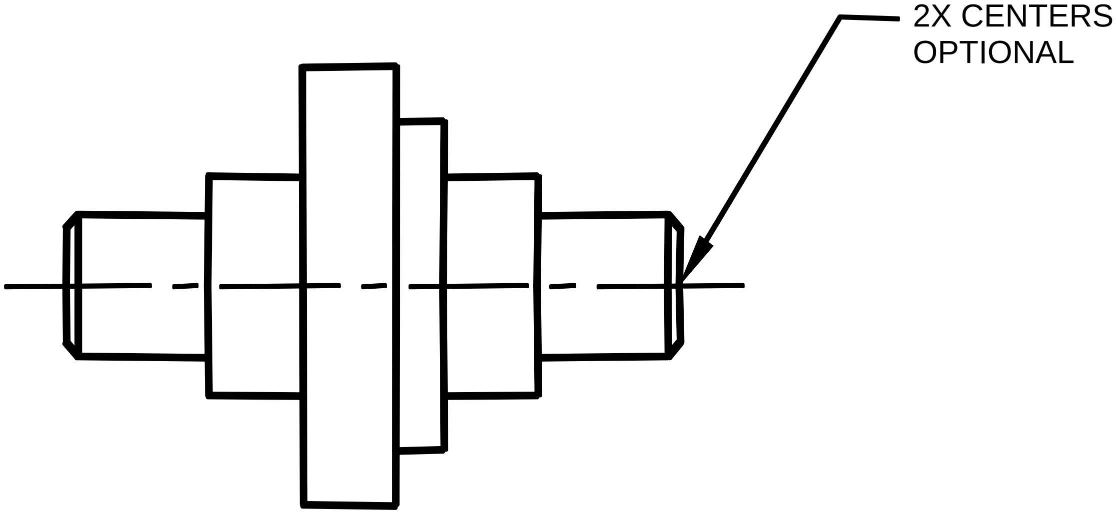
Note: See the table in subsection 26.4.3.1 for standard radii.

26.4.3.4 Machining Centers

The Problem: When to allow centers on symmetrical parts? The shops may turn the part from centers, requiring additional material, and then cut off the excess.

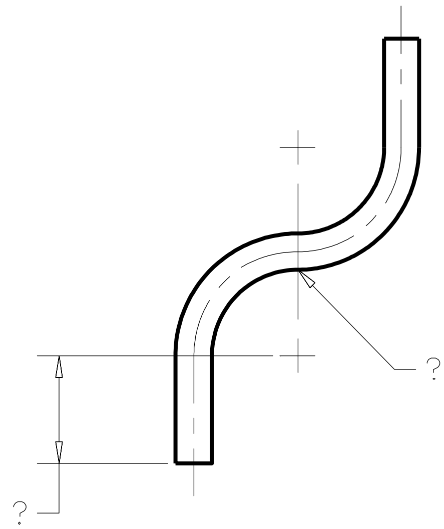


The Solution: A simple note, such as "2X CENTERS OPTIONAL" may save time and money.

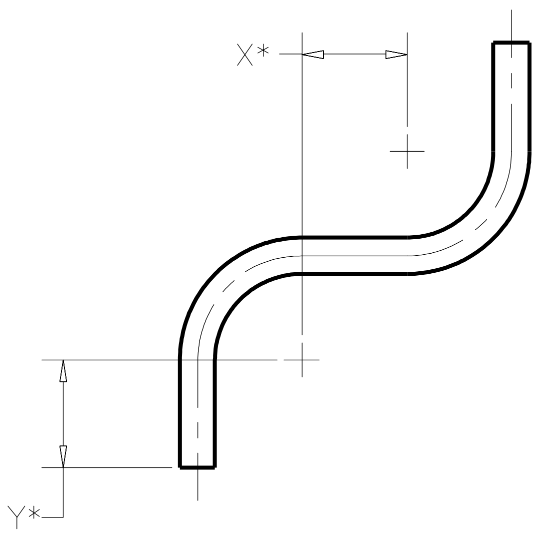


26.4.3.5 Tube Bending

The Problem: Clearance for standard bending, flaring tools, and fitting attachments has not been provided.

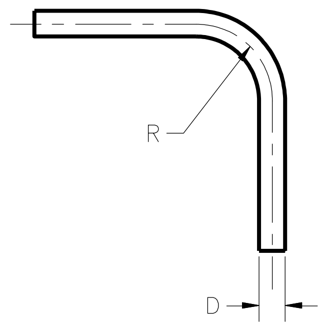


The Solution: During bending and flaring, the tubing must be rigidly clamped. A sufficient straight portion of tubing should be provided to meet the clamping requirements.



* Consult appropriate vendor catalogs for clearances, bend radii, and flaring requirements.

The Problem: What radii to specify on a bent tube detail?

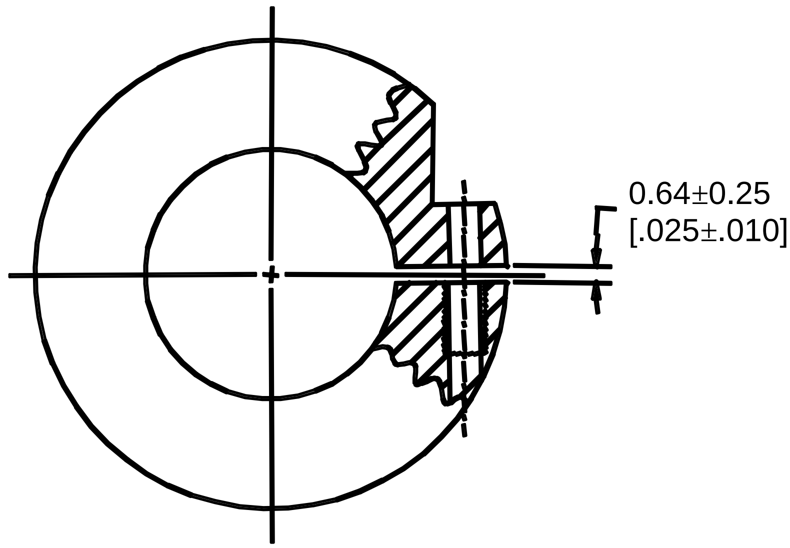


The Solution: Use the following radii whenever your design permits.

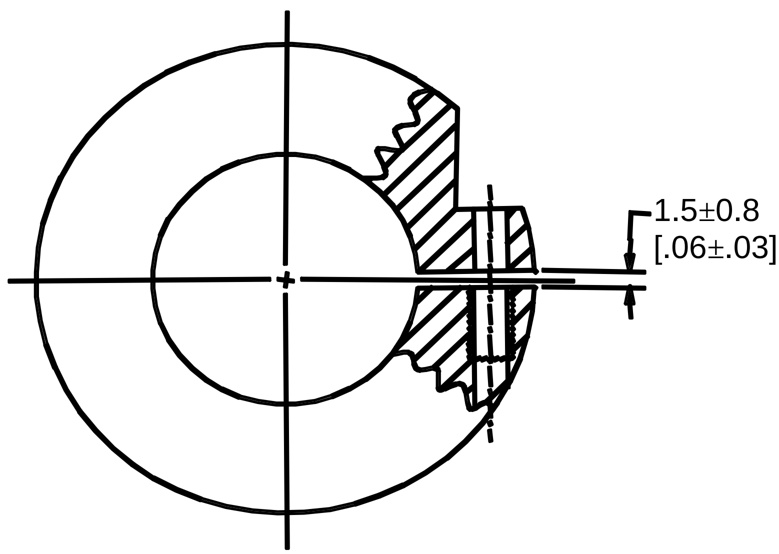
D	R	R	R
.125	.375	.750	1.000
.187	.500	.750	1.000
.250	.625	1.000	1.250
.312	.750	1.000	1.250
.375	1.000	1.250	
.500	1.250	2.000	3.000
.625	1.750	3.000	4.000
.750	2.000	3.000	4.000
.875	2.500	4.000	6.000
1.000	3.000	4.000	6.000
1.125	3.000	4.000	6.000
1.250	4.000	5.000	6.000
1/4 IPS	1.500	2.000	3.000
3/8 IPS	1.750	3.000	4.000
1/2 IPS	2.500	4.000	6.000
3/4 IPS	3.000	4.000	6.000
1 IPS	4.000	5.000	6.000

26.4.3.6 Saw Cuts

The Problem: When slits are specified with a width under 1.03 [.040] or tolerances that are too tight, they cannot be made inexpensively with a band saw.



The Solution: If design permits, specify a slit size that can accommodate a standard band saw cut widths 1.02, 1.14, and 1.78 [.040, .045, and, .070].



26.5 O-Ring Grooves

26.5.1 Purpose

This section defines LLNL-preferred drafting practices for specifying glands for O-ring seals.

26.5.2 Applicable Documents

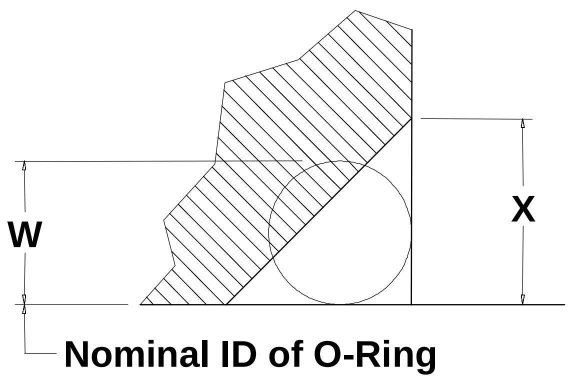
None.

26.5.3 Problem-Solution Examples

26.5.3.1 45º Chamfer for O-Ring (Metric)

The Problem: What is the preferred configuration for a 45° chamfer O-ring groove when using the O-ring for purposes other than sealing for pressure or vacuum (for example, using as a cushion in a lens assembly)?

The Solution: The following table provides information on this type of O-ring groove.

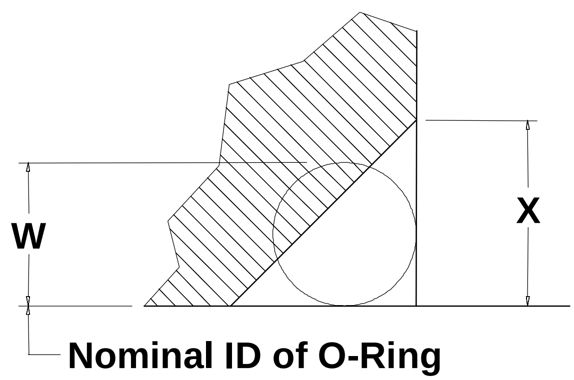


		Dimension X				
Nominal O-Ring Thickness W		35% Squeeze 1.212 W	30% Squeeze 1.283 W	25% Squeeze 1.354 W	20% Squeeze 1.424 W	15% Squeeze 1.495 W
1/16"	1.78	2.16	2.29	2.41	2.54	2.67
3/32"	2.62	3.18	3.35	3.56	3.73	3.91
1/8"	3.53	4.27	4.52	4.78	5.03	5.28
3/16"	5.33	6.45	6.83	7.21	7.59	7.98
1/4"	6.98	8.46	8.97	9.45	9.96	10.44

26.5.3.2 45º Chamfer for O-Ring (Inch)

The Problem: What is the preferred configuration for a 45° chamfer O-ring groove when using the O-ring for purposes other than sealing for pressure or vacuum (for example, using as a cushion in a lens assembly)?

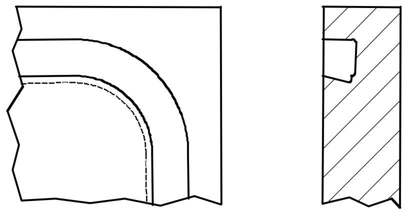
The Solution: The following table provides information on this type of O-ring groove.



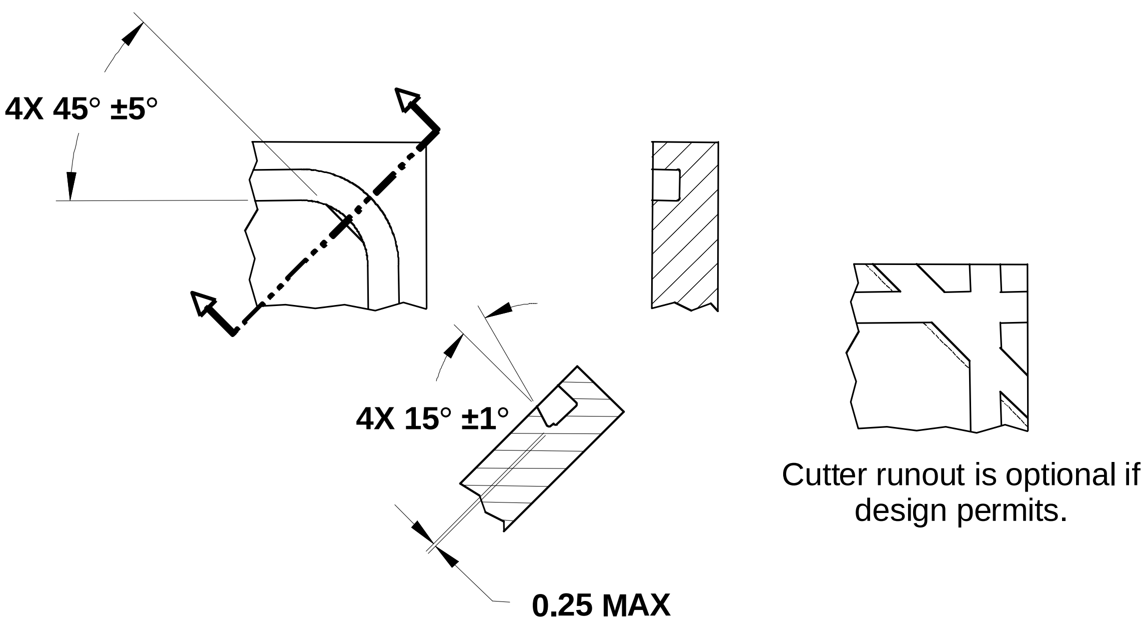
		Dimension X				
Nominal O-Ring Thickness W		35% Squeeze 1.212 W	30% Squeeze 1.283 W	25% Squeeze 1.354 W	20% Squeeze 1.424 W	15% Squeeze 1.495 W
1/16"	0.070	0.085	0.090	0.095	0.100	0.105
3/32"	0.103	0.125	0.132	0.140	0.147	0.154
1/8"	0.139	0.168	0.178	0.188	0.198	0.208
3/16"	0.210	0.254	0.269	0.284	0.299	0.314
1/4"	0.275	0.333	0.353	0.372	0.392	0.411

26.5.3.3 O-Ring Retaining Groove—Rectangular

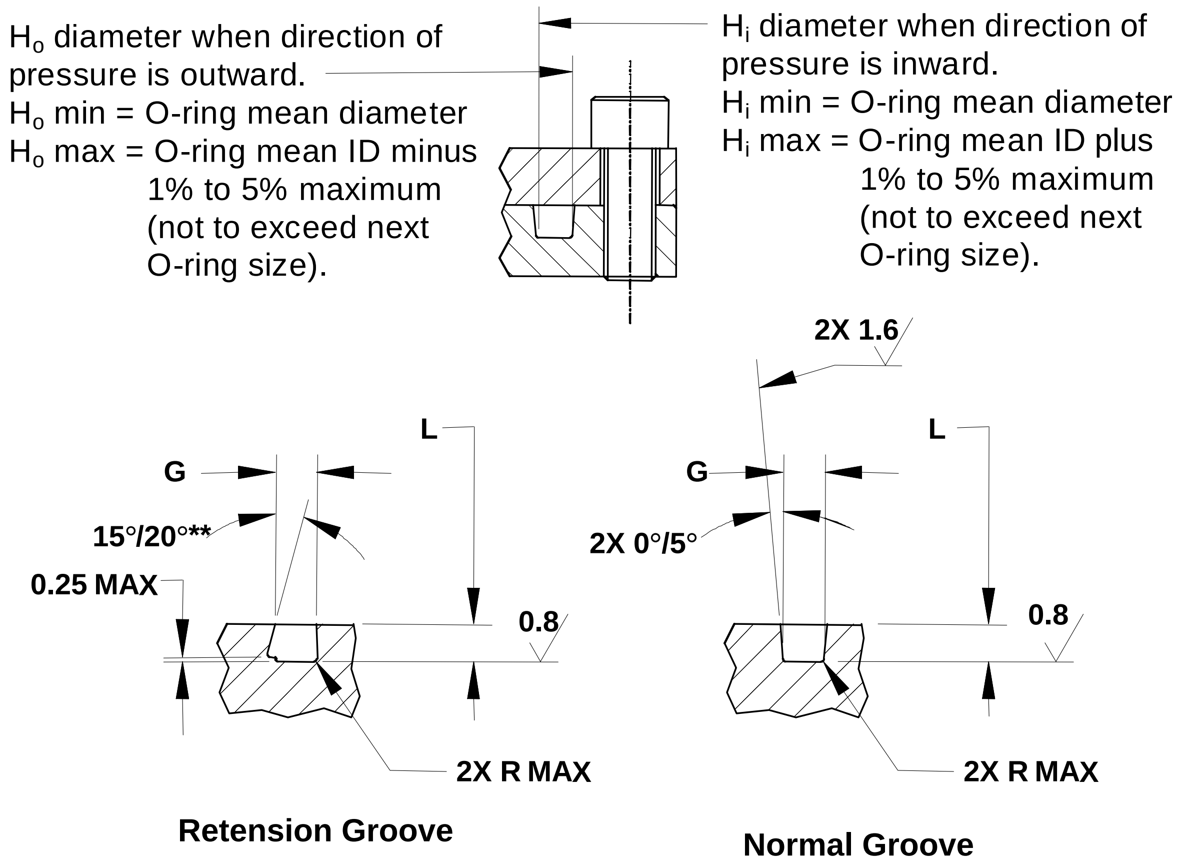
The Problem: On a rectangular O-ring groove, the undercut retaining angle all around is costly.



The Solution: Undercuts at the corners are adequate to hold the O-ring.



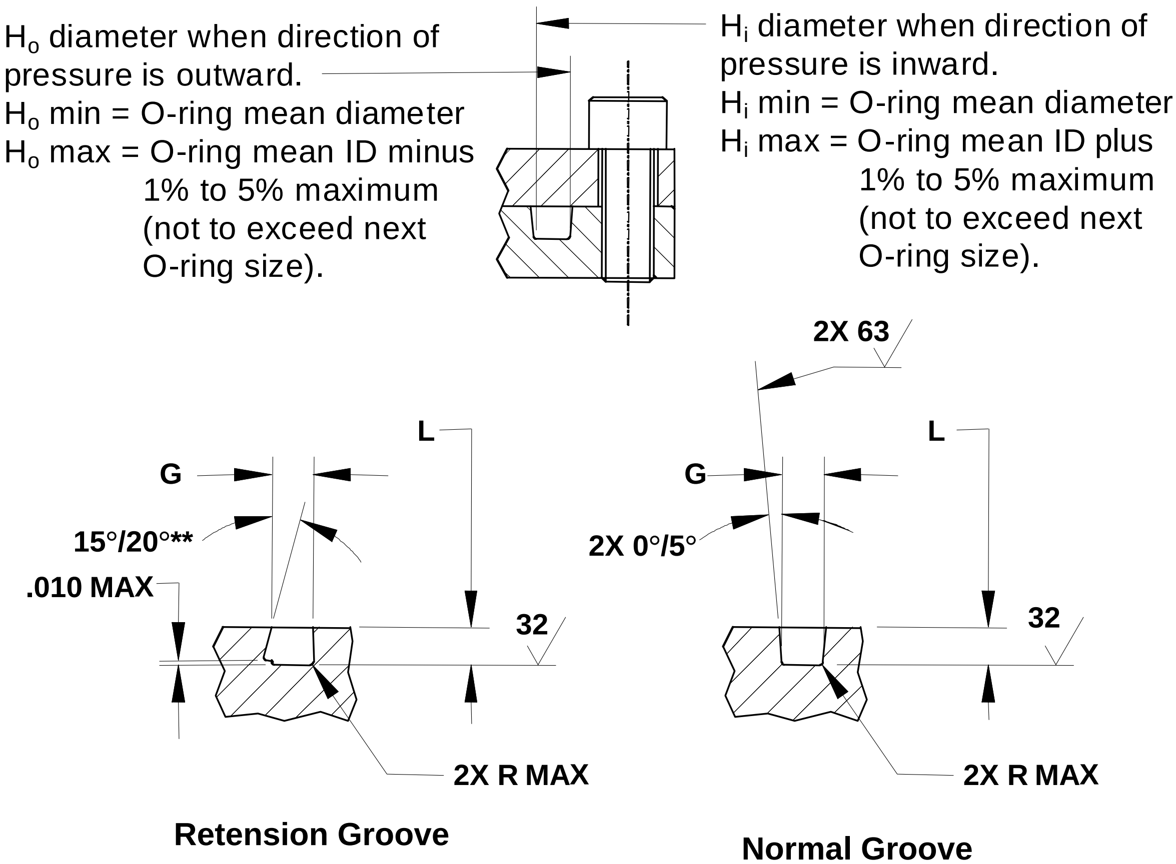
26.5.3.4 Vacuum Seal Gland for O-Ring (Metric)



O-Ring Size Parker #2	W Cross Section		L Gland Depth	G Groove Width	R Groove R	Squeeze Min/Max %
	Nominal	Actual*				
004–050	1/16"	1.78 ± 0.08	1.32 ± 0.05	2.16 ± 0.08	0.38 Max	19/32
102–178	3/32"	2.62 ± 0.08	1.96 ± 0.08	3.05 ± 0.08	0.38 Max	20/30
201–284	1/8"	3.53 ± 0.1	2.64 ± 0.08	4.06 ± 0.08	0.64 Max	20/30
309–395	3/16"	5.33 ± 0.13	3.99 ± 0.13	6.05 ± 0.08	0.9 Max	21/30
425–475	1/4"	6.99 ± 0.15	5.23 ± 0.13	7.8 ± 0.08	0.9 Max	21/29

* Tolerance on extruded O-ring stock is twice that shown.
** 15° ± 1° under normal conditions.
20° ± 1° when O-ring ID is extremely large and assembly is in an overhead condition.

26.5.3.5 Vacuum Seal Gland for O-Ring (Inch)



O-Ring Size Parker #2	W Cross Section		L Gland Depth	G Groove Width	R Groove R	Squeeze Min/Max %
	Nominal	Actual*				
004–050	1/16"	0.070 ± 0.003	0.052 ± 0.002	0.085 ± 0.003	0.015 Max	19/32
102–178	3/32"	0.103 ± 0.003	0.077 ± 0.003	0.120 ± 0.003	0.015 Max	20/30
201–284	1/8"	0.139 ± 0.004	0.104 ± 0.003	0.160 ± 0.003	0.025 Max	20/30
309–395	3/16"	0.210 ± 0.005	0.157 ± 0.005	0.238 ± 0.003	0.035 Max	21/30
425–475	1/4"	0.275 ± 0.006	0.206 ± 0.005	0.307 ± 0.003	0.035 Max	21/29

* Tolerance on extruded O-ring stock is twice that shown.
** 15° ± 1° under normal conditions.
20° ± 1° when O-ring ID is extremely large and assembly is in an overhead condition.

26.6 General Design Tips

26.6.1 Purpose

This section defines general design tips for LLNL-specific machine shop practices.

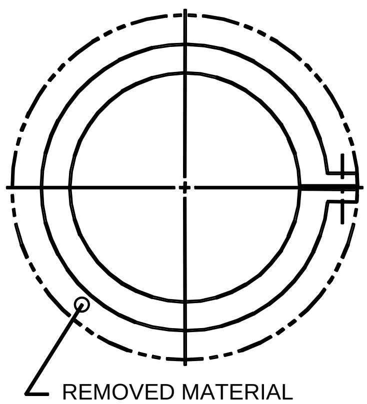
26.6.2 Applicable Documents

None.

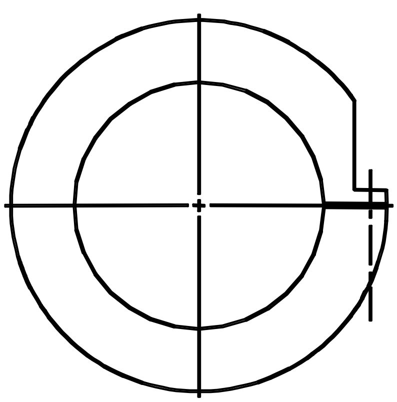
26.6.3 Problem-Solution Examples

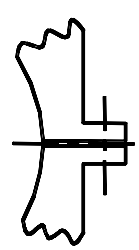
26.6.3.1 Reducing Fabrication Costs of Clamping Rings

The Problem: This design is costly to fabricate because of the protruding features.



The Solution: This design may be as functional as the one above but with a reduction in fabrication time.

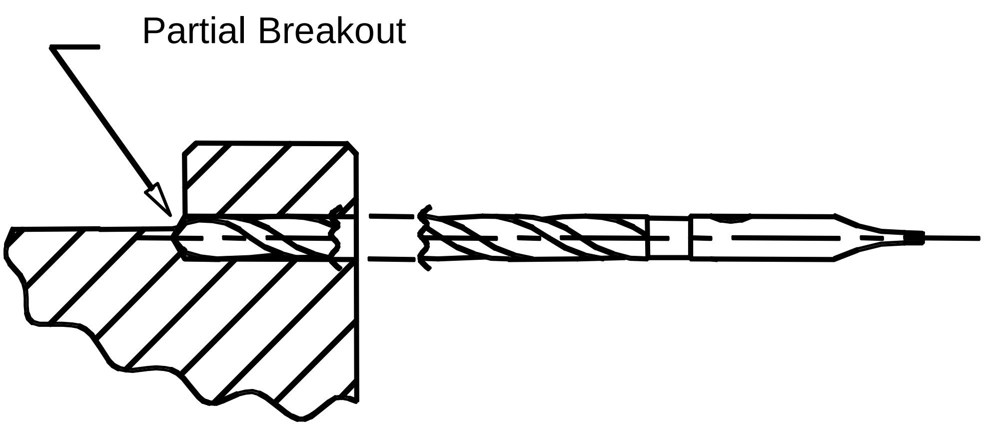




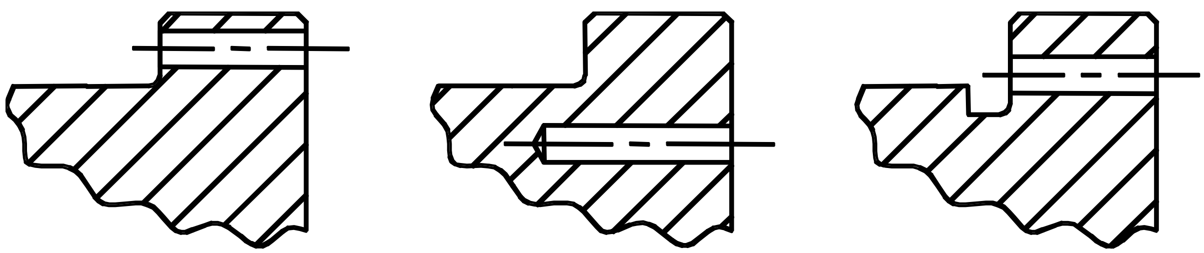
Alternative design configuration for a through bolt with nut

26.6.3.2 Drilled Hole—Partial Breakout

The Problem: Partial breakout of drilled holes will often result in broken drills.



The Solution: Design to avoid partial breakouts.

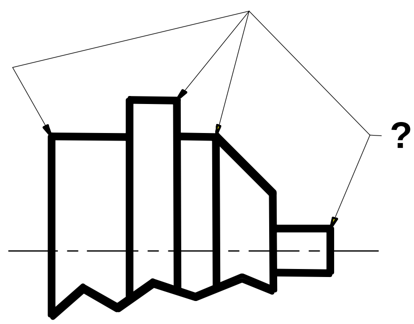


26.6.3.3 Radius or Chamfer Specification

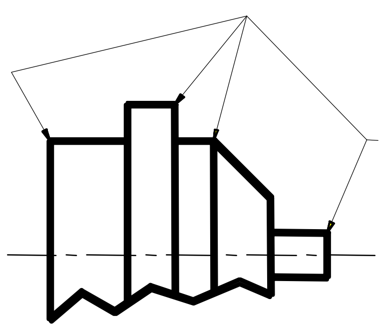
The Problem: Machined external corners may be done as either chamfers or as radii. The problem is in knowing which one to specify.

Radii are the preferred solution for numerical controlled machining.

Chamfers are the preferred solution for conventional machining.



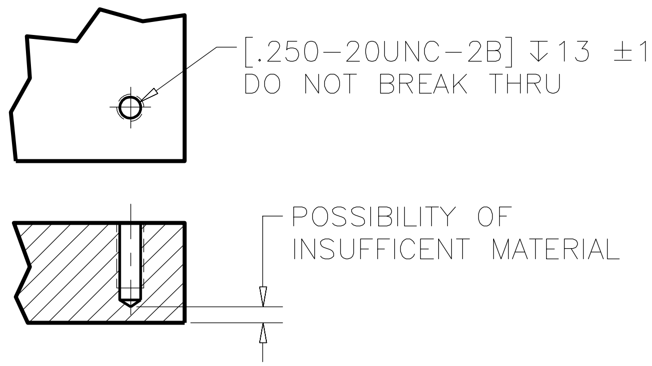
The Solution: Specify radius (R) or chamfer (CHAM) for corner definition when the design will allow. This gives flexibility to the shops.



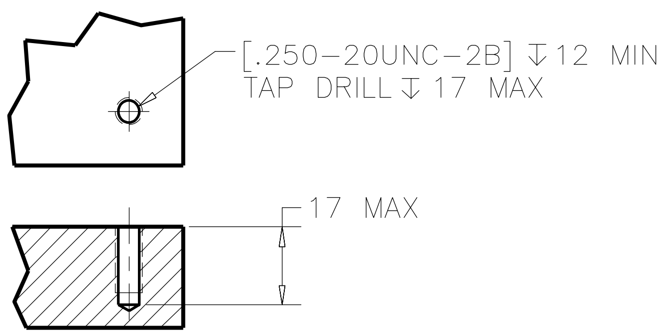
Note: Some CAM applications require the specification of a specific radius or chamfer in the database.

26.6.3.4 Blind Tapped Hole Depth

The Problem: Insufficient wall thickness at the bottom of a blind tapped hole.

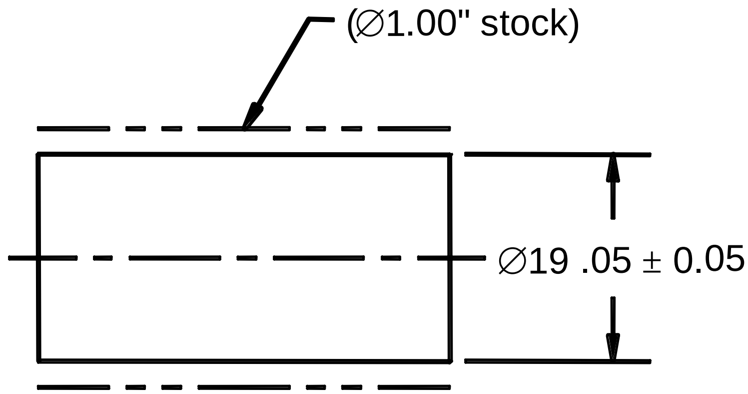


The Solution: Give specific dimensions for the tap drill depth.

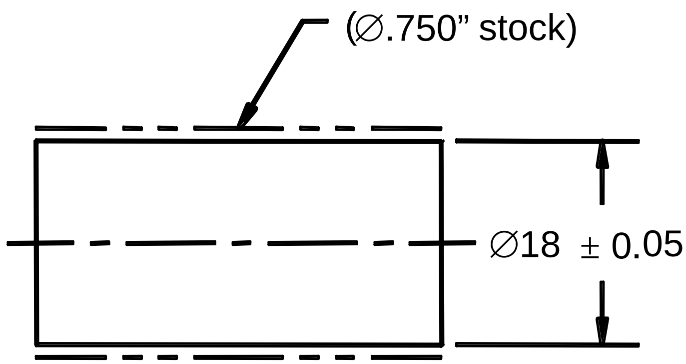


26.6.3.5 Machining Stock Material

The Problem: Specifying a tight tolerance on what would normally be a stock diameter size such as 19.05 [.750"] may require machining from a larger stock diameter.

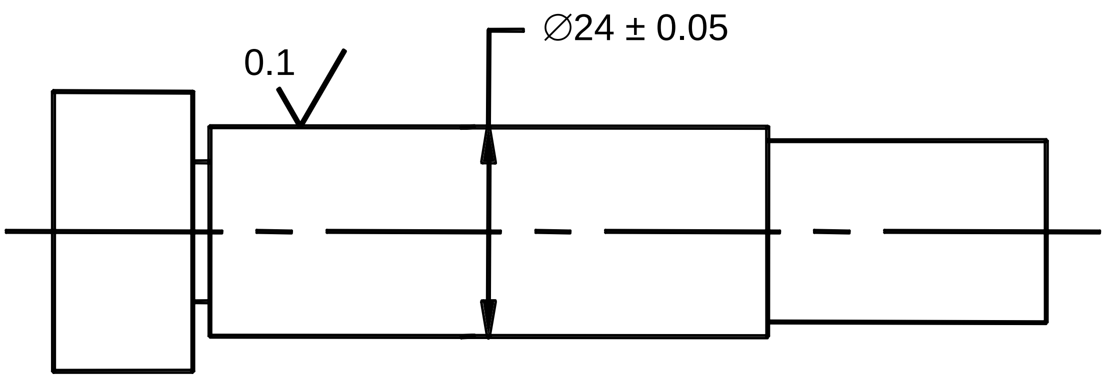


The Solution: If the design will allow, size the part 18 (0.708") such that it can be fabricated from stock material with a minimum of machining and material removal.

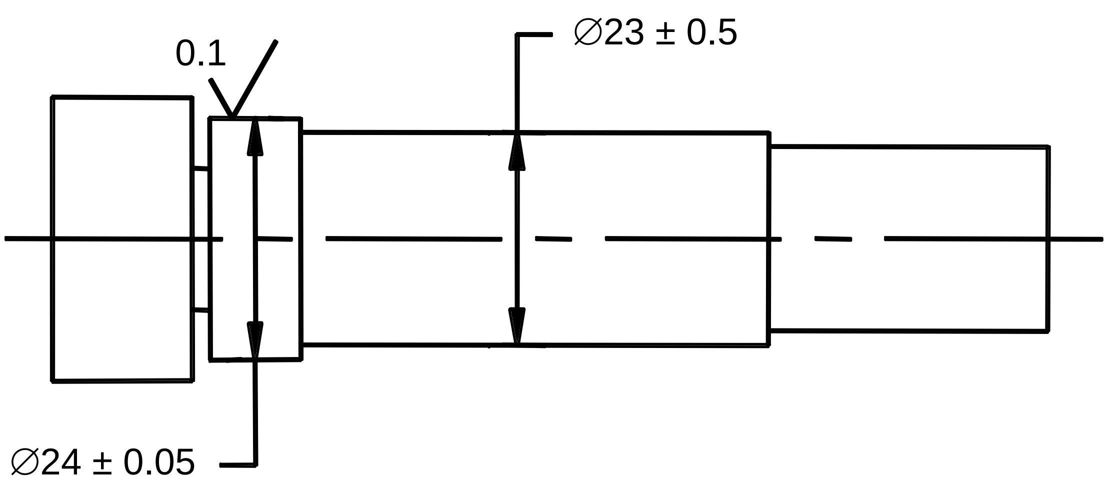


26.6.3.6 Minimizing Tolerance Area

The Problem: The entire length of this shaft must meet finish and tolerance requirements.

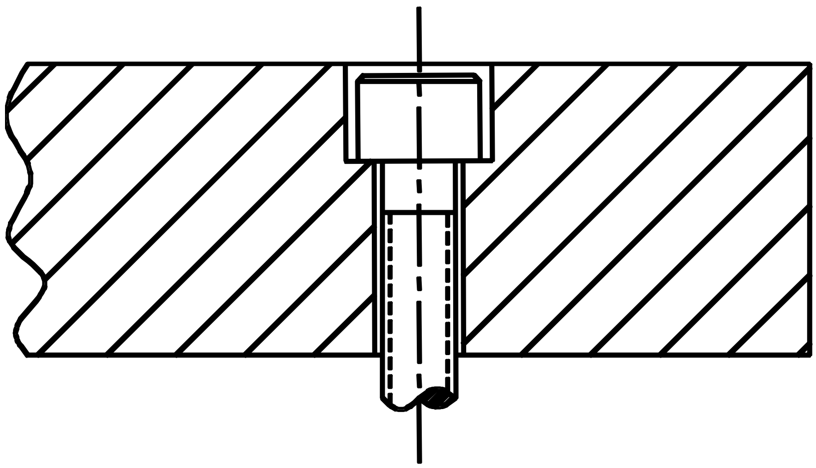


The Solution: Often only a small section of a shaft must be held within precision tolerances. To save time and money, step the noncritical length, and loosen the tolerance.

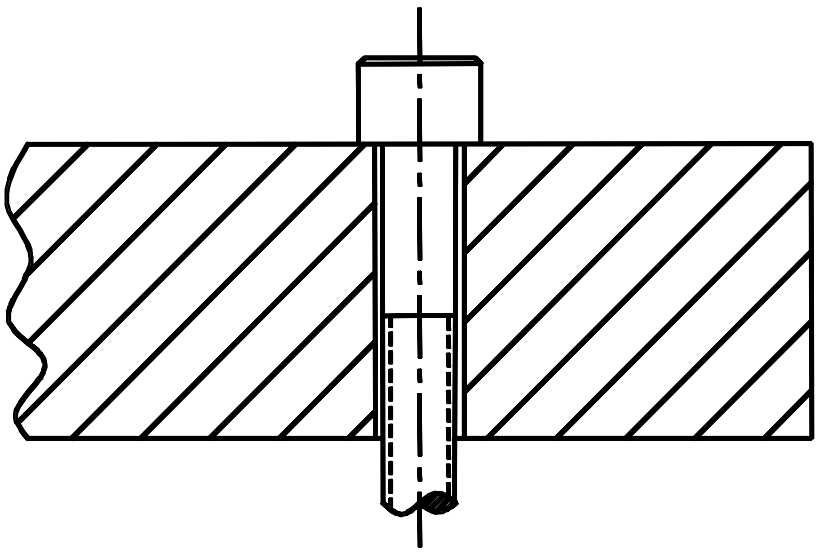


26.6.3.7 Nonfunctional Counterbore

The Problem: Specifying a counterbore for cosmetic or nonfunctional reasons. The cost is approximately doubled as compared to a drilled hole.

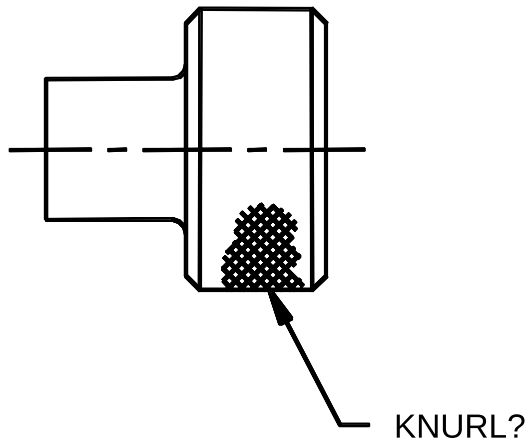


The Solution: Counterbore only when it is required. You will save fabrication time and money.

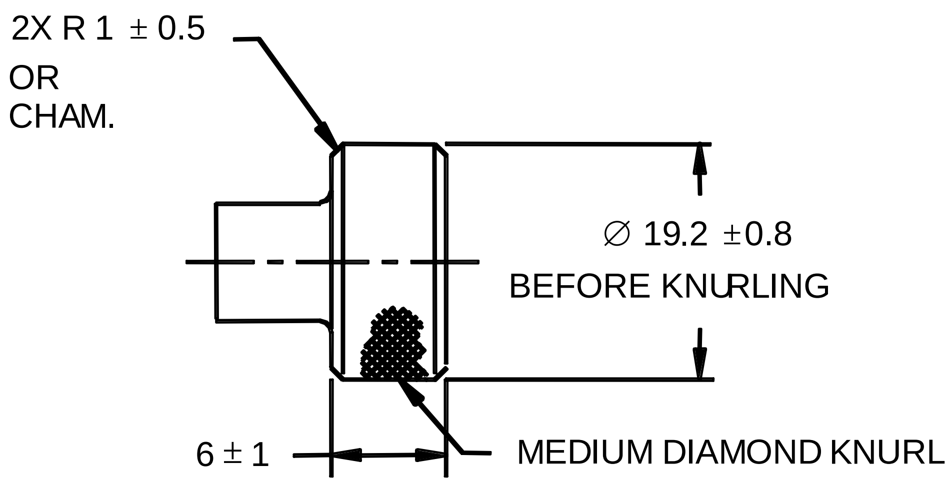


26.6.3.8 Knurling Specification

The Problem: How to specify a knurl for noncritical applications.



The Solution: Specify only the diameter before knurling, class, and pattern.



DIAMETER: The before knurling diameter expressed in multiples of 0.8 (1/32"). The recommended tolerance is ± 0.8.

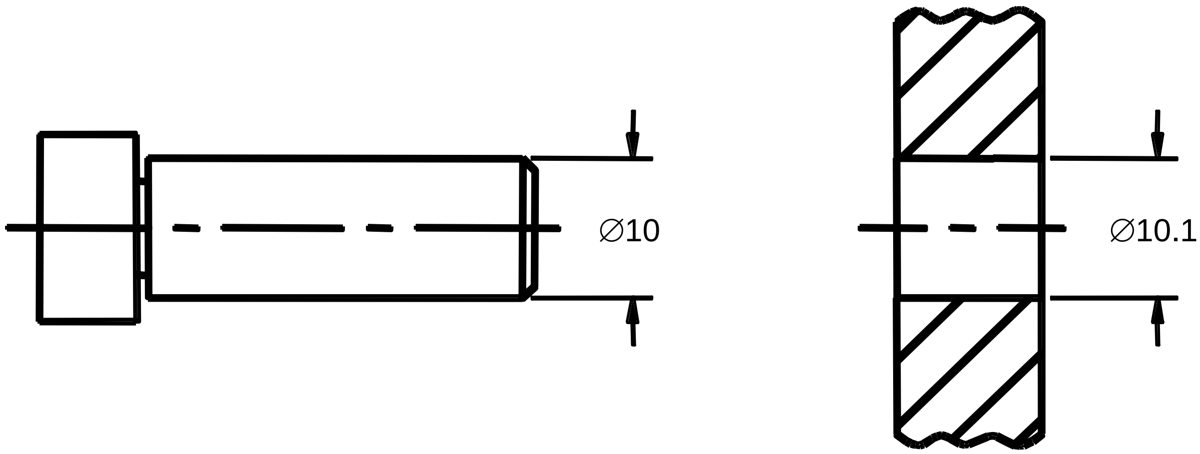
CLASS: Medium (preferred); also fine and coarse.

PATTERN: Diamond or straight.

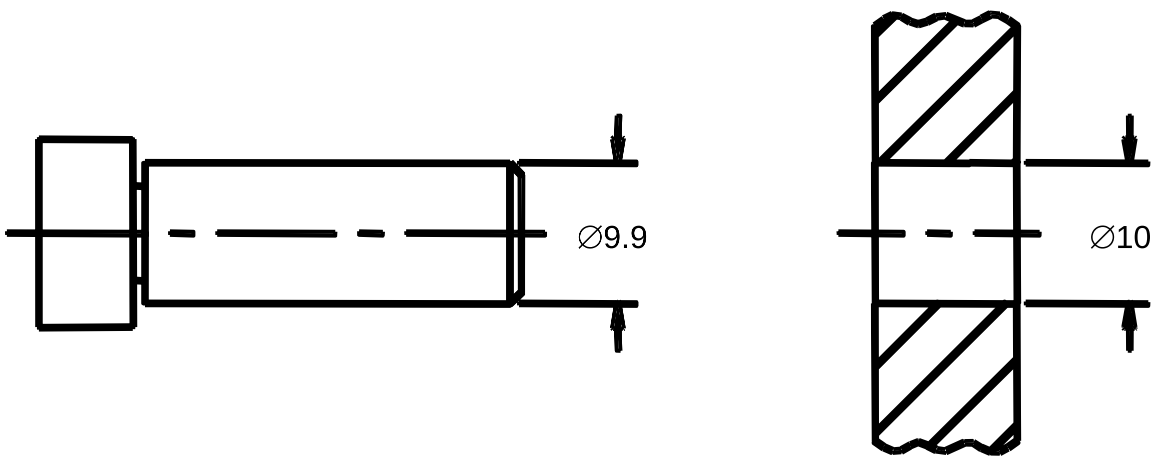
Note: For critical applications and general knurling information, see Knurling, ANSI/ASME B94.6-1984.

26.6.3.9 Shaft and Nonstandard Holes

The Problem: Special tooling is required to fabricate a nonstandard hole to fit a shaft; this results in added tooling cost and time.

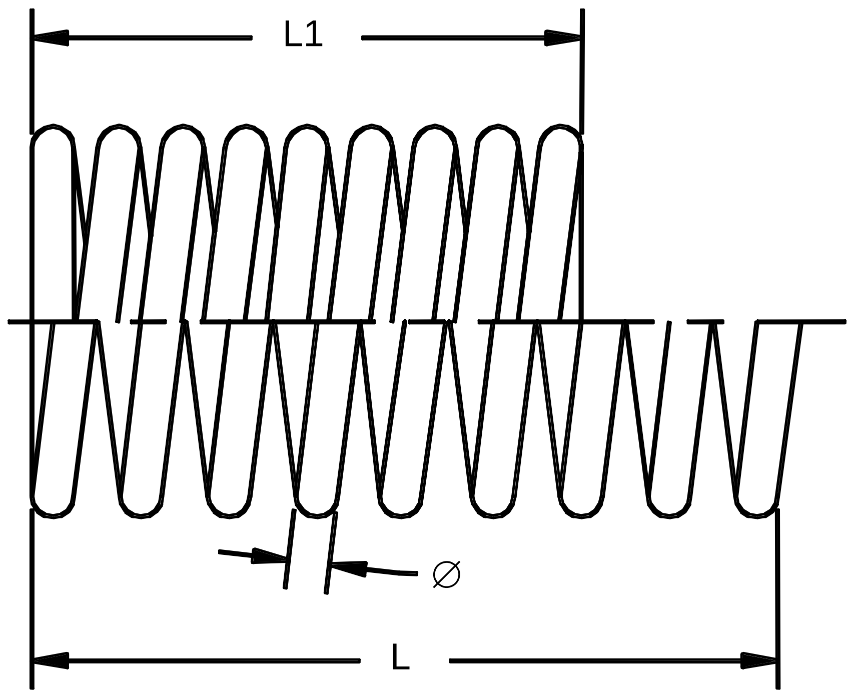


The Solution: Size the shaft to fit a standard hole.



26.6.3.10 Metric Springs

The Problem: How to specify and represent a metric spring.



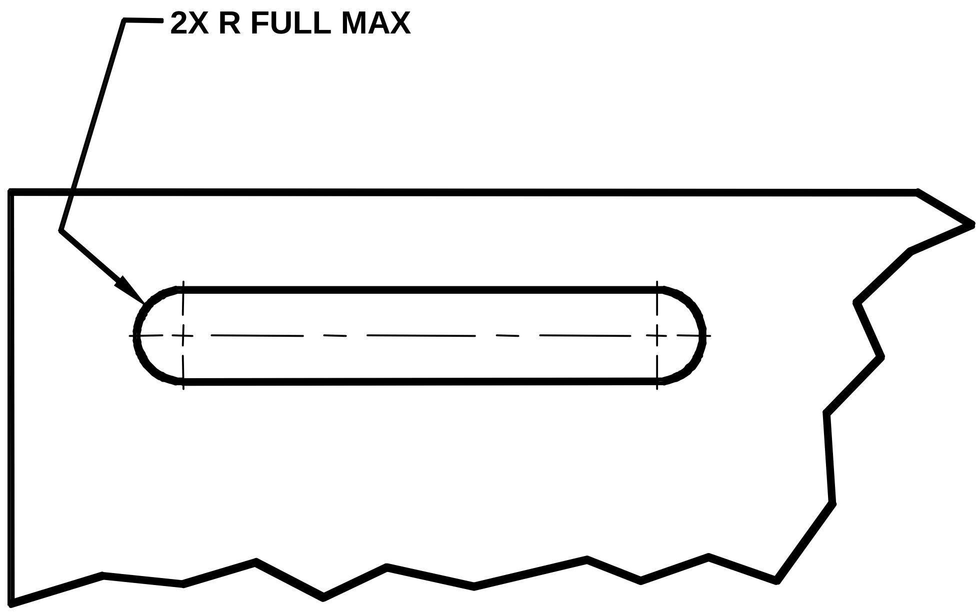
COMPRESSION SPRING SHOWN

The Solution: When it is required to specify a spring in metric units, the same rules for specification in inches apply, except units are metric, expressed in forces Newton (N), and spring rate is expressed in N/mm.

26.6.3.11 Radii on Slotted Holes

The Problem: The use of the term "R" on the ends of a slotted hole as described in ASME Y14.5M-1994, Paragraph 1.8.10, may be unnecessarily restrictive if the design will accept anything from a square corner to a full radius.

The Solution: Indicate as shown.



Section 27. Memos

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