



ENGINEERING SPECIFICATION

**TITLE: FABRICATION  
STANDARDS**

Spec. No.: **M7-13**

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Page **i** of **iii**

### **REVISIONS**

Added definitions and replaced the term "tube" with "VED." Added material-removal requirements for OFE copper forgings and castings. Removed references to Supplier Manual/Handbook. Clarified packaging requirements.



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**ATTENTION**  
**UNLESS OTHERWISE SPECIFIED ON THE PURCHASE ORDER(S)**  
**OR CPI INTERNAL SHOP WORK ORDER(S), CONFORMANCE**  
**TO ALL REQUIREMENTS OF THE DRAWING(S) AND**  
**SPECIFICATION(S) IS MANDATORY.**

## PREFACE

The object of the Fabrication Standards Specification No. M7-13 is to supplement design information on CPI drawings for microwave vacuum-electron device (VED) assemblies and components. Suppliers and CPI manufacturing units shall be responsible for the implementation of these standards in the performance of work for CPI as outlined in CPI purchase orders and shop work orders.

This standard has been revised to reflect the technical requirements common to the following three divisions within CPI:

Eimac Division  
Microwave Power Products Division

Section 6.0, "Coolants, Lubricants, and Solvents," which has been a part of previous revisions, is now a separate, subordinate document (M7-179) to facilitate subsequent revisions. All data therein are still considered flowdown requirements from M7-13.

**Failure to comply with the requirements contained in the Fabrication Standards may result in the rejection of the material produced. In the event of a conflict between the standards, the drawing, and/or the purchase order, the purchase order shall take precedence, the drawing next, and then the standards.**

All questions from Suppliers concerning the interpretation of the standards shall be directed to the individual CPI purchasing departments. Additional information or revisions shall be provided to Suppliers and all CPI departments engaged in fabrication of piece parts, subassemblies, and finished products.

## REFERENCES (Latest Revision)

|             |   |
|-------------|---|
| ANSI Y14.5  | Dimensions and Tolerancing                  |
| FED-STD-H28 | Screw Thread Standards for Federal Services |
| CPI P0-1    | Approved Sources for Critical Raw Materials |
| CPI P18-2   | Clean Packaging of Supplier-Provided Parts  |
| CPI M7-35   | Inventory Packaging                         |
| CPI M7-179  | Approved Lubricants, Coolants, and Solvents |



DEFINITIONS

|                     |   |
|---------------------|---|
| Non-Vacuum Assembly | An assembly that is not within or part of the vacuum envelope |
| Non-Vacuum Part     | A part that is not within or part of the vacuum envelope      |
| Vacuum Assembly     | An assembly that is within or part of the vacuum envelope     |
| Vacuum Part         | A part that is within or part of the vacuum envelope          |
| VED                 | Vacuum Electron Device (modern name for "microwave tube")     |

1.0 RAW MATERIALS

The performance of VEDs is critically dependent upon the raw materials' strict conformance to specifications and to proper processing and cleanliness practices. CPI's products are subjected to numerous high-temperature cycles during their assembly and processing and must still retain high vacuum integrity, strength, and inherent thermal and magnetic properties. To this end, the Supplier shall be required to use ONLY the material specified on the drawing or on the purchase order to fabricate the required parts.

**NOTE**  
**USE OF UNAUTHORIZED MATERIAL IS NOT ALLOWED.**  
 Violations shall result in removal from the Approved Supplier List and possible exposure to consequential damages.

Some of the raw materials used by CPI have directional properties resulting from segregation or inclusions that can seriously jeopardize the vacuum integrity of microwave VEDs. For example,

- Low-carbon steels have regions of high carbon content.
- Stainless steels contain sulfide or oxide inclusions.
- Cupronickel occasionally exhibits slag inclusions.

During ingot reduction, these concentrations of impurities are "stretched out" in the rolling or drawing direction, forming "stringers" (e.g., in the plane of flat or sheet stock and on the axis for bar stock). CPI parts designed for vacuum applications will always prescribe a material orientation that will ensure a potential stringer leak path will run parallel to the vacuum wall instead of piercing it. Allowable forms are defined in the purchasing specification (P-spec) and denoted in the materials block of individual drawings by a P-spec suffix. The "Grain Symbol" (← GRAIN →) may also be used in instances of critical orientation.

- 1.1 Sourcing of raw materials shall be in strict accordance with CPI P0-1, "Approved Sources for Critical Raw Materials."
- 1.2 All raw material must be positively identified and directly traceable to the certifications that demonstrate the material's conformance to stated requirements.



- 1.3 Surplus material, including remnants, overage, and scrap, that cannot be traced directly to its certifications shall under no circumstances be used to fabricate parts for CPI.
- 1.4 Alternate forms of raw materials (plate, bar, sheet, etc.) may not be substituted without written approval from CPI.
- 1.5 It is unallowable to use welded tubing or to roll and weld flat stock unless specifically prescribed in the drawing or purchase order.
- 1.6 It is unallowable to repair parts by welding, plugging, flame spraying, or other methods without written approval from CPI.

**2.0 STANDARDS FOR RAW-MATERIAL MACHINING ALLOWANCES**

This section prescribes recommended machining allowances for raw materials to ensure removal of surface defects and oxides. The recommendations apply only to material where the smallest cross-section is 0.25 inch and greater. Material of smaller section has been demonstrated to have a useable surface as received.

**2.1 Requirements**

**2.1.1 Minimums**

The allowances specified are minimums to be removed from each side. Where greater amounts must be removed, it is recommended that an equal amount be removed from both sides, as permitted by available raw-material dimensions. If surface defects are still visible after removal of the machining allowance, the material should not be used at all.

**2.1.2 Calculation of Raw-Material Dimensions**

The minimum size of the raw material shall be determined as follows:

Determine the "Finished" dimension from the print and ADD the following amounts:

| <b>For OFE Copper (All Forms Except Castings and Forgings)</b> |                               |                           |
|--|-------------------------------|---------------------------|
| <b>Under 0.250" Thick</b>                                      | <b>0.251" to 1.000" Thick</b> | <b>Above 1.000" Thick</b> |
| None   | 5% min. from each surface     | 0.062" from each surface  |



| <b>For OFE Copper Castings and Forgings</b> |                               |                           |
|---|-------------------------------|---------------------------|
| <b>Under 0.250" Thick</b>                   | <b>0.251" to 1.000" Thick</b> | <b>Above 1.000" Thick</b> |
| N/A   | N/A                           | 0.50 from each surface    |

| <b>For All Others (Flat Plate and Rectangular Bar)</b> |                               |                             |
|--|-------------------------------|-----------------------------|
| <b>Under 0.250" Thick</b>                              | <b>0.251" to 1.000" Thick</b> | <b>Above 1.000" Thick</b>   |
| None   | 2% min. to each surface       | 0.020" min. to each surface |

| <b>For All Others (Round Bar or Rod)</b> |                                   |                          |
|--|-----------------------------------|--------------------------|
| <b>Under 0.250" Dia.</b>                 | <b>0.251" Dia. to 1.000" Dia.</b> | <b>Above 1.000" Dia.</b> |
| None                                     | 4% min. to diameter               | 0.040" min. to diameter  |

**2.1.3 Tubing**

The raw material sizes for the OD of tubing shall be calculated in the same way as the round bar diameter.

The maximum ID of tubing shall be calculated by DEDUCTING the following amounts from the "Finished" dimension:

| <b>Under 1.000" ID</b> | <b>Above 1.000" ID</b> |
|------------------------|------------------------|
| None                   | 0.040" min.            |

**3.0 CERTIFICATION**

This section defines the items requiring certification as specified by CPI and states the minimum information that must accompany the material. When a certification is required, the purchase order will state "Certification (Certs) Required." If a type of certification is specified on the purchase order and not listed here, the Supplier should contact the CPI buyer before proceeding with the order.



### **3.1 Delivery or Storage of Certifications**

Each CPI division shall have specific instructions on the delivery or retention of the required certifications. To ascertain the proper procedure for the correct processing of certifications, consult the Materials organization for the specific division for which material is being supplied.

### **3.2 Requirements on All Certifications**

The following information must be provided with all certifications:

- A. CPI Purchase Order Number
- B. CPI Part Number/Specification Number and Revision Letter
- C. Quantity or Amount in Shipment
- D. Manufacture Lot, Heat, and/or Batch Number
- E. Compliance Statement
- F. Signature, Title of Company Representative, and Date

### **3.3 Certification Types**

The following information must also accompany these specific products or processes:

#### **3.3.1 Age-Dated/Environmentally Controlled Material**

- A. Material Description and Type
- B. Storage Conditions

**NOTE**

Specific storage conditions other than normal ambient and environment must be stated on the exterior of the package.

- C. Expiration Date (must also appear on each container of the product itself)

#### **3.3.2 Ceramics**

- A. Material Description
- B. Method of Manufacture (isostatic, extruded, etc.)



**3.3.3 Raw Material (When required by P-spec)**

- A. CPI Material Procurement Specifications (P3-1B, P1-7D, etc.)
- B. Size and/or Shape of Material
- C. Test Reports (chemical and physical)

**3.3.4 Special Processing (Typical processing certifications include plating, priming, heat-treating, ceramic metallizing, brazing, welding, etc.)**

- A. Total Quantity Processed
- B. Definition of Process (CPI specification, MIL specification, or other brief description)

**3.3.5 Specific Requirements or Tests (Mechanical, Electrical, Environmental)**

Description of the specific item being certified

- A. CPI Drawing and Note Number
- B. Applicable Specification and Requirement

**4.0 PACKAGING AND LABELING**

**4.1 Parts Protection in Packing**

Parts shall be packaged for shipment so they are protected from damage and contamination, prevented from nesting and entangling, and easy to unpack. Step 4.1.2.2 lists several packaging schemes that can be used as an aid. For more detail on packaging items, see Section 1 of M7-35.

**4.1.1 Unacceptable Packing Materials**

Dusty and linty materials, such as sawdust, shredded newspaper, and excelsior



**4.1.2 Suitable Packing Materials**

4.1.2.1 Cellulose wadding (Kimpack), corrugated paper board, and expanded plastics (Specific notes on drawings concerning packing requirements take precedence.)

4.1.2.2 The following table lists recommended packaging schemes for several commodities:

| <b>Commodity</b>  | <b>Recommended Packaging</b>   |
|---|--|
| Ceramics  | Individually package; bubble wrap  |
| Braze Wafers/Washers  | Poly bag, then lay flat in container (see P18-2 for clean-parts packaging)               |
| Bellows   | Individually package; divider trays; Rondo boards  |
| Small Drift Tubes and TWT Anodes  | Cavity tray VMC-35, purchased from Odyssey (408) 260-4012<br>Individually wrap; poly bag |
| Large Drift Tubes (MPP)   | Use plastic end caps to protect the nose   |
| Diaphragms  | Divider trays; individually wrap; poly bag (one piece per bag)                           |
| CONFLAT® Flanges  | Individually wrap in bubble wrap, end cap on knife-edge side                             |
| Coupled-Cavity Pole Pieces and Cavity Plates                                | Divider trays P-99056, F-19951, F-19952; poly bag (one piece per bag)                    |
| Polished Parts (parts having an exposed surface with a 16 finish or better) | Individually wrap in lint-free paper, then place in a bubble bag                         |

**4.1.3 Clean Parts Packaging**

Refer to CPI specification P18-2 for clean packaging requirements.

**4.1.4 Properly Packed Materials**

Pack large shipments and heavy parts in small lots for easier handling. Shipments packaged in a single corrugated carton shall not exceed 40 pounds.



## **4.2 Transportation**

### **4.2.1 Corporate Freight Rates**

Suppliers are encouraged to take advantage of CPI's corporate freight rates. Consult Purchasing for current carrier names and account numbers.

## **4.3 Package Labeling**

### **4.3.1 Label Requirements**

Label each package as follows:

- A. Name of Supplier
- B. CPI Division Purchase Order Number
- C. Receiving Area
- D. CPI Division Part Number and Revision Letter
- E. Quantity (use same unit of measure as stated on purchase order)
- F. Other applicable information (e.g., Just-in-Time Delivery labels, EPA requirements, clean-parts labels, etc.)

### **4.3.2 Multiple-Container Lots**

Lots shipped in more than one container must be sequentially labeled (e.g., Box 1 of 3, Box 2 of 3, etc.)

### **4.3.3 EPA Labeling Requirements**

The Environmental Protection Agency (EPA) has established the Final Rule (40 CFR Part 82, Protection of Stratospheric Ozone) that requires warning labels on products containing or manufactured with certain ozone-depleting substances and on containers of these products. The rule covers all products introduced into interstate commerce after May 15, 1993. The substances covered by this rule are listed in the rule as Class I chemicals, including chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and 1,1,1-trichloroethane (TCA).

For further information, contact the Stratospheric Ozone Protection Branch, Stratospheric Protection Division, Office of Atmospheric Programs, Office of Air and Radiation (6202-J), 401 M Street SW, Washington, D. C, 20460, telephone (202) 233-9742. The Stratospheric Ozone Information Hotline at 1-800-296-1996 can also be contacted for further information.



## **5.0 GEOMETRIC DIMENSIONING AND TOLERANCING SYSTEM**

Interpret dimensions and tolerances according to the latest revision of ANSI Y14.5.

### **5.1 Unspecified Tolerance**

When the tolerance limit is not specified on the drawing or sketch, the following shall apply:

Decimal:        1 place  $\pm 0.1$   
                     2 places  $\pm 0.02$   
                     3 places  $\pm 0.005$   
                     4 places  $\pm 0.0005$

Fraction:         $\pm 1/64$

Angles:          $\pm 1^\circ$

### **5.2 Unspecified Finish**

The finish requirement for machined surfaces shall be 125  $\sqrt{\quad}$  unless otherwise specified. Flaws are not included in surface finish measurements. The following flaws are not acceptable unless otherwise specified:

- Splits, tears, and cracks
- Displaced metal, folds (ironed-in or smeared-over scratches and burrs)
- Inclusions (imbedded particles—chips, burrs, foreign matter)
- Oxide (rust or corrosion)
- Seams

The surface finish must not exceed the average value of microinches shown in the symbol ( $\sqrt{\quad}$ ).

Unless otherwise specified, the general finish in the title block applies only to machined surfaces.

Commercial stock surface finish is acceptable when “stock” is specified as a dimension.



**5.3 Unspecified Flatness**

When flatness is not specified, it shall not exceed the values in Table 1 and shall not violate the MMC perfect-form boundary.

| <b>TABLE 1<br/>Flatness Tolerance</b> |  |  |
|---------------------------------------|--|--|
| <b>Surface Finish<br/>Required</b>    | <b>Unit Variation<br/>in any Direction</b> | <b>Total Variation<br/>if Length is 1" or More</b>                           |
| 63<br>✓<br>or better                  | 0.003 in. per in.                          | 0.003 times the longest<br>element of the feature with a<br>maximum of 0.012 |
| 64<br>✓<br>or rougher                 | 0.005 in. per in.                          | 0.005 times the longest<br>element of the feature with a<br>maximum of 0.020 |

**5.4 Unspecified Cylindricity**

When cylindricity is not specified on the drawing, diameters shall be cylindrical within one-half the feature size tolerance and shall not violate the MMC perfect-form boundary.

**5.5 Unspecified Perpendicularity**

When implied right (90°) angles are not specified in the drawing, they shall be within  $\pm 0^\circ 15'$  of the intended 90° angle or 0.004 inch per inch maximum error and shall not violate the MMC perfect-form boundary.

**5.6 Unspecified Parallelism**

When surfaces shown in parallel relationship are not specified on the drawing, they shall be parallel within 0.002 inch per inch of width or length and shall not violate the MMC perfect-form boundary.

**5.7 Unspecified Concentricity**

When concentricity is not specified on the drawing, the concentricity of any two round features shown on the same centerline shall be equal to one-half the arithmetic sum of the feature size tolerances. The feature having the smallest total tolerance shall be considered datum, if no datum is specified.

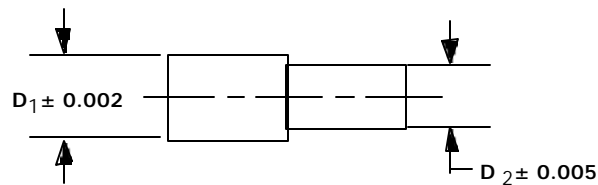
Example: The concentricity between D1 and D2 will be:

Tolerance D1 =  $\pm 0.002 = 0.004$  THIS IS DATUM (smallest total tolerance)

D2 =  $\pm 0.005 = 0.010$

Axis of D2 must be concentric to axis of D1 by 0.007 or less.

$$[(0.004 + 0.010)/2 = 0.014/2 = 0.007]$$



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### 5.8 Unspecified Position

When positional symmetry is not specified, ( $\oplus$  formerly  $\equiv$ ) features shown as lying on the centerline of a part, e.g., a slot in a screw head, shall be symmetrical within the total width tolerance of the feature.

### 5.9 Unspecified Circularity

Diameters that do not have a specified roundness tolerance shall be round within one-half the feature size tolerance but must not extend beyond the MMC perfect-form boundary.

### 5.10 Unspecified Countersinks

Unless otherwise specified, all countersinks shall be  $82^\circ \pm 5^\circ$ .



## **6.0 TOOLING**

Parts contamination can result from contact with some materials commonly used for tooling. Tooling made of brass, bronze, or platinum shall not be used. Cadmium- or zinc-plated tooling shall not be used.

**Exception:** Parts that are not used inside the vacuum envelope of microwave, power-grid, and X-ray VEDs or similar devices are exempt from this requirement. These parts are either made from brass, aluminum, zinc, lead, and plastic or designated by the drawing as not used in the vacuum envelope of the VED.

## **7.0 PLATING AND COATING OF SURFACES**

Plating, coating, or other metal finishing to be performed by Suppliers shall be specified on the drawing using military or industry standards. All quality-assurance provisions in the standard shall apply. Processes to be performed within CPI shall refer to the CPI specification.

When a part or assembly drawing specifies plating or coating, dimensions on the drawing are the machined/fabricated dimensions. The part/assembly has been designed to allow for the application of the plating or coating as specified. Any dimensions that apply after plating will be noted separately.

Coating thicknesses specified are the average thickness for the entire part. Normal thickness distribution based on current density is assumed. For example, areas of high current density, such as sharp edges and outer ends of parts, can have considerably more than the specified coating thickness. Areas of critical thickness will be noted on the drawing. Compliance to critical thickness specifications must be verified and documented.

## **8.0 BURRS**

Burrs adversely affect VED performance by acting as traps for chemical cleaning solutions, serving as "virtual" leaks, and serving as point emission sources in areas of high electrical potential.

### **8.1 Definition**

A burr is found at the edge of a stamped or machined feature and is defined as an objectionable small projection of material that interrupts the normal contour of the plane or surface. (Note that this definition says a burr can only occur at an edge of a feature; anything on the surface is a nodule or particle, etc.)



8.2 Types

Various types of burrs are defined as follows:

- An imbedded burr is any burr that has been pressed into the material
- A feather burr is a very fine or thin burr generally less than 0.001-inch thick.
- A hanging burr is a burr that is not firmly attached to the workpiece.
- A rolled-over burr is a tight burr that is curled over on itself in such a manner that it traps contaminants within itself.

ROLLED-OVER AND IMBEDDED BURRS ARE NOT ALLOWED. EMBEDDED PARTICLES ARE NOT ALLOWED.

8.3 Height

Hanging burrs and feather burrs are subject to the limits prescribed below.

Burr height is defined as the maximum distance the burr projects above the surface of the workpiece.

| Maximum Burr Heights Allowed for Machined Features |                   |                             |
|--|-------------------|-----------------------------|
| 32<br>✓<br>Finish or Better                        | 63<br>✓<br>Finish | 125<br>✓<br>Finish or Worse |
| 0.0005   | 0.002             | 0.003                       |

A suggested method of determining burr height is to use a 30X microscope with a calibrated reticle in the eyepiece to measure the actual distance from the surface of the workpiece to the top of the burr. If this method is used, it is important to make the initial burr height determination using only a 10-power microscope.

In addition to burr height, burr direction may be a critical factor for sheet-metal parts. If so, the burr direction will be called out on the drawing (refer to Section 10.12).

Maximum burr heights for sheet-metal parts will be found in Section 10.11.

#### **8.4 Removal**

It shall be standard practice to remove burrs from the edges of all surfaces, even if this requirement is not noted on the drawing, such that the requirements stated in Sections 8.2 and 8.3 are satisfied.

The notation "No Burrs" appearing on a drawing specifies that burrs be removed to the extent they are not visible under 10X magnification.

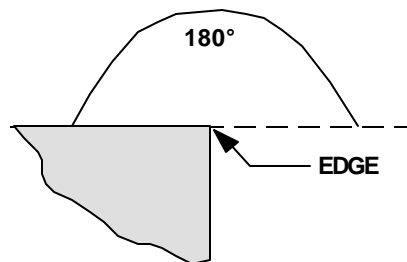
While deburring, it is imperative that excessive material is not removed; after deburring, the parts must still be within the dimensional tolerances specified on the print.

The deburring method used must not introduce any contamination, and all loose particles must be removed.

Contamination resulting from embedded particles introduced during the deburring processes can adversely affect the performance of our product. The use of a Cratex stick or other similar bonded abrasives that can leave embedded particles is **NOT** acceptable.

#### **8.5 Edges**

An edge is defined as the intersection of two planes of base material at an angle greater than  $180^\circ$  (outside).



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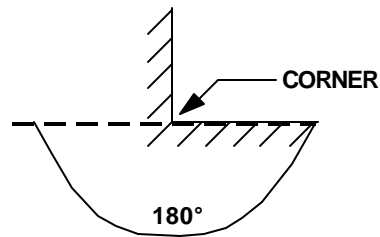
It shall be standard practice to remove all sharp edges unless otherwise specified.

Edges shall be broken by either a 45° chamfer or a radius. If limits are not specified on the drawing, a 0.005-inch maximum chamfer or radius is acceptable for lengths less than 1 inch. For features greater than 1 inch, a 0.010-inch maximum chamfer or radius is acceptable.

A “sharp edge” callout on a drawing shall be interpreted as being limited to a 0.002-inch maximum chamfer or radius.

### **8.6 Corners**

A corner shall be defined as the intersection of two or more planes of base material at an angle less than 180° (inside).



D4020

Unless otherwise specified on the drawing, all corners shall be limited to a 0.010-inch maximum radius.

A “sharp corner” callout on a drawing shall be interpreted as being a corner with no greater than a 0.002-inch maximum radius.

Undercuts shall be subject to rejection unless otherwise specified on the drawing.

### **8.7 Sheet Metal**

For additional requirements concerning burrs on sheet-metal products, see Paragraph 10.11.

### **9.0 THREADS**

All threads, unless otherwise specified on the drawing, shall conform to the unified tabulations and formulations of FED-STD-H28. Unified form threads, American National Form threads, special threads, and unified miniature screw threads shall be defined by the unified system.

### 9.1 Internal Threads

All internal threads shall be tapped using standard machine screw taps or machined. THREAD-FORMING TOOLS ARE PROHIBITED UNLESS OTHERWISE SPECIFIED, as formed threads can trap contaminants. **EXCEPTION:** Parts that are not used inside the vacuum envelope of vacuum-electron devices are exempt from this requirement. These parts are either made from brass, aluminum, zinc, lead, or plastic or are designated by the drawing as not used in the vacuum envelope of the VED.

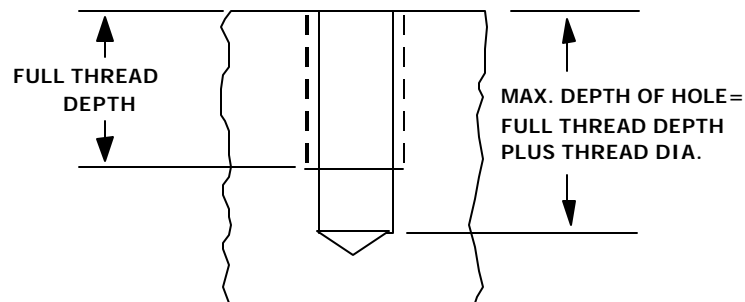
### 9.2 Threaded Holes

All threaded holes shall be countersunk  $82^\circ \pm 5^\circ$  to a diameter equal to at least the major diameter of the specified thread. In the case of through-holes, this requirement shall apply to both ends. The countersink diameter shall not exceed 0.020 inch over the major thread diameter.

The specified depth of a threaded hole shall mean there shall be full threads to that depth.

Where a three-place decimal dimension ( $\pm 0.005$  tolerance) is used to define thread depth, one full thread shall be allowed beyond the dimension.

The depth of the tap drill shall not be specified unless critical. If the depth of a tap/twist drill hole is not specified, the depth of the hole shall not exceed the full thread depth plus a dimensional allowance equal to the nominal thread diameter.



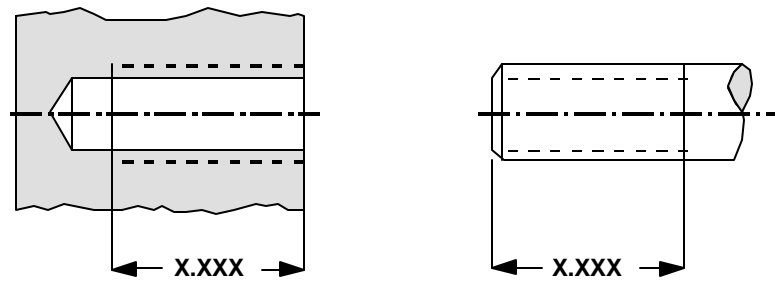
In gauging a threaded hole, the "No-Go" gauge shall not penetrate more than three turns. Exceptionally short thread length (less than three pitches) may pass over the plug gauge provided there is a perceptible drag. The "Go" gauge shall freely penetrate the full length of the thread.

### 9.3 Threaded Parts

The end of all external threads shall be chamfered at  $45^\circ \pm 5^\circ$  to the minor diameter.

### 9.4 Full-Form Threads

The length of fully formed threads is dimensioned. When only one dimension is used to specify the length of threads, it is interpreted to mean the length of fully formed threads, excluding runout. Where a chamfer, not exceeding two pitches in length, exists at the entering end of the thread, it is included in the length of fully formed threads. The figure below shows methods of delineating with no limit on runout.



THREAD LENGTH

D4025

### 9.5 Unspecified Thread Class of Fit

| Thread Description        | Thread Class of Fit |
|---------------------------|---------------------|
| External Threads          | 2A                  |
| Internal Threads          | 2B                  |
| External Threads (Metric) | 6G                  |
| Internal Threads (Metric) | 6H                  |
| Threaded Inserts (#3-#8)  | 2B                  |
| Threaded Inserts (>#8)    | 2B or 3B            |



**10.0 SHEET-METAL PRODUCTS FABRICATION REQUIREMENTS**

**10.1 Sheet Metal**

Sheet metal is considered to be sheet stock that has a nominal thickness of 0.250 (1/4) inch, or less.

**10.2 Features and Surfaces**

Features and surfaces of sheet-metal parts shall be within drawing dimensional limits of size in the unrestrained condition unless otherwise specified.

**10.3 Machined Features**

Obvious machined features such as countersinks, chamfers, screw threads, and close-tolerance (0.003 inch or less) holes shall conform to the body of this standard.

**10.4 Circular Runout**

The circular runout of any internal or external diameter shall not exceed the value specified in Table 2 with respect to any other diameter on the same axis. If a datum axis is established by the drawing, the circular runout shall be in relation to that datum axis.

| <b>TABLE 2<br/>Circular Runout of Diameters</b> |   |
|---|---|
| <b>DIAMETER<br/>(Inches)</b>                    | <b>CIRCULAR RUNOUT<br/>TOLERANCE<br/>(Inches)</b> |
| Through 6.00                                    | 0.040   |
| 6.001 through 9.000                             | 0.070   |
| 9.001 through 20.000                            | 0.100   |
| 20.001 through 36.000                           | 0.150   |
| Over 36.000                                     | 0.200   |

**10.5 Washer-type Punching**

The center hole of washer-type punchings shall be located within the position tolerance shown in Table 3 in relation to the outside diameter.



| TABLE 3<br>True Position of Washer-Type Punchings<br>Relative to OD as Datum Feature |   |
|--|---|
| INSIDE<br>DIAMETER<br>(Inches)   | POSITION<br>TOLERANCE (MMC)<br>(Inches) |
| Through 6.0  | 0.030 dia.                              |
| 6.001 through 12.000   | 0.060 dia.                              |
| 12.001 through 24.000  | 0.100 dia.                              |
| Over 24.000  | 0.150 dia.                              |

**10.6 Flatness**

Variations in surface flatness shall not exceed the values shown in Tables 4 and 5 and shall not violate the dimensional limits of size.

| TABLE 4<br>Flatness for Nonwelded Surfaces |                                    |
|--|------------------------------------|
| NOMINAL STOCK<br>THICKNESS (Inches)        | UNIT VARIATION IN<br>ANY DIRECTION |
| Through 0.090                              | 0.010 in/in                        |
| 0.091 through 0.250                        | 0.007 in/in                        |

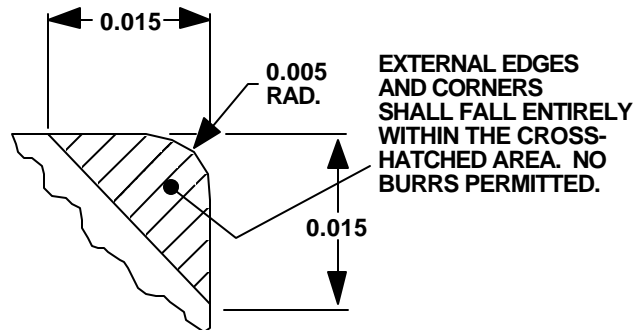
| TABLE 5<br>Flatness for Welded/Brazed Surfaces |                                    |
|--|------------------------------------|
| NOMINAL STOCK<br>THICKNESS (Inches)            | UNIT VARIATION IN<br>ANY DIRECTION |
| Through 0.032                                  | 0.025 in/in                        |
| 0.033 through 0.060                            | 0.020 in/in                        |
| 0.061 through 0.125                            | 0.015 in/in                        |
| 0.126 through 0.250                            | 0.005 in/in                        |

**10.7 Parallelism and Perpendicularity**

The elements of flat sheet-metal surfaces that are shown as parallel or perpendicular shall be parallel or perpendicular to each other within 3°. The datum shall be the longest adjacent surface that is parallel or perpendicular to the surface being measured.

### 10.8 Edges and Corners

Sheared edges are permissible but they, and all other edges and corners, shall be broken in accordance with the illustration below. This applies only to finished parts and not to "in-process" pieces of a welded or brazed assembly.

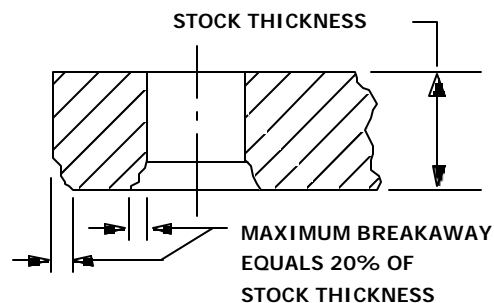


### 10.9 Stock Thickness After Forming

Sheet-metal thickness in areas affected by forming may be reduced by a maximum of 25 percent of the maximum stock thickness. Local thickening due to the part shape and the forming process is acceptable up to 30 percent of the maximum stock thickness.

### 10.10 Breakaway

The maximum breakaway of punched or sheared edges shall be not more than 20 percent of the stock thickness as shown below. The dimensional limits of size apply only to those portions of the edge where breakaway has not occurred.



**10.11 Burrs**

The following burr specifications are in addition to those covered in Section 8:

Limitations — under the conditions specified below, maximum burr heights are as follows (also see illustration in Section 10.12):

| <b>STOCK THICKNESS</b>    | <b>MAX. BURR HEIGHT ALLOWANCE</b> |
|---------------------------|-----------------------------------|
| 0.004 and under           | 0.001                             |
| over 0.004 to 0.014 incl. | 0.0015                            |
| over 0.014 to 0.039 incl. | 0.002                             |
| over 0.039 to 0.124 incl. | 0.003                             |
| over 0.124 to 0.186 incl. | 0.004                             |
| over 0.186 to 0.311 incl. | 0.005                             |
| over 0.311                | 0.010                             |

Wire and ribbon burrs on cut lengths of wire and ribbon, including flattening because of shearing pressure, shall not exceed 10 percent of the diameter or thickness, unless otherwise specified.

**10.12 Burr Symbols and Drawing Callouts**

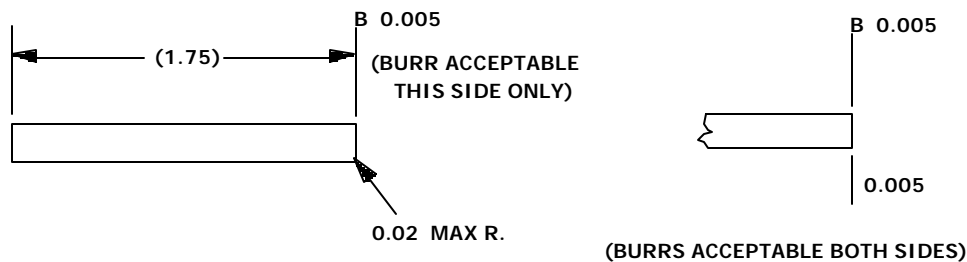
“B” placed on extension lines indicates that burrs are acceptable.

The maximum burr height allowed is shown adjacent to the symbol.

Arrowheads may be used to indicate the side on which burrs may occur.

Symbols placed on both sides indicate that burrs are acceptable on both sides.

A radius may be specified on an edge to show the direction of punching.





## 11.0 CASTING AND FORGING REQUIREMENTS

- 11.1 Position**—The position of coaxial or coplanar cast or forged features shall be in accordance with Table 6 with respect to each other; it should be noted that position does not include out-of-roundness. If a cast or forged datum axis is established by the drawing, the position control shall be in relation to that datum axis. The concentricity shall be  $\pm 0.010$ " at the lowest point on the surface of the forging before any surface-removal procedure (OFE Copper only).
- 11.2 Flatness**—Surface flatness shall not exceed the values specified in Table 7 except in the area of a parting line.
- 11.3 Cleanup**—Gates, risers, flash, runners, and parting lines on surfaces not subject to subsequent machining shall be trimmed and blended smooth with the part contour. Surfaces subject to subsequent machining shall be finished according to normal industry practice.
- 11.4 Mismatch**—Parting-line mismatch for forgings shall not exceed 0.05 inch maximum. Mismatch is defined as a defect resulting from die misalignment, producing an offset on the surfaces of the forging at the parting line. The mismatch of castings shall be contained within the applicable position requirements.
- 11.5 Draft**—Draft shall be applied as additional material to the dimensions shown on the drawing and shall not exceed the limits specified in Table 8.
- 11.6 Repair**—Castings and forgings shall not be repaired by welding, plugging, impregnating, peening, or any other methods except as permitted by specific drawing notes. Castings that shall be subsequently welded or brazed shall not be impregnated. Surface conditioning using standard shop practice for removal of surface defects is permissible within drawing dimensional limits.



| <b>TABLE 6<br/>Position of Coaxial/Coplanar Features</b>              |                          |                              |
|---|--------------------------|------------------------------|
|   | <b>Feature Dia/Width</b> | <b>Position Tol. RFS (S)</b> |
| Sand Casting  | Up to 6.000              | 0.060                        |
|   | 6.001 to 12.000          | 0.090                        |
|   | Over 12.00               | 0.120                        |
| Die Castings  | Up to 6.000              | 0.020                        |
|   | 6.001 to 12.000          | 0.040                        |
|   | Over 12.000              | 0.060                        |
| Shell, Plaster, Ceramic,<br>Permanent Mold, or<br>Investment Castings | Up to 6.000              | 0.040                        |
|   | 6.001 to 12.000          | 0.060                        |
|   | Over 12.000              | 0.080                        |
| Forgings  | Up to 6.000              | 0.060                        |
|   | 6.001 to 12.000          | 0.090                        |
|   | Over 12.000              | 0.120                        |

| <b>TABLE 7<br/>Flatness</b> |                       |                                       |  |
|-----------------------------|-----------------------|---------------------------------------|--|
|                             | <b>Surface Finish</b> | <b>FLATNESS TOLERANCE</b>             |  |
|                             |                       | <b>Variation In<br/>Any Direction</b> | <b>Total Variation<br/>(Lengths of More Than 1 Inch)</b> |
| Castings                    | 250 and Finer         | 0.015 in./in.                         | 0.060 max.   |
|                             | 251 Through 500       | 0.020 in./in.                         | 0.080 max.   |
| Forgings                    | 500 and Finer         | 0.010 in./in.                         | 0.060 max.   |
|                             | 500 and Over          | 0.020 in./in.                         | 0.100 max.   |

| <b>TABLE 8<br/>Draft Angle</b>                 |                    |                 |
|--|--------------------|-----------------|
|  | <b>DRAFT ANGLE</b> |                 |
|  | <b>Internal</b>    | <b>External</b> |
| Sand, Shell Mold, and<br>Ceramic Mold Castings | 3° max.            | 3° max.         |
| Plaster Mold Castings                          | 3° max.            | 1°30' max.      |
| Investment Castings                            | 1°30' max.         | 1°30' max.      |
| Permanent Mold and<br>Semiperm Mold Castings   | 4° max.            | 4° max.         |
| Forgings                                       | 10° max.           | 8° max.         |

**APPENDIX A: GEOMETRIC SYMBOLOGY**

| This Symbol on Drawing | Means                                | ANSI Reference |
|------------------------|--------------------------------------|----------------|
|                        | Datum Symbol                         | 3.3.2          |
|                        | Datum Target                         | 3.3.3          |
|                        | Basic Dimension                      | 3.3.4          |
|                        | Diameter                             | 3.3.7          |
|                        | Spherical Diameter                   | ---            |
|                        | Reference                            | 3.3.8          |
|                        | Feature Control Frame                | 3.4.2.1        |
|                        | Least Material Condition (LMS)       | 3.3.5          |
|                        | Regardless of Feature Size (RFS)     | 3.3.5          |
|                        | Maximum Material Condition (MMC)     | 3.3.5          |
|                        | Projected Tolerance Zone             | 3.3.6          |
|                        | Radius                               | 3.3.7          |
|                        | Spherical Radius                     | 1.8.2.5        |
|                        | Arc Length                           | 3.3.9          |
|                        | Chain Line                           | ---            |
|                        | Flatness                             | 6.4.2          |
|                        | Flatness on Older Prints             | ---            |
|                        | Straightness                         | 6.4.1          |
|                        | Circularity (roundness)              | 6.4.3          |
|                        | Cylindricity                         | 6.4.4          |
|                        | Perpendicularity                     | 6.6.4          |
|                        | Angularity                           | 6.6.2          |
|                        | Parallelism                          | 6.6.3          |
|                        | Profile of a Line                    | 6.5.2 (b)      |
|                        | Profile of a Surface                 | 6.5.2 (a)      |
|                        | Circular Runout                      | 6.7.2.1        |
|                        | Total Runout                         | 6.7.2.2        |
|                        | Concentricity/Coaxiality             | 5.11.3         |
|                        | Position                             | 5.2            |
|                        | Symmetry (use of position preferred) | ---            |
|                        | Counterbore or Spotface              | 3.3.10         |
|                        | Countersink                          | 3.3.11         |
|                        | Depth                                | 3.3.12         |
|                        | Repetitive Features & Dimensions     | ---            |