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# GENERAL WORKMANSHIP STANDARD

## MACHINED PARTS, TOLERANCES, SURFACE FINISH, AND STANDARD CONFIGURATIONS

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# Revision History

| Rev | Date | Preparer | Control Number | Description of Change |
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| B | 03/21/2013 | Varuzhan Sarkiyan | ECN-14936 | Response to customer CAR |
| C | 06/12/2019 | Jackie Jimenez | ECN008731 | Adding paragraphs to cover fabrication and inspection of threaded holes. |
| D | 12/07/2023 | George Parker | ECN042267 | Per NCM 0062420. Added borescope inspections as required for ID inspection in paragraph 5.2.2.2. |

## 1.0 PURPOSE

To specify criteria for workmanship standards and for specifying, mitigating, and proper removal of burrs.

## 2.0 SCOPE

Covers requirements for tolerances, surface finishes and standard configurations for machined parts and final assemblies.

## 3.0 RESPONSIBILITIES

3.1 Document Owner: Engineering

3.2 Quality Control: Ensuring that visual and dimensional inspection of all machined parts per the requirements of this procedure and inspection for unacceptable burrs as defined in this procedure.

3.3 Machine Shop: In-house or outside machine shop supplier are responsible for removing all unacceptable burrs as defined in this procedure.

## 4.0 DEFINITIONS

| Term or Acronym | Definition |
|---|---|
| Roughness | Roughness consists of the finer irregularities in the surface texture, including those irregularities which result from the inherent action of the production process. These are considered to include traverse feed marks and other irregularities within the limits of the roughness-width cut off (Figure 4). |
| Precision Machining | Precision machining, as used in this specification, includes all dimensions with a total tolerance of 0.0001 to 0.0005 inch and Ultra Precision Machining (UPM) tolerances which are less than 0.0001 inch total tolerance. |
| Dimensional Tolerance | Dimensional tolerance is defined by the difference between two limiting sizes as a means of specifying the degree of accuracy; e.g., for 2.500 ± 0.010, the tolerance is 0.020 inch. |
| Flatness | Flatness is the condition of a surface having all elements in one plane. A flatness tolerance specifies a tolerance zone confined by two parallel planes within which the surface must lie. |
| Roundness | Roundness is a condition of a surface of revolution such as a cylinder, cone, or sphere, where all points of the surface intersected by any plane are equidistant from the axis. |
| Parallelism | Parallelism is a condition of a surface or line which is equidistant at all points from a datum plane or axis. A parallel tolerance specifies a zone confined by two planes parallel to a datum feature (axis, surface or cylinder). |
| Angularity | Angularity is the condition of a surface, axis or center plane which is at a specified angle (other than 90 degrees, which would be perpendicularity) from a plane or axis. |
| Block Tolerance | Block tolerance is a tolerance given in the title block of the drawing which defines a tolerance that is not specified on the body of the drawing. |

| Term or Acronym | Definition |
|---|---|
| Centerline | A centerline shown in the center of a part and not dimensioned in reference to any surface shall be defined as being the true center of that part. |
| Concentricity | Concentricity is a condition in which two or more regular features (such as cylinders, cones, spheres, etc.), in any combination, have a common axis (or centerline). The deviation from concentricity is eccentricity. The eccentricity may be measured between any two surfaces. In the case of multiple surfaces, the eccentricity of each surface must be measured in respect to a designated reference surface. In machining practice, concentricity (eccentricity) is normally called out and measured as Total Indicator Reading (TIR). The actual eccentricity (centerline displacement between two surfaces) is one-half of the TIR value. |
| Cylindricity | Cylindricity is a condition of a surface of revolution in which all elements form a cylinder. A cylindricity tolerance specifies a tolerance zone confined to the annular space between two concentric cylinders within which the surface must lie. |
| Total Indicator Reading (TIR) | The range of variation from a true surface (highest to lowest points) on the entire surface including roughness and waviness which can be used to define the surface of a plane, cylinder, cone, sphere or other geometrical shape. |
| Runout | A runout tolerance establishes a means of controlling the functional relationship of two or more features of a part within the allowable errors of concentricity, perpendicularity and alignment of the features. It also takes into account variations in round- ness, straightness, flatness, and parallelism of individual surfaces. There are two types of runout control, circular runout and total runout, as follows. |
| Circular Runout | A circular runout provides control of circular elements of a surface. The tolerance is applied independently at any circular measuring position as the part is rotated 360°. Where applied to surfaces constructed around a datum axis, circular runout may be used to control the cumulative variations of circularity and coaxiality. Where applied to surfaces constructed at right angles to the datum axis, circular runout controls circular elements of a plane surface. |
| Total Runout | A total runout provides composite control of all surface elements. The tolerance is applied simultaneously to all circular and profile measuring positions as the part rotates 360°. Where applied to surfaces constructed around a datum axis, total runout is used to control cumulative variations of circularity, straightness, coaxiality, angularity, taper and profile of a surface. Where applied to surfaces constructed at right angles to a datum axis, total runout controls cumulative variations of perpendicularity (to detect wobble) and flatness (to detect concavity or convexity). |
| Surface | A surface is considered to extend to the point where it intersects another surface or becomes tangent to an area of transition. The control exercised by the individual symbol ends at this point. |

| Term or Acronym | Definition |
|---|---|
| Straightness | A condition where an element of a surface is a straight line. A straightness tolerance specifies a tolerance zone uniform width along a straight line within which all points of the considered line must lie. |
| Perpendicularity | A condition of surfaces, axes or lines which are at right angles to each other. A perpendicularity tolerance specifies a zone confined by two parallel planes perpendicular to a datum plane within which the surface of a feature must lie. |
| Free State Variation | Distortion of a part within an elastic range after removal of forces applied during manufacturing. This distortion is principally due to weight and flexibility of the part and the release of internal stresses resulting from fabrication. |
| Chamfer | Defined by an angle and a linear dimension, or by two linear dimensions. |
| Burr | A burr is a rough piece or protrusion extending above the surface of a machined part. It is generally located at, or adjacent to, the intersection of two surfaces. This protrusion may or may not be solidly attached to the part. |
| Sharp Protruding Burr | This burr protrudes above the surface, is firmly attached to the part, and presents a sharp cutting edge. It is normally found at an edge and can be the result of machining forcing a lip or edge into an existing surface, or handling damage (see Table 7). |
| Loose or Weakly Attached Burr | This burr protrudes above the surface and is weakly attached to the part. It may be in any position, including flattened against the surface or standing. The flattened or feather edged burr can result from a tumble deburring operation that does not remove the burr from the part. The standing burr of this type indicates lack of deburring, for this burr is usually removed with ease (see Table 7). |
| Protuberance | This burr protrudes above the surface, is firmly attached to the part, and is not sharp. This type is usually the result of incomplete burr removal (see Table 7). |

## 5.0 PROCEDURE

### 5.1 Requirements

In the event of any conflict between the requirements of this specification and drawings calling out this specification, the requirements of the drawing shall take precedence. Exceptions are as stipulated in the Requirements section.

**NOTE:** All tooling used in the processes (during setup and operation), shall be checked by the person using the tool, to ensure it is in good operating condition and free of damage before and after its use.

#### 5.1.1 In-Process Parts Protection

Machined parts shall be protected, handled, and stored in accordance with VACCO standards.

#### 5.1.2 Machined Surface Finishes

The specific method used to machine a surface shall be optional. Drawing notes that specify "Lap 16" or "Grind 20" shall not restrict manufacturing to that particular process, provided the alternate process used results in a surface roughness not greater than that specified on the drawing (see Section 4 for the definition of roughness).

5.1.3 Surface Cleaning

5.1.3.1 Surface Cleaning of Machined Metal Parts

Machined parts surfaces shall be cleaned per standard commercial practices unless otherwise specified.

5.1.4 Machining Fluids for Plastics

Plastics shall be machined dry (no lubricant) and be cooled with air or an air/water mist. Organic lubricants or coolants may be used only with the approval of VACCO Industries Engineering.

5.1.5 Detailed Requirements

5.1.5.1 Engineering

5.1.5.1.1 Tolerances

5.1.5.1.1.1 Form Tolerance

Form tolerance shall apply to all dimensions, whereas the part can be of any shape or size providing it is within the tolerance envelope. Specific requirements, such as flatness, roundness, parallelism and angularity, shall be indicated by the Geometric Dimensioning and Tolerancing as shown in the applicable ASME Y14.5 standard and on the engineering drawing. See also Section 4 for definitions of flatness, roundness, parallelism, and angularity, respectively.

5.1.5.1.1.2 Positional Tolerance

Positional tolerance shall apply as specified in this specification unless a closer tolerance is required by the drawing and is so indicated by one of the Geometric Dimensioning and Tolerancing, as shown in the applicable ASME Y14.5 standard and on the engineering drawing.

5.1.5.1.1.3 Block Angular Tolerance

The block angular tolerance of ±2° shall apply to all implied (non-dimensioned) angles as well as all specified angles having no tolerance called out on the drawing (see Section 4 for definition of block tolerance).

5.1.5.1.2 Centerline Deviation

Holes, slots, and tangs presented on the true centerline of a part, but not dimensioned, shall be permitted to deviate from the centerline as shown in Table 1. The allowable deviation shall be a function of the tolerance of the overall width of the part containing the feature (see section 4 for definition of centerline).

5.1.5.1.3 Concentricity

Cylindrical surfaces having a common axis shall be concentric as specified in paragraphs 5.1.5.1.3.1 through 5.1.5.1.3.4 (see Section 4 for definition of concentricity).

5.1.5.1.3.1 Two Cylindrical Surfaces

When two cylindrical surfaces having a common axis are machined, they shall be concentric within a total indicator reading (TIR) or 0.010 inch (see Section 4 for definition for cylindricity and TIR).

5.1.5.1.3.2 Three or More Cylindrical Surfaces

When more than two cylindrical surfaces having a common axis are machined, the concentricities shall be measured using the diameter with the closest diametrical tolerance as a reference. The requirement specified in paragraph 5.1.5.1.3.1 shall then be followed.

5.1.5.1.3.3 Stock Diameter and Machined Surfaces

When one surface is specified as "stock diameter" and one or more surfaces are machined, each machined surface shall be concentric to the stock diameter as specified in Table 2.

5.1.5.1.3.4 Hole Runout

The runout of deep drilled holes (depth of drilled holes six or more times the drill diameter) shall be within 0.030 inch TIR concentricity of the adjacent diameter on center drilled parts. The runout of other holes shall be within the limits of Table 3 (see section 4 for definitions of runout, circular runout, and total runout).

5.1.5.1.4 Equal Spacing

An implied dimension and tolerance shall be considered to exist between any two holes or other features of a group governed by an applicable note or symbol for equal spacing. The tolerance on the overall dimension shall apply to holes or individual features, adjacent as well as non-adjacent (non-accumulative) (see Figure 3). For exceptions to the angular tolerance, see paragraph 5.1.5.1.1.3.

5.1.5.1.5 Surface Finish-Transition Areas

Surface finish in areas of transition, such as chamfers and fillets, shall conform to the roughest of the adjacent areas unless otherwise indicated (see Figure 4). See Section 4 for definition of surface.

5.1.5.1.6 Flatness and Straightness

5.1.5.1.6.1 Flatness

If the flatness is specified and surface roughness or waviness height is not specified, the values of surface roughness and waviness height which correspond to the flatness requirement as described in paragraph 5.1.5.1.13 and shown in Table 4 shall apply, subject to the limitations of 5.1.5.1.12.

5.1.5.1.6.2 Straightness

All linear features shall be straight within the total envelope tolerance, e.g., if a feature is shown to have a ± 0.010 tolerance on size, that feature shall be straight within 0.020 inch (see section 4 for definition of straightness).

5.1.5.1.7 Centerline of Holes or Other Features Governed by a Single Centerline

The centerline of holes or other features governed by a single centerline shall lie within the tolerance specified for the location of the centerline of the part (see Table 1.)

5.1.5.1.8 In-Line Holes (Pertaining to Holes on the Same Axis)

All holes thus specified shall meet the required diametrical tolerance individually. In addition, all holes so specified shall simultaneously accept a single cylindrical gauge of a diameter, or diameters, equal to the minimum specified for each hole.

5.1.5.1.9 Perpendicularity

When a plane surface is shown perpendicular to an axis or other plane surface or surfaces, and a tolerance is not specified on the drawing, the implied tolerance shall be the block angular tolerance (see paragraph 5.1.5.1.1.3) when normality is specified in terms of TIR (see section 4 for definition of perpendicularity).

5.1.5.1.10 Parallelism

When parallelism is not specified, the distance be- tween the entire two surfaces in question shall be within the dimensional tolerance specified on the drawing. (Dimensions apply for the full surface which they indicate.)

5.1.5.1.11 Roundness/Cylindricity

To isolate roundness as an individual function and because roundness may be confused with cylindricity or concentricity by use of some gauging methods, roundness shall be checked at numerous points around the diameter perpendicular to the common axis. Cylindricity shall be checked along the entire length; however, cylindricity checks roundness, straightness end parallelism.

5.1.5.1.12 Surface Finish and Tolerance

5.1.5.1.12.1 The surface finish of any machined surface shall be governed by the closest tolerance given for any dimension of that surface.

5.1.5.1.12.2 Table 5 shall be used to determine the maximum surface roughness permitted for a specified tolerance. See Figure 5 for lay symbols. Surfaces shall contain no discontinuities (e.g., scratches, nicks or gouges) with a depth greater than 10 times the RHR callout expressed in millionths of an inch, when the width is less than 40 times the RHR callout, expressed in millionths. Discontinuities shall not exceed 1 per square inch of surface; e.g., a surface area of five square inches is allowed to have a maximum of five discontinuities.

EXAMPLE: For a surface finish of 63 RHR,

D = 0.000063 X 10 = 0.0006 inch, and

W = 0.000063 X 40 = 0.0025 inch

5.1.5.1.12.3 Nicks and Dings on Body Blocks

It is not necessary to reject blank body blocks (identified as "Block-XX", where XX is any number) for any minor nicks and dings that occur along the corners for the following reasons:

- Prior to machining, the machinist breaks the corners with a file or equivalent.
- Normal handling of these blocks may cause additional nicks and dings. It is not necessary to handle these blocks in a manner that would completely eliminate the nicks and dings.
- Neither VACCO nor the customer use the corners for indicating or assembly. Any nicks and dings are cosmetic only.
- Any nicks and dings which have occurred during manufacturing will be blended out during final deburr.
- Any gouges on the corner of the block deeper than .060 or upset metal over .030 above the surface should be forwarded to Engineering for disposition.

5.1.5.1.13 Waviness Height, Cut-Off and Flatness

Machined surfaces designated as flat shall have a waviness height not greater than and a surface finish within the limits listed in Table 4, depending upon the required flatness. Waviness height shall not be cumulative and applies only to a one-half inch increment on any portion of a surface. The full waviness height tolerance shall apply for the extent of any surface which is less than 0.500 inch long. A 0.030 inch cut-off shall be used (see Figure 6).

5.1.5.1.14 Free State Variation

Free state variation, unless otherwise specified, shall be within an elastic range that will allow the part to be brought within drawing tolerances by forces equivalent to those that can be exerted by employing the expected method of assembly (see section 4 for definition of free state variation).

5.1.5.2 Operations

5.1.5.2.1 Chamfer

The tolerances specified in Table 6 shall apply to chamfer angles (see section 4 for definition of chamfer).

5.1.5.2.2 Counterbore and Spot face

For counter boring and spot facing operation the block angular tolerance (paragraph 5.1.5.1.1.3) shall apply and the surface roughness shall be 125 maximum.

5.1.5.2.3 Countersink

For countersinking operation the surface roughness shall be 125 maximum. Pilot drilled holes may be oversized if the material thickness is less than the full contour of the countersink.

5.1.5.2.4 Deburring

All parts shall be deburred (see section 4 for definition of burr for type of burrs). Appendix A contains more explanation on the removal of burrs.

5.1.5.2.4.1 Breaking of Edges

The size of a break resulting from deburring an edge shall be determined from the surface finish specified for the two adjacent surfaces. The coarser of these two surfaces shall determine the size of the break. A broken edge shall signify that either a radius or a chamfer is acceptable as the result of the deburring process. All edges shall be broken as follows.

- For edges specified as sharp, the edges shall be broken 0.000 to 0.005 inch.
- For finishes 32 or finer, break edge 0.003 to 0.010 inch.
- For finishes 33 or coarser, break edge 0.005 to 0.015 inch.

5.1.5.2.4.2 Burrs

Acceptance of burrs shall depend upon the surface finish required for the surfaces, the type, size (protrusion) and position. The size of the burr shall be determined by visual inspection and magnification level per Table 7 and paragraph 5.2.2. All levels of inspection shall be conducted using an illumination level of 100 ± 10 foot candles and 20/20 to 20/30 vision. The maximum acceptable protrusion shall be that size of burr which does not protrude discernibly above a surface under the conditions specified in Table 7.

5.1.5.3 Drilling

The specified hole shall be made by any process that maintains the block tolerance and provides a surface roughness of 125 maximum. The diametrical tolerance of holes of greater than four but less than 10 drill diameters deep shall be within twice the normal tolerance for that diameter.

5.1.5.3.1 Drill Breakthrough

A part shall be acceptable if drilling causes a protuberance or breakthrough providing all features, i.e., size depth, drill point angle, and related dimensions, are within specified tolerances.

5.1.5.4 Knurling

The circular pitch of the knurl for use with the corresponding diameters shall be as shown in Table 8. The tooth angle of the knurl of hard materials shall be 60 ± 5 degrees and for soft materials (150 BHN or less) it shall be 90 ± 5 degrees.

5.1.5.5 Machined Surface Deviations

5.1.5.5.1 Single Flat or Curved Surfaces

Where two or more machined cuts (Figure 6a) are required to produce a single surface, the maximum misalignment of adjacent cuts shall not exceed 0.003 inch on parts less than 12 X 12 inches (144 square inches) in area and 0.006 inch on parts greater than 12 X 12 inches in area, unless otherwise specified. The minimum cutter radius shall be 0.063 inch.

5.1.5.5.2 Intersecting Surfaces (One Surface Not Machined)

When two or more surfaces intersect and one of the surfaces is not machined (Figure 6b), or where an un-machined and a machined surface are in the same plane (Figure 6c), the misalignment of the surfaces shall not exceed 0.030 inch with a 0.063 inch minimum fillet radius produced by the cutter.

5.1.5.5.3 Intersecting Surfaces (Both Surfaces Machined)

Where two or more machined surfaces intersect, the misalignment between any of the surfaces shall not exceed 0.010 inch and the fillet radius produced by the cutter shall be 0.010 ± 0.005 inch (Figure 6d).

5.1.5.5.4 Intersecting Surfaces (After Plating)

When two intersecting plated surfaces are machine finished after plating, the plating shall not be removed from the undercut.

5.1.5.6 Machining Centers

When the drawing allows a machining center, but does not specify or control its dimensions, the following requirements shall apply:

- Internal machining centers shall be as shown in Table 9.
- External machining centers shall be as shown in Table 10.
- Hollow part machining centers shall be as shown in Table 11.

5.1.5.7 Plating

All dimensions and tolerances for plated or anodized parts shall apply after processing has been completed.

5.1.5.8 Profiled Surfaces

Where parts are contour-machined by milling, sawing, hand finishing or flame cutting, the misalignment of intersecting adjacent surfaces shall not exceed the values listed in Table 12 for the specified surfaces. The maximum misalignment shall be governed by the rougher of the two adjacent surfaces.

5.1.5.9 Radii (Fillet)

Unless otherwise specified on the engineering drawing, the machined fillet radii produced by the cutter shall be 0.010 ± 0.005 inch.

5.1.5.10 Threads

5.1.5.10.1 Standard Cut Threads

Standard cut threads shall be in accordance with MIL-S-7742 or Handbook H-28, as applicable. Their maximum surface roughness shall be as specified in Table 13. The coarser Finish 125 specified in Table 13 for die and tap threads shall apply. When a thread rolling process is used, the drill size shall be as recommended by the manufacturer.

5.1.5.10.2 Cold Rolled Threads

Internal cold rolled threads shall be in accordance with MIL-S-70335. The material shall meet the ductility properties required for thread rolling. The cold rolled thread surface finish shall be as specified in Table 13.

5.1.5.10.3 Tapped Hole Countersink Diameters

Tapped hole countersink diameters shall be as shown in Table 14.

5.1.5.10.4 Screw Thread Chamfers

Screw thread chamfers shall be as shown in Table 15.

5.1.5.11 Undercuts

When the engineering drawing calls out for thread undercuts, but does not specify or control its dimensions, the following requirements shall apply:

5.1.5.11.1 Undercuts for External Threads

Undercuts for external threads shall be as specified in Table 16.

5.1.5.11.2 Undercuts for Internal Threads

Undercuts for internal threads shall be as shown in Table 17. Table 17 shall apply only to diameters greater than 0.375 inch.

5.1.5.11.3 Standard Undercuts

Standard undercuts shall be used only in designated locations and as specified in Table 18.

5.1.5.12 Thread Depth General Practice

The usual method for fabricating an internal thread is to drill a pilot hole, and then cut threads into it with a tap. On VACCO drawings, the pilot hole and the threads both have depth dimensions, subject to the applied tolerance or the general tolerance block.

For blind, tapped internal threads, the pilot hole depth shall be drilled to print. It is acceptable for the depth of the threads to be considered a minimum. As long as the minimum thread depth specified on the drawing is achieved, it is acceptable for the threads to go as deep into the tapped hole as practicable.

The diameter of the pilot hole beyond the threads is considered to be for reference only, and will not to be subject to measurement. An exception is that obvious damage to this area due to tool breakage or other anomaly will be subject to Engineering disposition.

5.1.5.12.1 Unless otherwise specified on the drawing, this general practice is not applicable to the following conditions:

- If the threads are cut into a pilot hole that steps down into a smaller hole, the threads shall only go as deep as the pilot hole. See Figure 1
- If a thread relief is described, the threads shall not extend beyond the thread relief. See Figure 1
- If the pilot hole crosses through another hole, the thread shall only go through one wall. See Figure 2.
- If the pilot hole has a specific surface finish beyond the threads, then the thread depth with the proper tolerance shall be to print. The diameter of the pilot hole beyond the threads is subject to the applied diameter, tolerance, and surface finish, and it shall be inspected. See Figure 1.

## 5.2 Quality Assurance Provisions

### 5.2.1 Inspection

Inspection to determine compliance with the applicable drawing and/or Section 5.1 requirements shall be performed in accordance with the corresponding verification paragraphs of 5.2.2.1 and 5.2.2.2.

### 5.2.2 Inspection Methods

#### 5.2.2.1 Dimensions

All machined parts shall be examined to verify compliance with paragraph 5.1.5 and drawing requirements. Standard gauges and measurement methods shall be used for this inspection.

#### 5.2.2.2 Visual Examination

All machined parts shall be visually examined to verify compliance with paragraph 5.1.5 and the drawing. Visual examination shall be performed without magnification except when inspecting for burrs, which shall be inspected using the level of magnification required by Table 7, or when inspecting small parts which cannot be effectively inspected without the use of magnification. If an anomaly is observed during visual inspection, magnification shall be used to classify the defect and to determine the acceptability of the product. Magnification shall be illuminated by a light source sufficient to perform the inspection. In addition, for internal diameter measurements, a borescope may be used to identify anomalies.

## 5.3 Deburring and Surface Refining

This section describes the deburring and surface refining standards that must be attained in order to ensure proper performance of valves and filter, manifolds, and like equipment manufactured by VACCO Industries.

### 5.3.1 Burr Analysis

A burr is an imperfection in a machined or fabricated component caused by the machining process. The following types of burrs (illustrated in Figure 7) are often encountered and are unacceptable unless otherwise noted.

- A rolled edge is acceptable unless it has altered the dimensions of the flow passage, or prevents the smooth entry of mating part.
- A crowned burr is unacceptable.
- A hinged burr is unacceptable.

- Extruded material is acceptable unless it has altered the dimensions of the flow passage.
- A doughnut burr is unacceptable.
- A loose/sliver burr is unacceptable.
- Feathered burrs usually occur where two unlike surfaces meet. They are acceptable in some cases but not others, and acceptance will be established by Quality Control inspection personnel.
- A rough/broken burr is unacceptable.

5.4 Deburring Hazards

The deburring process itself often introduces contamination in the form of dislodged fragments, edges, or shavings from the tools being used. Nylon wool, abrasive paper, and rubber-impregnated materials are especially susceptible to shredding and should not be used in blind or deep drilled holes or other areas where this secondary contamination might not be easily detected or removed. In all cases, deburring tools should be inspected frequently to ensure that they are in good condition and not depositing residue in the flow passages or scratching critical surfaces. Figure 8 illustrates typical areas where heavy burrs place considerable stress on drills and reamers.

5.5 Critical Areas for Deburring and Contamination Removal

5.5.1 Close-Toleranced Parts

Because close tolerances usually indicate close-fitting or sliding parts, even minute burrs and contaminants must be removed.

5.5.2 Elbow-Type Flow Passages

Deburring and contamination removal in elbow-type flow passages is of vital concern because they may be located downstream of the inlet filter. Therefore, any contamination that remains in these passages has direct access to a critical area.

5.5.3 Flow Passage Intersections Near Chamfers

Before deburring or contamination removal at intersections near O-ring chamfers, an inspection of drilled passage location must be performed. If the passage intersects with the chamfer such that the overlap exceeds 1/4 of the chamfer width, the condition is unacceptable because the O-ring may be clipped during installation. The resulting O-ring particles will be forced into the nozzle passage which may cause system failure. Figure 10 illustrates both an acceptable and unacceptable drilled passage chamfer intersections. Following inspection of passage location, thorough deburring and contamination removal must be performed.

5.6 Deburring of Interconnecting Passages

Interconnecting passages are routed through manifold blocks in various configurations, ranging from simple 90° turns to compound angles that branch off in several directions. Because of this often complex network of passages, there are a number of areas where proper deburring is difficult, yet essential. The following subparagraphs, plus Figure 10 and Figure 12 highlight the required standards.

5.6.1 Continuity Inspection

The continuity of the interconnecting passages must be verified before deburring and contamination removal. This involves making sure that passages intersect correctly to ensure proper flow of fluid through the system. Figure 10 shows examples of acceptable and unacceptable passage intersections. Those units that fail to meet the illustrated standards shall be rejected.

5.6.2 Multi-Interconnecting Passages

Multi-interconnecting passages often present a problem after deburring because dislodged material can be accidentally pushed ahead and deposited into a hidden recess or ports. This is especially possible in sealed passages (see Dimensional Tolerance definition) where routine flushing techniques may not be effective.

5.6.3 Sealing Surfaces

A sealing surface is an area covered by an O-ring or seal that can be severely damaged by even a slight scratch caused by improper use of tools. They are typically called out on the drawing and usually require a surface finish better than 16 rms. This condition is critical when the scratch extends completely across the sealing surface (See Figure 11) because a "canal" under the O-ring seal will be formed allowing fluid to leak past the seal. Also, if the scratch is deep enough, it can become a reservoir for tiny particles that have been dislodged through deburring elsewhere in the unit.

5.6.4 Scalloped and Counter Bore Recesses and Flow Passage Extensions

These areas present a challenge in deburring and contamination removal because the problem area is often hidden from view. The machining process often leaves extruded or rolled burrs at the point where flow passages enter bores. Also, shavings may be deposited in flow passage extensions. Careful study of the engineering drawings and plastic models will reveal the locations of these potentially troublesome recesses and extensions (See Figure 12).

5.7 Surface Refining

The difficulty in directing sufficient coolant to the drill point in deep hole drilling often results in rough internal surfaces. The combination of excessive heat and friction can effect a "welding" of stripped metal to the walls of the hole. Figure 13 illustrates this condition. Surface refining must include removal of all such potentially loose metal particles.

5.7.1 Polishing

In all deburring and contamination removal operations, it is essential to consult engineering drawings to determine surface polishing requirements. The instructions are often provided for on parts containing critical sealing surfaces.

**NOTE:** Since polishing is a metal-removal process, it is essential to verify all critical dimensions after polishing.

**6.0 REFERENCES**

- ASME Y14.5 – Geometric Dimensioning and Tolerancing

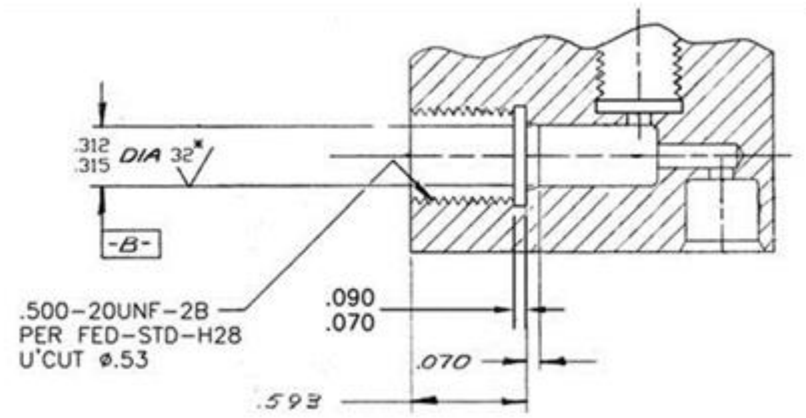



Figure 1: Thread with relief

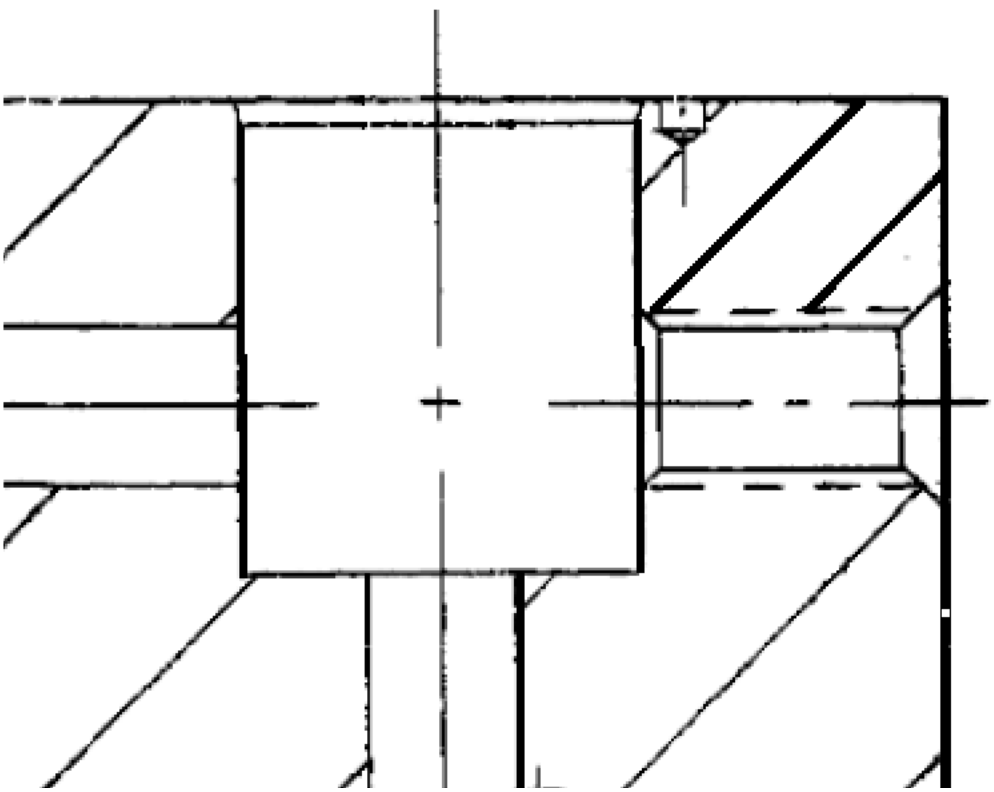


Figure 2: Thread through Single Wall

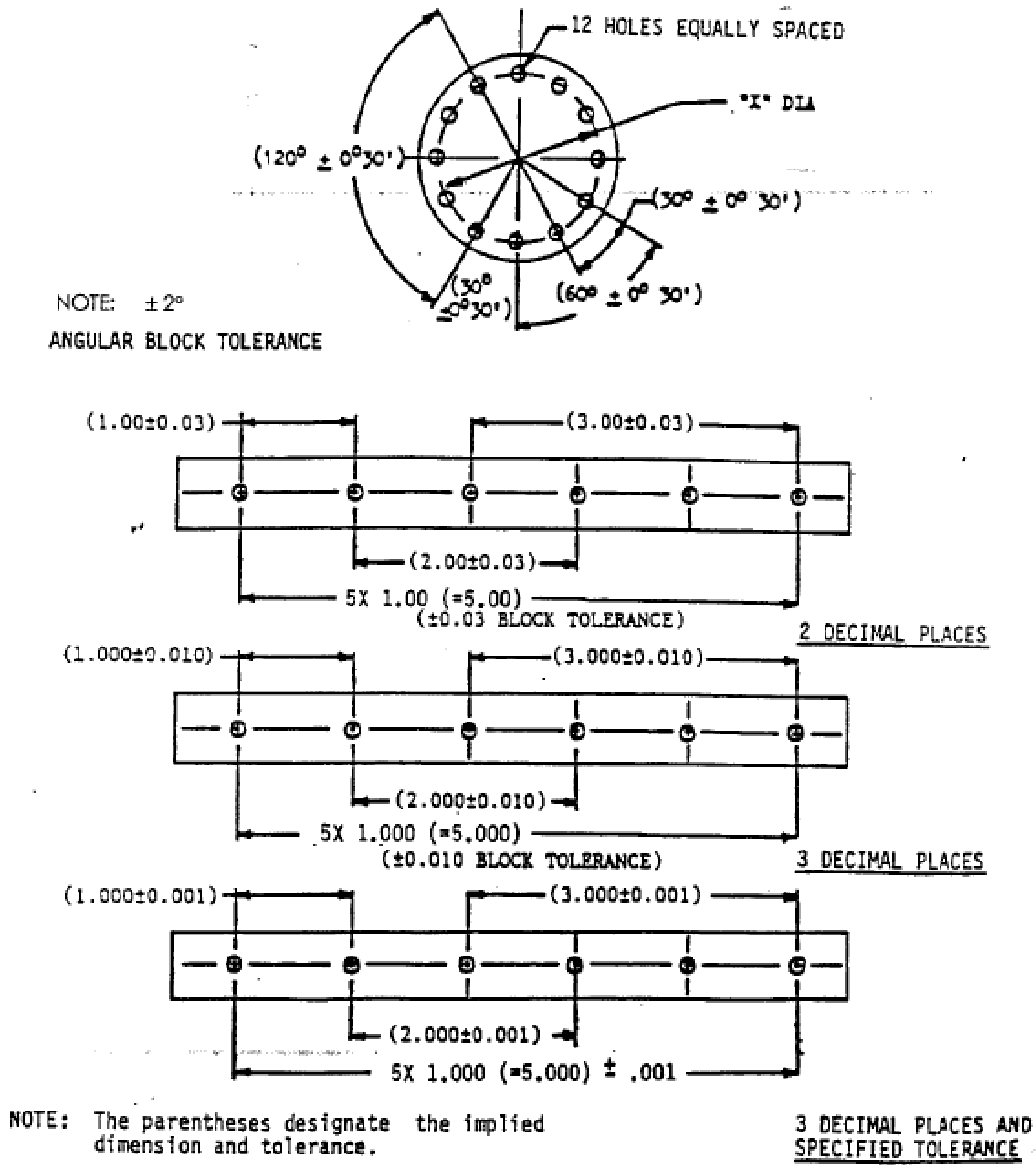



Figure 3: Equal Spacing

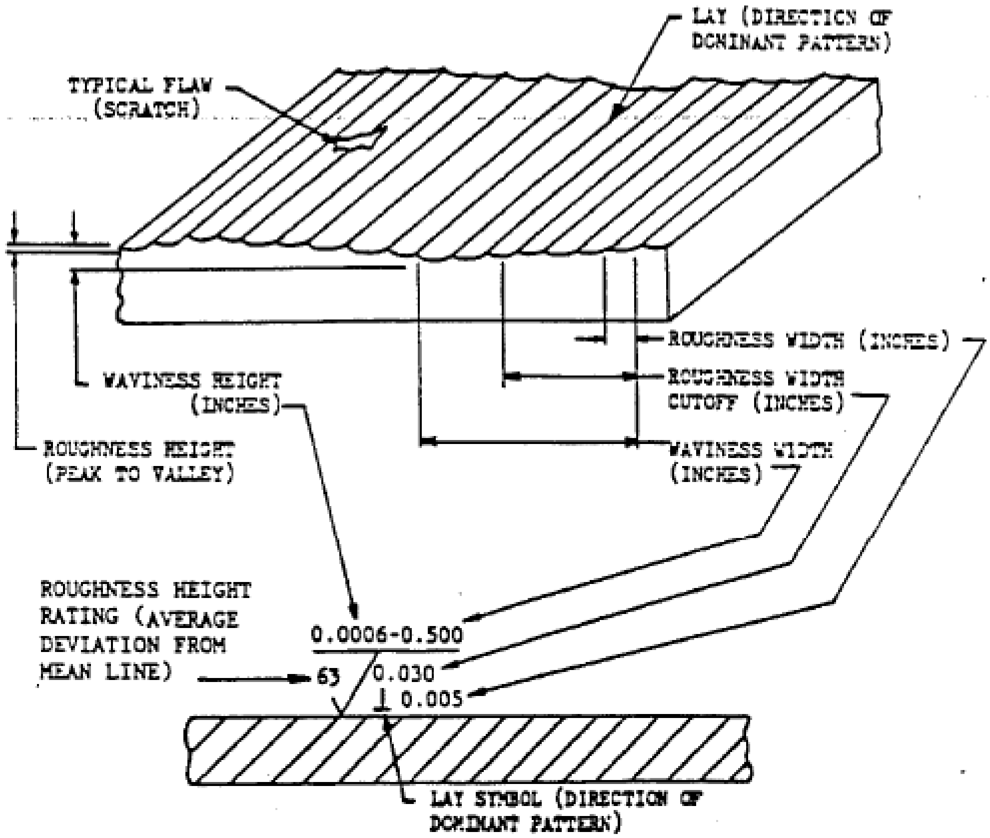



Figure 4: Surface Finish

| LAY SYMBOLS | | |
|---|---|---|
| LAY SYMBOL | DESIGNATION | EXAMPLE |
| = | Lay parallel to the boundary line representing the surface to which the symbol applies. | Direction of Tool Marks |
| ⊥ | Lay perpendicular to the boundary line representing the surface to which the symbol applies. | Direction of Tool Marks |
| X | Lay angular in both directions to the boundary line representing the surface to which symbol applies. | Direction of Tool Marks |
| M | Lay multidirectional. | |
| C | Lay approximately circular relative to the center of the surface to which the symbol applies. | |
| R | Lay approximately radial relative to the center of the surface to which the symbol applies. | |

Figure 5: Lay Symbols

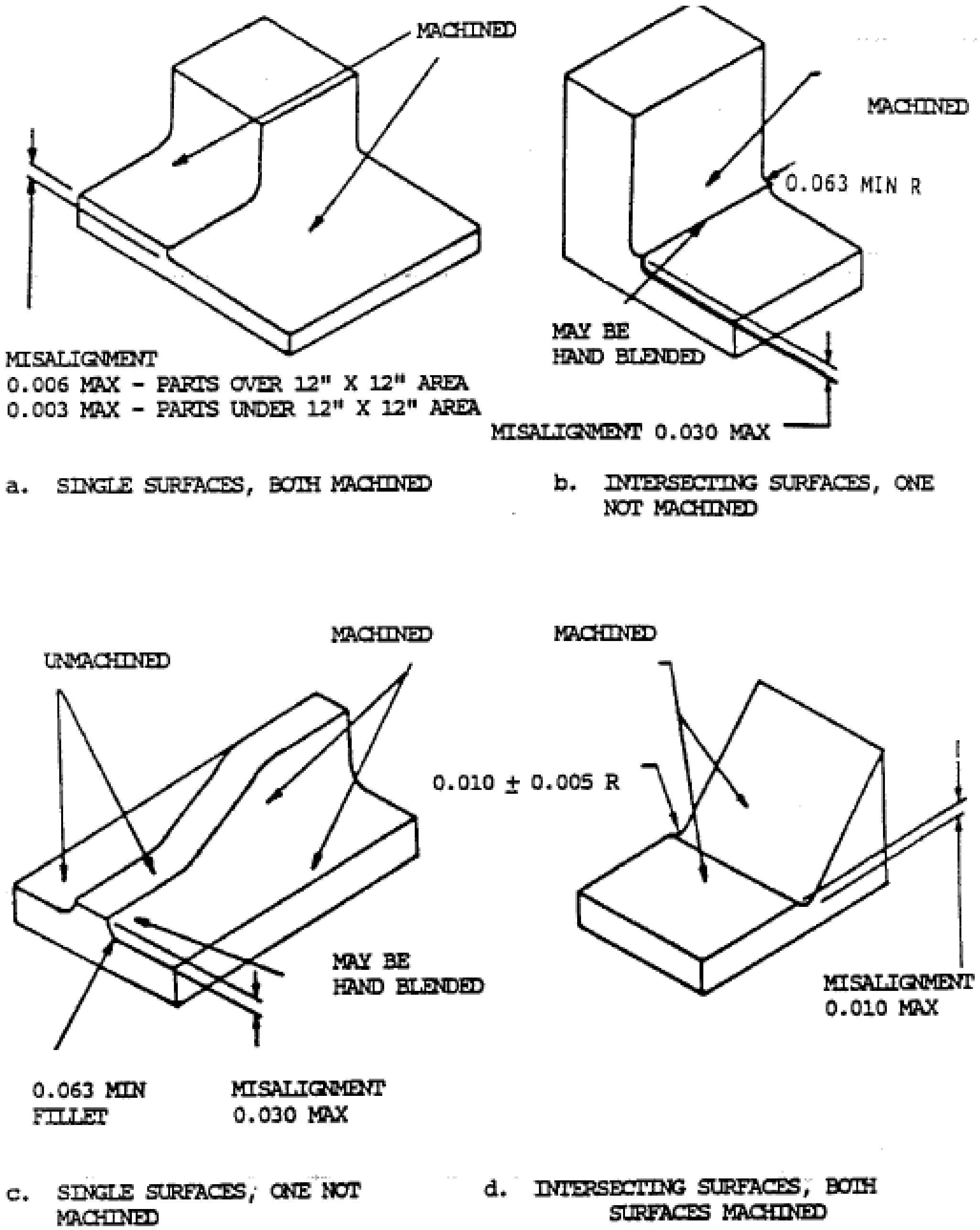



Figure 6: Machined Surface Deviations

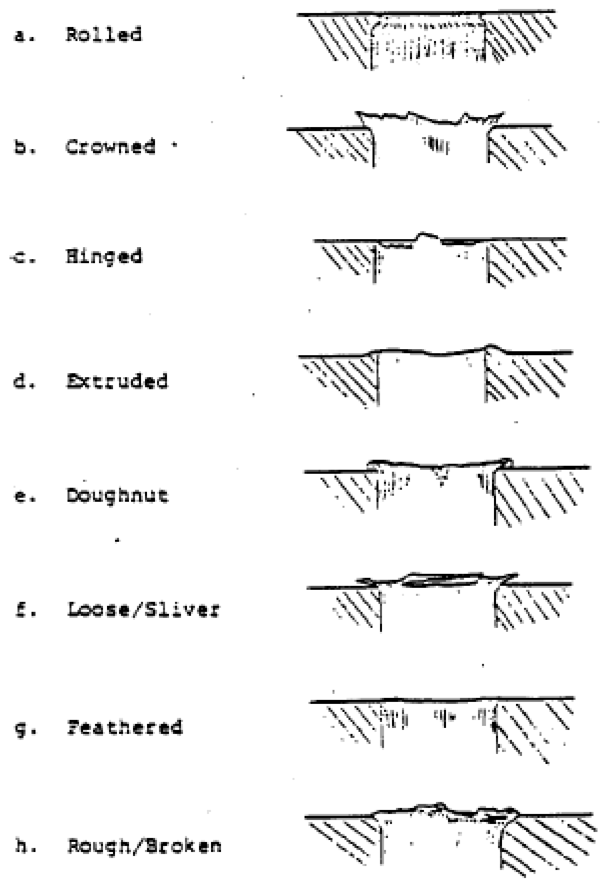



Figure 7: Types of Burrs

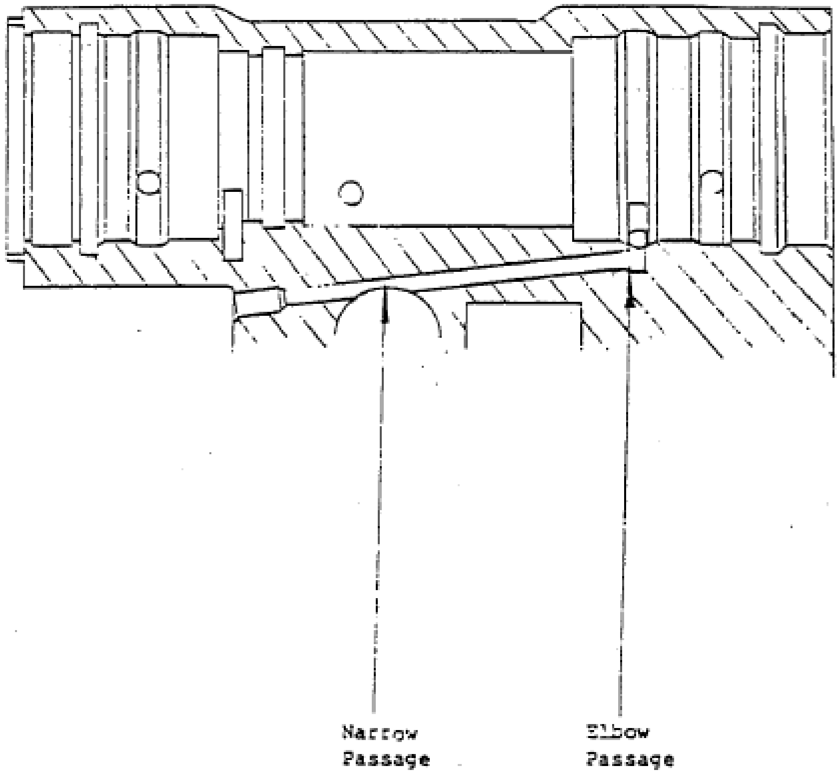



Figure 8: Critical Areas for Drill and Reamer Breakage

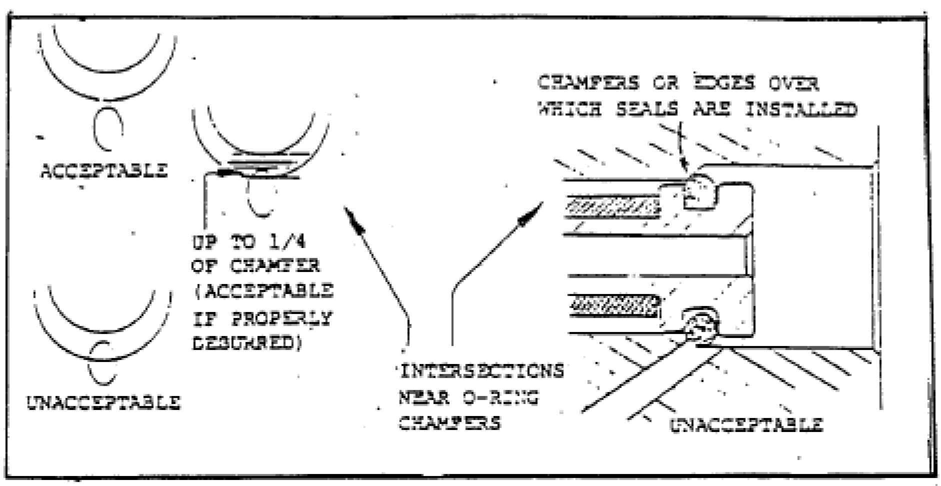



Figure 9: Critical Deburring Areas and Contamination Control

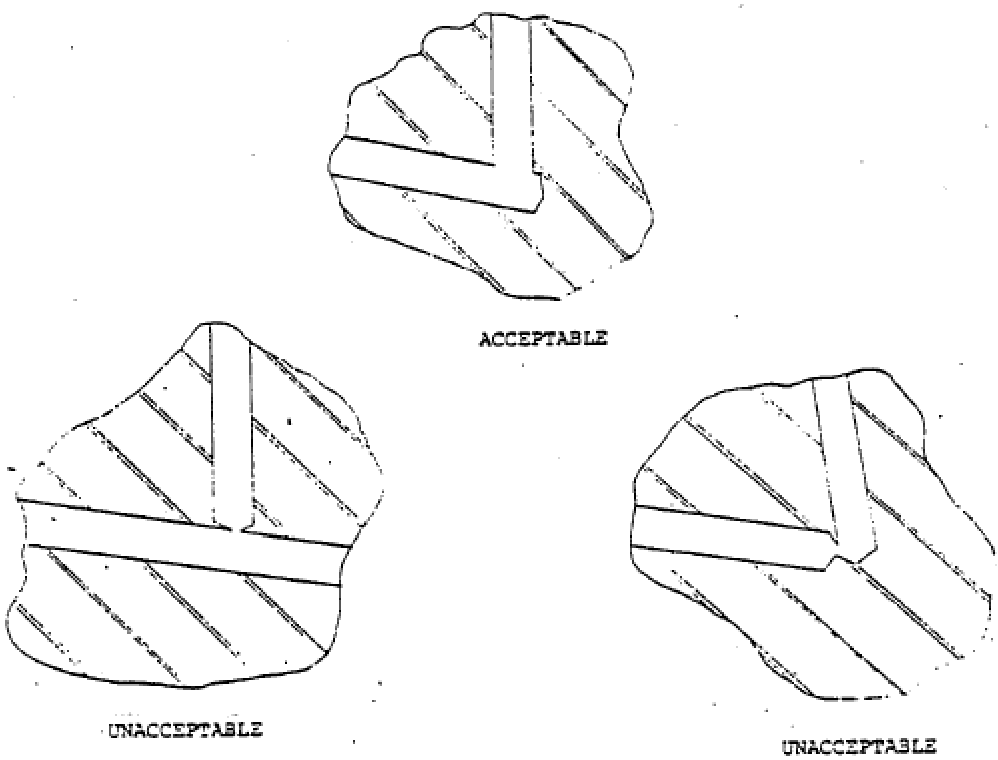



Figure 10: Passage Intersections

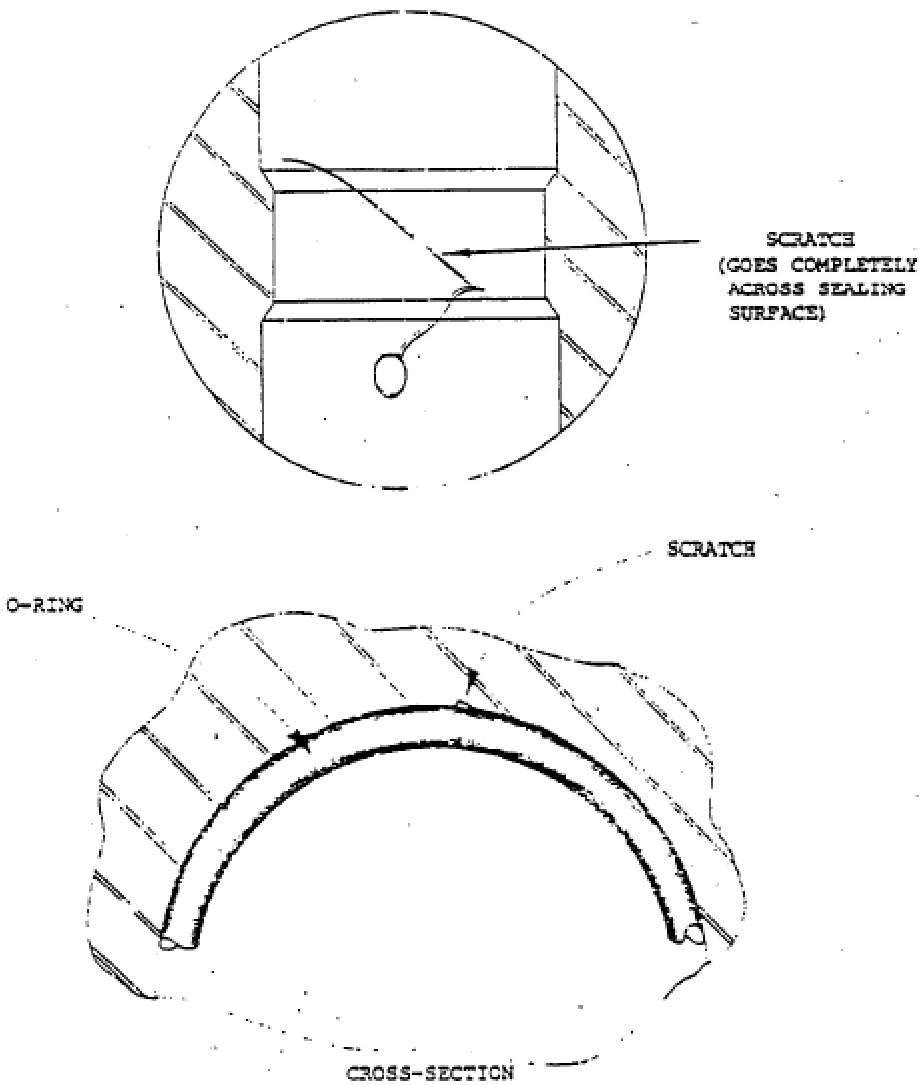



Figure 11: Effects of Scoring on Sealing Surfaces

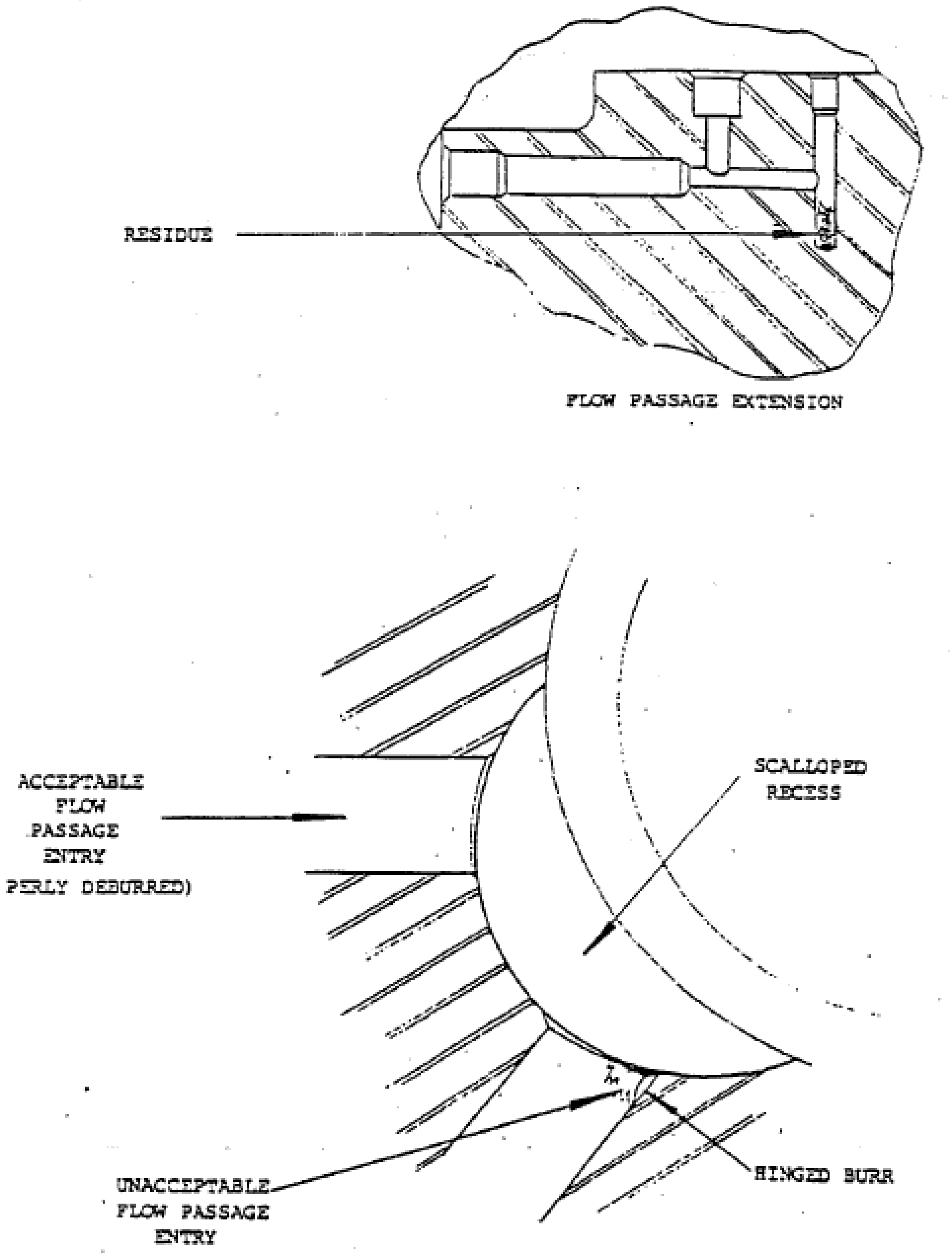



Figure 12: Recesses and Flow Passage Extensions

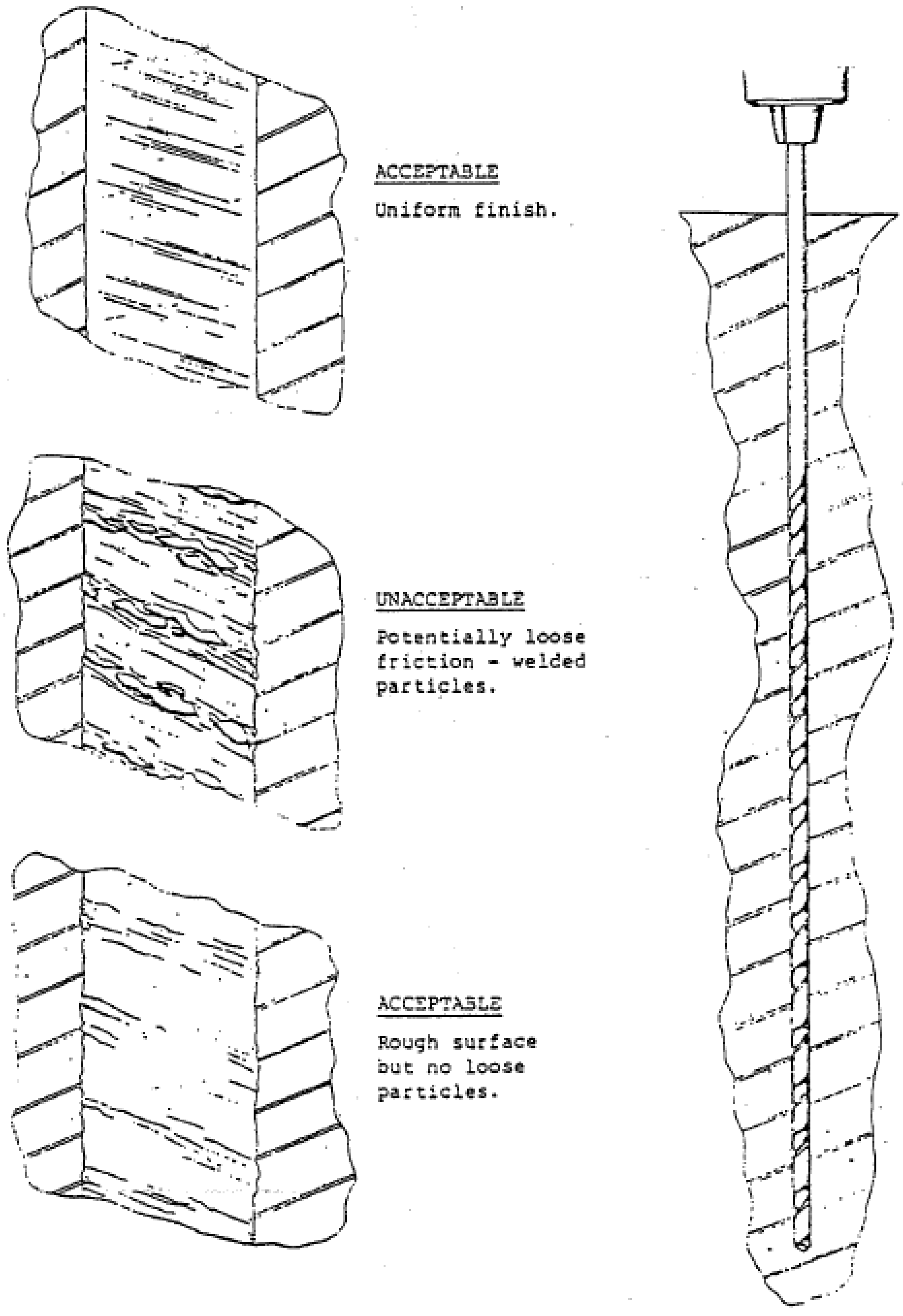
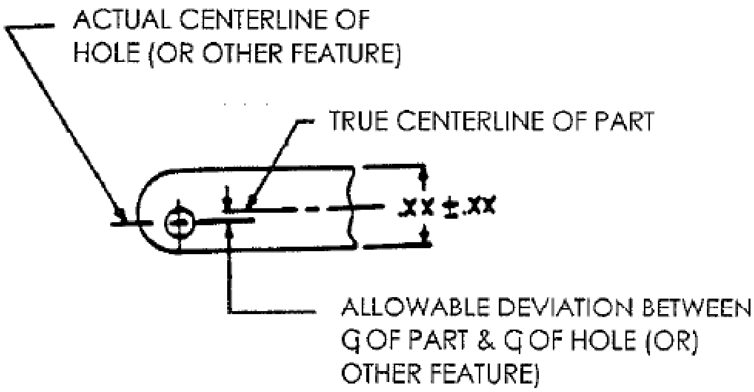



Figure 13: Effects of Insufficient Coolant During Deep Drilling

Table 1: Centerline Deviation




| TOLERANCE OF OVERALL WIDTH (INCHES) | ALLOWABLE DEVIATION (INCHES) |
|---|---|
| 0.094 or greater | 0.032 maximum |
| 0.031 - 0.093 | 0.015 maximum |
| 0.030 or less | 0.010 maximum |

Table 2: Stock Diameter

| STOCK DIAMETER (INCHES) | MACHINED DIAMETER CONCENTRIC WITHIN (TIR) |
|---|---|
| To and including 1.50 | 0.015 inch |
| 1.51 to and including 3.00 | 0.020 inch |
| 3.01 to and including 5.50 | 0.025 inch |
| 5.51 and over | 0.030 inch |

Table 3: Runout

| DRILL | SIZE | CIRCULAR RUNOUT (MAXIMUM) |
|---|---|---|
| From: | To: | |
| 0 | #80 (0.0135) | 0.002 inch |
| #79 (0.0145) | #60 (0.0400) | 0.008 inch |
| #59 (0.0410) | #40 (0.0980) | 0.012 inch |
| #39 (0.0995) | #20 (0.1610) | 0.018 inch |
| #19 (0.1660) | D (0.2460) | 0.020 inch |
| 1/4 (0.250) | 3/8 (0.375) | 0.022 inch |
| V (0.3770) | 1/2 (0.500) | 0.025 inch |
| Sizes over 1/2 (0.5000) | | 0.030 inch |

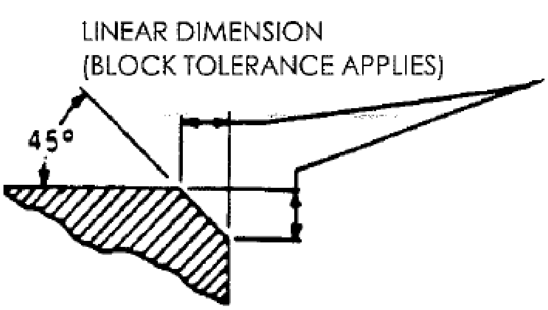
Table 4: Flatness Relationship, Waviness, Roughness

| FLATNESS (INCH/INCH) | WAVINESS HEIGHT (INCH/ONE-HALF INCH INTERVAL) | ROUGHNESS ( ✓ ) |
|---|---|---|
| 0.0050 | 0.0025 | 250 |
| 0.0025 | 0.00125 | 125 |
| 0.00125 | 0.00063 | 63 |
| 0.00063 | 0.00032 | 32 |
| 0.00032 | 0.00016 | 16 |
| 0.00016 | 0.00008 | 8 |
| 0.00008 | 0.00004 | 4 |
| 0.00004 | 0.00002 | 2 |
| 0.00002 | 0.00001 | 1 |
| 0.00001 | 0.000005 | 1/2 |
| 0.000005 | 0.000003 | 1/4 |

Table 5: Tolerance – Surface Finish Relationship

| CLOSET TOLERANCE ± (EQUAL TO OR LESS THAN) INCH | ROUGHNESS HEIGHT RATING MAXIMUM |
|---|---|
| 0.00002 | 1 |
| 0.00004 | 2 |
| 0.00008 | 4 |
| 0.0003 | 8 |
| 0.0008 | 16 |
| 0.002 | 32 |
| 0.005 | 63 |
| 0.020 | 125 |
| Over 0.020 | 250 |

Table 6: Exception to Block Angular Tolerance for Chamfers




| CHAMFER | ANGULAR TOLERANCE |
|---|---|
| Up to and including | |
| 0.010 | ± 5° |
| 0.031 | ± 3° |
| 0.062 & over | ± 2° |

Table 7: Burr Classifications

| UNACCEPTABLE BURR TYPES<br>Type 1 - sharp burr<br>Type 2 - loose burr<br>Type 3 - protuberance | SURFACE FINISH f OF SURFACE "A"<br>0 to 8 1/ | <br>9 to 32 | <br>33 and over |
|---|---|---|---|
| Magnification level required | 15X | 7X | 0X |
| Unacceptable burr type<br>Area A - Surface above which the burr protrudes | 1,2,3 | 1,2,3 | 1,2 |
| Unacceptable burr type<br>Area B - edge | 2 | 2 | 2 |

1/ Also for edge break specified on drawing as sharp, or less than 0.006.

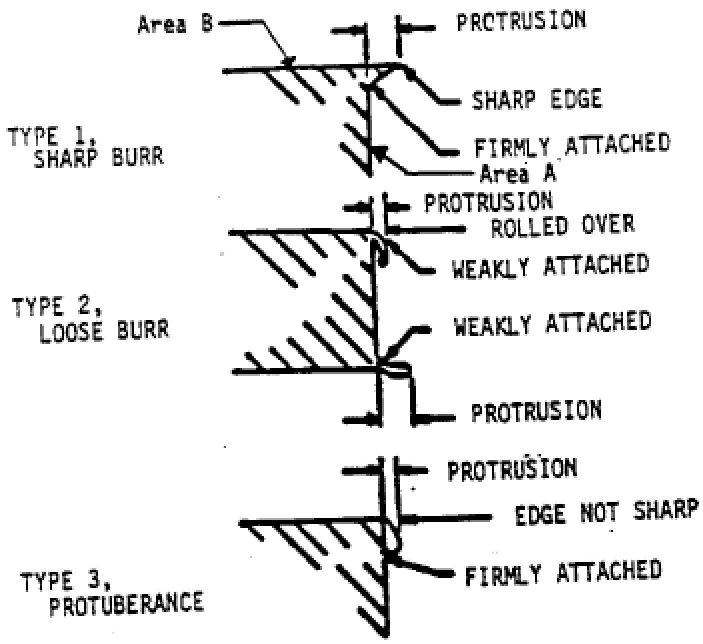



Table 8: Standard Knurls

| DIAMETER (INCHES) | CIRCULAR PITCH (INCHES) | PITCH (TEETH/ONE INCH CIRCUMFERENCE) |
|---|---|---|
| 1.0 and greater | 0.0625 | 16 |
| 0.50 - 0.999 | 0.0312 | 32 |
| 0.125 - 0.499 | 0.0208 | 48 |
| 0.1249 or less | 0.0166 | 60 |

Table 9: Standard Internal Machine Centers

| OUTSIDE DIAMETER 1/ (INCHES) | "D" DIAMETER (MAXIMUM) (INCHES) | MACHINE CENTER SIZE | "B" DIAMETER +.005, -.000 (INCHES) | "C" (MAXIMUM) (INCHES) |
|---|---|---|---|---|
| 0.0937 - 0.129 | 0.075 | 00 | 0.025 | 0.100 |
| 0.130 - 0.156 | 0.093 | 0 | 0.032 | 0.112 |
| 0.157 - 0.249 | 0.112 | 0 | 0.032 | 0.125 |
| 0.250 - 0.312 | 0.120 | 1 | 0.047 | 0.131 |
| 0.313 - 0.499 | 0.188 | 2 | 0.078 | 0.172 |
| 0.500 - 0.999 | 0.219 | 3 | 0.109 | 0.203 |
| 1.000 - 1.499 | 0.281 | 5 | 0.188 | 0.266 |
| 1.500 - 1.999 | 0.422 | 6 | 0.219 | 0.391 |
| Over 2.000 | 0.488 | 8 | 0.313 | 0.469 |

| DIAMETRICAL TOLERANCE (INCHES) (LESS THAN) | CONCENTRICITY TIR (INCHES) (LESS THAN) | SURFACE ROUGHNESS (RMS MAXIMUM) |
|---|---|---|
| 0.005 | 0.005 | 125 |
| 0.001 | 0.002 | 63 |
| 0.0005 | 0.0005 | 32 |
| 0.0001 | 0.0002 | 16 |

1/ Internal centers shall be used for all diameters 0.0937 inch and over unless otherwise specified.

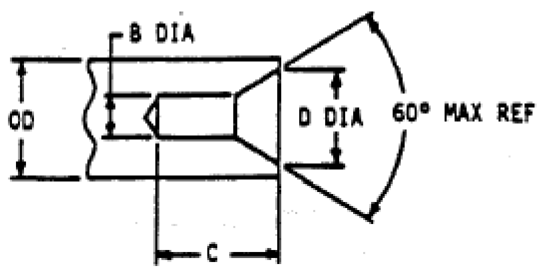


Table 10: Standard External Machine Centers

| "A" DIAMETER (INCHES) | "C" (REF) (INCHES) | "D" DIAMETER (± 0.002) (INCHES) | SIZE DESIGNATION |
|---|---|---|---|
| 0.0250 - 0.0399 | 0.009 | 0.015 | A |
| 0.0400 - 0.0469 | 0.009 | 0.030 | B |
| 0.0470 - 0.0549 | 0.013 | 0.032 | C |
| 0.0550 - 0.0780 | 0.013 | 0.040 | D |
| 0.0781 - 0.0937 | 0.021 | 0.054 | E |
| 0.0938 - 0.1245 1/ | 0.021 | 0.070 | F |
| 0.1246 - 0.1560 1/ | 0.026 | 0.093 | G |

| DIAMETRICAL TOLERANCE (INCHES) (LESS THAN) | CONCENTRICITY TIR (INCHES) (LESS THAN) | SURFACE ROUGHNESS (RMS MAXIMUM) |
|---|---|---|
| 0.005 | 0.005 | 125 |
| 0.001 | 0.002 | 63 |
| 0.0005 | 0.0005 | 32 |
| 0.0001 | 0.0002 | 16 |

1/ Not to be used unless specifically called out on the drawing.

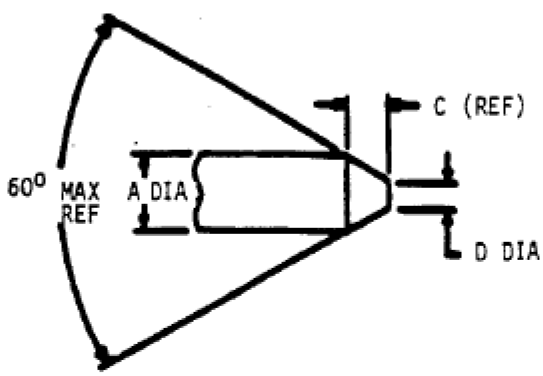


Table 11: Standard Hollow Part Machine Centers

| HOLE "E" DIAMETER (INCHES) | COUNTERSINK "F" DIAMETER (INCHES) | "C" (MINIMUM) 1/ (INCHES) |
|---|---|---|
| To and including 0.125 | E + 0.045 ± 0.005 | 0.015 |
| 0.125 - 0.500 | E + 0.063 ± 0.010 | 0.030 |
| 0.501 - 1.000 | E + 0.094 ± 0.010 | 0.060 |
| 1.000 - 1.500 | E + 0.125 ± 0.010 | 0.125 |
| Over 1.500 | E + 0.187 ± 0.015 | 0.125 |

| DIAMETRICAL TOLERANCE (INCHES) (LESS THAN) | CONCENTRICITY TIR (INCHES) (LESS THAN) | SURFACE ROUGHNESS (RMS MAXIMUM) |
|---|---|---|
| 0.005 | 0.005 | 125 |
| 0.001 | 0.002 | 63 |
| 0.0005 | 0.0005 | 32 |
| 0.0001 | 0.0002 | 16 |

1/ In case of thin walls where "C" (MINIMUM) cannot be met concurrently with F Diameter, the manufacturing activity shall request clarification prior to machining.

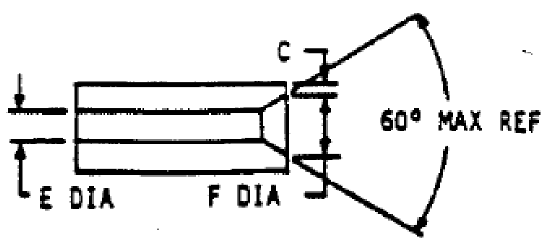


Table 12: Permissible Misalignment for Profiled Surfaces

| SURFACE ROUGHNESS (✓) | ALLOWABLE MISALIGNMENT (INCHES) |
|---|---|
| 250 | 0.025 |
| 125 | 0.0125 |
| 63 | 0.0063 |
| 32 | 0.0032 |
| 16 | 0.0016 |
| 8 | 0.0008 |
| 4 | 0.0004 |

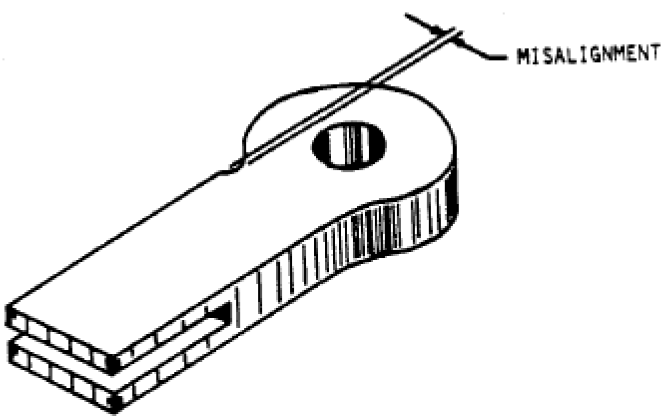



Table 13: Screw Thread Surface Finish

| OPERATION (THREADS) | SURFACE ROUGHNESS (✓) |
|---|---|
| Rolled | 16 |
| Ground | 16 |
| Die or tap | 125 |
| Milled | 63 |
| Turned | 63 |
| Cold Formed | 125 |

Table 14: Tapped Hole Countersink Dimensions

| THREAD SIZE (MAJOR DIAMETER) | | COUNTERSINK DIAMETERS | |
|---|---|---|---|
| | | MAXIMUM | MINIMUM 1/ |
| No. 0 | (0.060) | 0.075 | 0.060 |
| No. 1 | (0.073) | 0.088 | 0.073 |
| No. 2 | (0.086) | 0.101 | 0.086 |
| No. 3 | (0.099) | 0.119 | 0.099 |
| No. 4 | (0.112) | 0.132 | 0.112 |
| No. 5 | (0.125) | 0.150 | 0.125 |
| No. 6 | (0.138) | 0.163 | 0.138 |
| No. 8 | (0.164) | 0.194 | 0.164 |
| No. 10 | (0.190) | 0.220 | 0.190 |
| No. 12 | (0.216) | 0.251 | 0.216 |
| 1/4 | (0.250) | 0.285 | 0.250 |
| 5/16 | (0.312) | 0.352 | 0.312 |
| 3/8 | (0.375) | 0.415 | 0.375 |
| 7/16 | (0.437) | 0.487 | 0.437 |
| 1/2 | (0.500) | 0.550 | 0.500 |
| Over 1/2 | | * | * |

* For threaded sizes over 1/2 inch: Maximum countersink diameter = major diameter + 0.060. Minimum countersink diameter = major diameter.

1/ 90° included ± 10°

Table 15: Screw Thread Chamfers

| THREAD SIZE | MAJOR DIAMETER | "A" (POINT DIAMETER) | |
|---|---|---|---|
| | | MAXIMUM | MINIMUM |
| 0 - 80 | 0.060 | 0.045 | 0.035 |
| 1 - 64 | 0.073 | 0.050 | 0.040 |
| 1 - 72 | 0.073 | 0.055 | 0.045 |
| 2 - 56 | 0.086 | 0.060 | 0.050 |
| 2 - 64 | 0.086 | 0.060 | 0.050 |
| 3 - 48 | 0.099 | 0.065 | 0.055 |
| 3 - 56 | 0.099 | 0.070 | 0.060 |
| 4 - 40 | 0.112 | 0.075 | 0.065 |
| 4 - 48 | 0.112 | 0.075 | 0.065 |
| 5 - 40 | 0.125 | 0.085 | 0.070 |
| 5 - 44 | 0.125 | 0.090 | 0.075 |
| 6 - 32 | 0.138 | 0.095 | 0.080 |
| 6 - 40 | 0.138 | 0.100 | 0.085 |
| 8 - 32 | 0.164 | 0.115 | 0.100 |
| 8 - 36 | 0.164 | 0.120 | 0.105 |
| 10 - 24 | 0.190 | 0.130 | 0.110 |
| 10 - 32 | 0.190 | 0.140 | 0.120 |
| 12 - 24 | 0.216 | 0.150 | 0.130 |
| 12 - 28 | 0.216 | 0.160 | 0.140 |
| 1/4 - 20 | 0.250 | 0.175 | 0.150 |
| 1/4 - 28 | 0.250 | 0.190 | 0.165 |
| 5/16 - 18 | 0.312 | 0.225 | 0.195 |
| 5/16 - 24 | 0.312 | 0.240 | 0.210 |
| 3/8 - 16 | 0.375 | 0.275 | 0.240 |
| 3/8 - 24 | 0.375 | 0.300 | 0.255 |
| 7/16 - 14 | 0.437 | 0.320 | 0.280 |
| 7/16 - 20 | 0.437 | 0.345 | 0.305 |
| 1/2 - 13 | 0.500 | 0.370 | 0.330 |
| 1/2 - 20 | 0.500 | 0.400 | 0.360 |

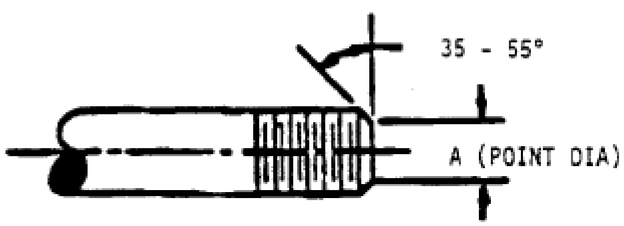


Table 16: Undercuts for External Threads

| THREAD SIZE | "A" DIAMETER (INCHES) | "B" (± 0.010) (INCHES) | "R" (± 0.005) (INCHES) |
|---|---|---|---|
| 0 - 80 | 0.035 +0.000/-0.005 | 0.045 | 0.015 |
| 1 - 64 | 0.043 +0.000/-0.005 | 0.050 | 0.015 |
| 2 - 56 | 0.053 +0.000/-0.005 | 0.055 | 0.015 |
| 4 - 40 | 0.076 +0.000/-0.005 | 0.073 | 0.020 |
| 4 - 48 | 0.073 +0.000/-0.005 | 0.062 | 0.020 |
| 6 - 32 | 0.085 +0.000/-0.010 | 0.088 | 0.020 |
| 6 - 40 | 0.093 +0.000/-0.010 | 0.073 | 0.020 |
| 8 - 32 | 0.111 +0.000/-0.010 | 0.088 | 0.020 |
| 8 - 36 | 0.116 +0.000/-0.010 | 0.080 | 0.030 |
| 10 - 32 | 0.137 +0.000/-0.010 | 0.098 | 0.020 |
| 10 - 24 | 0.123 +0.000/-0.010 | 0.120 | 0.030 |
| 1/4 - 28 | 0.191 +0.000/-0.010 | 0.100 | 0.030 |
| 1/4 - 20 | 0.172 +0.000/-0.010 | 0.135 | 0.030 |
| 1/4 - 32 | 0.197 +0.000/-0.010 | 0.088 | 0.020 |
| 5/16 - 24 | 0.246 +0.000/-0.010 | 0.120 | 0.030 |
| 5/16 - 18 | 0.227 +0.000/-0.010 | 0.150 | 0.030 |
| 5/16 - 32 | 0.260 +0.000/-0.010 | 0.088 | 0.020 |
| 3/8 - 24 | 0.308 +0.000/-0.010 | 0.120 | 0.030 |
| 3/8 - 16 | 0.281 +0.000/-0.010 | 0.166 | 0.030 |
| 3/8 - 32 | 0.322 +0.000/-0.010 | 0.088 | 0.020 |
| 7/16 - 20 | 0.359 +0.000/-0.010 | 0.135 | 0.030 |
| 7/16 - 14 | 0.331 +0.000/-0.010 | 0.190 | 0.030 |
| 7/16 - 28 | 0.377 +0.000/-0.010 | 0.100 | 0.030 |
| 1/2 - 13 | 0.386 +0.000/-0.010 | 0.200 | 0.030 |
| 1/2 - 20 | 0.422 +0.000/-0.010 | 0.135 | 0.030 |
| 1/2 - 28 | 0.441 +0.000/-0.010 | 0.100 | 0.040 |

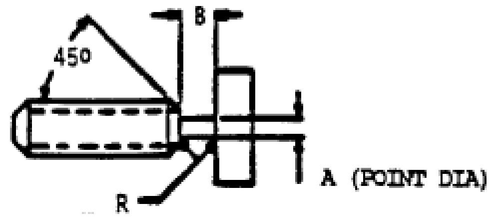


Table 17: Undercuts for Internal Threads

| DIAMETER "A" (FOR SPECIFIED MAJOR DIAMETER) (INCHES) | | |
|---|---|---|
| MAJOR DIAMETER | "A" DIAMETER | TOLERANCE |
| 0.375 | 0.400 | ± 0.005 |
| 0.437 | 0.464 | ± 0.005 |
| 0.500 | 0.527 | ± 0.005 |
| 0.562 | 0.591 | ± 0.005 |
| 0.625 | 0.655 | ± 0.005 |
| 0.687 | 0.718 | ± 0.005 |
| 0.750 | 0.788 | ± 0.005 |
| 0.812 | 0.846 | ± 0.005 |
| 0.875 | 0.910 | ± 0.005 |
| 0.937 | 0.973 | ± 0.005 |
| 1.000 | 1.042 | ± 0.010 |
| 1.062 | 1.106 | ± 0.010 |
| 1.125 | 1.170 | ± 0.010 |
| 1.187 | 1.233 | ± 0.010 |
| 1.250 | 1.297 | ± 0.010 |
| 1.312 | 1.361 | ± 0.010 |
| 1.375 | 1.425 | ± 0.010 |
| 1.437 | 1.490 | ± 0.010 |
| 1.500 | 1.555 | ± 0.010 |
| 1.562 | 1.617 | ± 0.010 |
| 1.625 | 1.680 | ± 0.010 |
| 1.687 | 1.745 | ± 0.010 |
| 1.750 | 1.810 | ± 0.010 |
| 1.812 | 1.873 | ± 0.010 |
| 1.875 | 1.937 | ± 0.010 |
| 1.937 | 2.000 | ± 0.010 |
| 2.000 | 2.062 | ± 0.010 |
| 2.062 | 2.125 | ± 0.010 |
| 2.125 | 2.187 | ± 0.010 |
| 2.187 | 2.250 | ± 0.010 |
| 2.250 | 2.312 | ± 0.010 |
| 2.312 | 2.375 | ± 0.010 |
| 2.375 | 2.437 | ± 0.010 |
| 2.437 | 2.500 | ± 0.010 |
| 2.500 | 2.563 | ± 0.010 |
| 2.625 | 2.687 | ± 0.010 |
| 2.750 | 2.813 | ± 0.010 |
| 2.875 | 2.937 | ± 0.010 |
| 3.000 | 3.062 | ± 0.010 |
| 3.125 | 3.187 | ± 0.010 |
| 3.250 | 3.312 | ± 0.010 |
| 3.375 | 3.437 | ± 0.010 |
| 3.500 | 3.562 | ± 0.010 |
| 3.750 | 3.812 | ± 0.010 |
| 4.000 | 4.062 | ± 0.010 |

| DIMENSION "B" (FOR SPECIFIED PITCH) | |
|---|---|
| PITCH | "B" ± 0.010 (INCHES) |
| 32 | 0.088 |
| 28 | 0.100 |
| 24 | 0.120 |
| 20 | 0.135 |
| 18 | 0.150 |
| 16 | 0.166 |
| 14 | 0.190 |
| 13 | 0.200 |
| 12 | 0.225 |
| 11 | 0.246 |
| 10 | 0.270 |
| 9 | 0.300 |
| 8 | 0.337 |
| 7 | 0.394 |
| 6 | 0.447 |
| 5 | 0.540 |
| 4-1/2 | 0.600 |
| 4 | 0.625 |

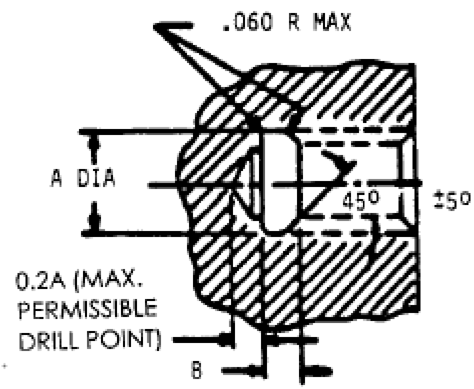


Table 18: Standard Undercuts

| DIAMETER (INCHES) | "A" (INCHES) | "B" (INCHES) | "R" (INCHES) |
|---|---|---|---|
| 0.250 and under | 0.007 +0.000/-0.002 | 0.020 +0.005/-0.000 | 0.010 +0.005/-0.000 |
| 0.251 - 0.750 | 0.008 +0.000/-0.003 | 0.030 +0.005/-0.000 | 0.015 +0.005/-0.000 |
| 0.751 and over | 0.010 +0.000/-0.004 | 0.055 +0.010/-0.000 | 0.020 +0.005/-0.000 |