



Machined Parts

Design Standard

ME0001-DS

Revision History

Date	Version	Section/Changes	Changed By	Approved By
07/23/2024	0.1	First draft.	D. Diemetric TC Manager	R. Gordon Director, Engineering
09/10/2024	1.0	First release.	D. Diemetric TC Manager	R. Gordon Director, Engineering

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




1 Purpose

This document identifies technical requirements for machined parts that fabricators must comply with to meet Invio Automation (Invio) quality requirements, including:

- Tolerances for the permissible degree of deviation in final dimensions or measured values.
- Information not included on mechanical drawings.

These requirements apply only to Invio drawings, as identified in the drawing Title Block.

Figure 1: Example Title Block and Notes

	5	6	7	8																																	
	<p>NOTES:</p> <ol style="list-style-type: none"> 1. UNLESS OTHERWISE SPECIFIED, REMOVE ALL BURRS AND SHARP EDGES TO WITHIN 0.1mm TO 0.3mm. 2. ALL MANUFACTURING METHODS TO BE COMPLIANT WITH INVIO AUTOMATION "MACHINED PART SPECIFICATIONS", LOCATED AT: https://www.invioautomation.com/suppliers-and-vendors  3. ADDITIONAL NOTES MAY BE ADDED BY REPLACING THIS TEXT. 				A																																
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Requirements specified in the drawing Title Block or Notes take precedence over requirements defined in this document.

2 General drawing practices

General drawing practices (including tolerances for gears, sprockets, pulleys, etc.) are in accordance with standards in effect at the time a drawing is created. Standards include those published by the American National Standards Institute (ANSI), the American Society of Mechanical Engineers (ASME), the International Organization for Standardization (ISO), or Deutches Institut für Normung (DIN).

2.1 Tolerances in drawing Title Blocks apply to:

- New drawings.
- Existing drawings whenever variations occur and are determined by Invio to be acceptable. When feasible, Invio will modify the drawings.

2.2 Metric drawings: Dimensions not otherwise specified are in millimeters.

2.3 Imperial drawings: Dimensions not otherwise specified are in inches.

2.4 Standard temperature: The temperature for measuring parts is room temperature, which is approximately 21 degrees C (70 degrees F).

2.5 Dimensions on drawings are final dimensions. This includes the thickness of plating, coating, shrinkage, or growth due to heat treatment, or other factors that affect the thickness. The exception is painted parts, where dimensions are before painting.

2.6 Dimensions for unfinished surfaces on castings, forgings, moldings, or weldments are not included in drawing tolerances. Unless otherwise noted by specific tolerances or notes, these dimensions are governed by average commercial limitations. Any deviation from these standards must be stated on the drawing and will govern those dimensions.

2.7 Unless otherwise specified, holes with $\pm 0.05\text{mm}$ (± 0.002 inch) tolerance or less and tapped holes are not to be plated.

2.8 Reference dimensions on drawings are intended as guides and must not be used for fabrication or inspection purposes.

2.9 Except for structural steel, bar stock, castings, and weldments where the standard manufacturing tolerances of the material is in effect, parallelism and perpendicularity must adhere to this design standard.

2.10 Concentricity must be measured by Total Indicator Reading (TIR).

2.11 Finished parts that are not within the dimensional limits specified on the drawing or in this standard will be designated as having failed the quality requirement. The Invio Quality Control System (QMS) shall determine the disposition of such parts.

2.12 Tolerances are not accumulative.

2.13 Drawings must not be scaled.

3 Surface roughness (finish)

3.1 Finish symbol

The finish symbol indicates the average surface roughness height.

Table 2: Average roughness height values

Micrometers	50	25	12.5	6.3	3.2	1.6	0.8	0.4	0.2	0.1	0.05	0.025
Microinches	2000	1000	500	250	125	63	32	16	8	4	2	1

3.2 Application in drawings

3.2.1 Unless otherwise specified, all machined surfaces must be 3.2 micrometers (125 microinches) or less. A smoother finish than indicated by the finish symbol is permissible.

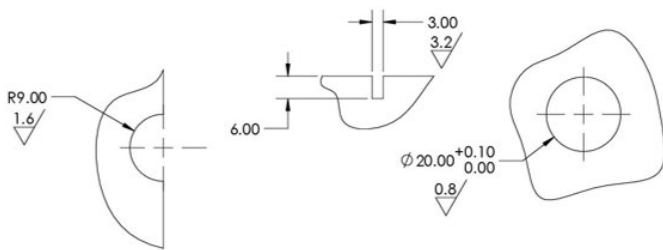
3.2.2 On surfaces that will be plated, the roughness requirement also applies to the surface before plating.

3.2.3 The finish symbol, with the appropriate micrometer/microinch number, specifies the surface roughness height, which is the roughest finish acceptable. This does not indicate the method or process by which acceptable roughness is achieved. (Use special notes to clarify requirements.)

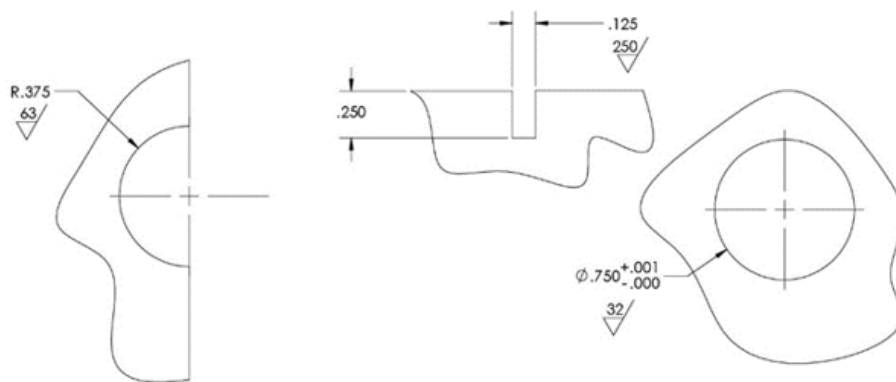
3.2.4 When the finish symbol is used with a dimension, the acceptable roughness applies to all surfaces defined by that dimension.

Figure 1: Finish symbol, in metric and imperial drawings

Metric

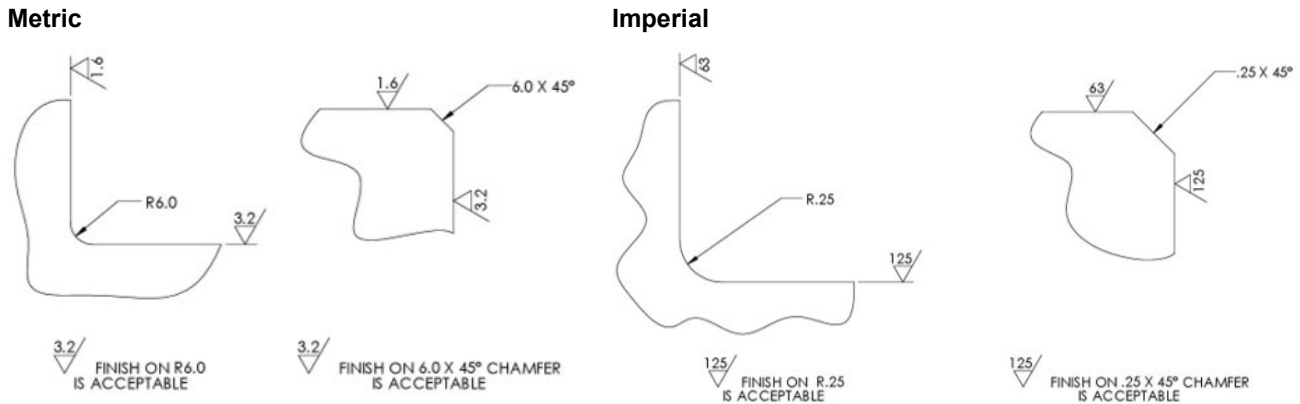


Imperial



3.2.5 Unless otherwise specified, areas of transition, such as chamfers and fillets, must conform to the roughest adjacent finished area.

Figure 2: Area of transition



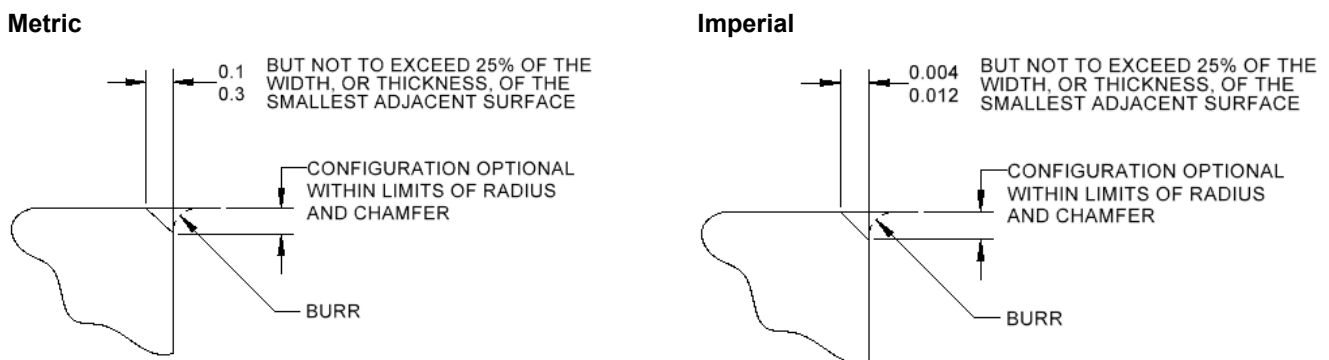
4 Edge and corner condition

4.1 Burrs and sharp edges other than holes

If a specific edge or corner break is not on a drawing, the edge or corner is acceptable if:

- It has been made dull by any process that produces a radius, chamfer, or combination of these equivalent to 0.1mm to 0.3mm (.004 inch to .012 inch).
- Does not exceed 25% of the width or thickness of the smallest adjacent surface.

Figure 3: Burrs and sharp edges



4.2 Internal sharp corners (except counterbores and keyways)

When a sharp internal corner without a fillet dimension is on a drawing, the acceptable corner radius, or equivalent must be:

- Metric: a maximum of 0.4 mm, but not to exceed 25% of the width or thickness of the smallest adjacent surface.
- Imperial: a maximum of 0.015 inch, but not to exceed 25% of the width or thickness of the smallest adjacent surface.

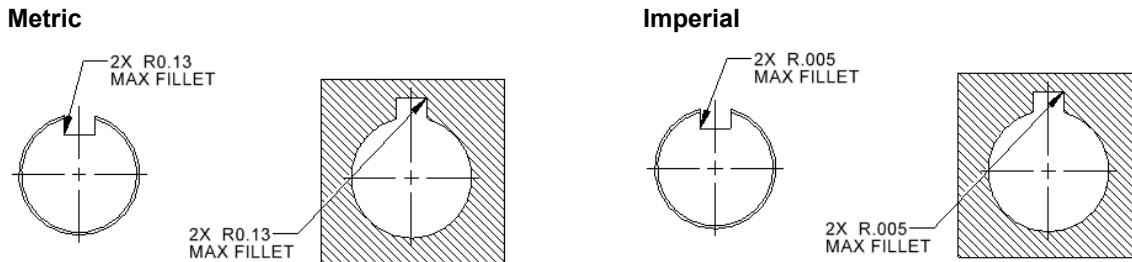
4.2.1 When a drawing of a groove shows a tolerance of 0.05mm (0.002 inch), the acceptable internal corner radius must be in accordance with standard keyway tolerances.

5 Keyways

5.1 Corner condition

When a sharp internal corner of a groove, keyway, or keyseat is on a drawing without a fillet dimension, the acceptable corner radius or equivalent must be 0.13mm (0.005 inch) maximum. Dimensioning on the drawing is not necessary.

Figure 4: Corner condition



5.2 Keyway location relative to centerlines

The centerline of a keyway in a shaft or bore must be centered within the following tolerances.

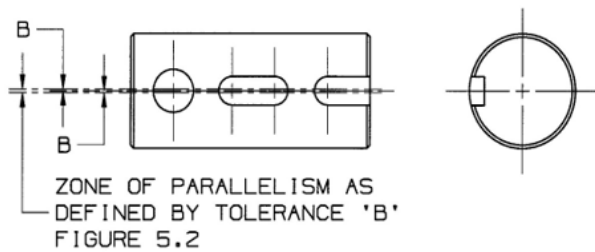
Table 3: Keyway location relative to centerlines

Metric		Imperial	
Diameter (A) Range (mm)	Tolerance (B)	Diameter (A) Range (in.)	Tolerance (B)
0 to 50	0.03	0.000 to 2.000	0.001
50 to 100	0.04	2.000 to 4.000	0.0015
100	0.05	4.000	0.002

5.3 Multiple key relation (inline)

When a drawing includes two or more keyways inline on a shaft or bore, each keyway must be on the same radial centerline within tolerance B (as shown in Table 3) and parallel within the same limits.

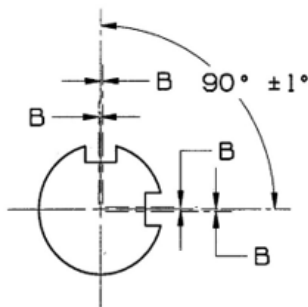
Figure 5: Multiple key relation (inline)



5.4 Angular key location

Keyways in drawings that are 90 degrees radially from one another with no angle specified must comply with the requirements in Table 3. In addition, the keyways must be located 90 degrees within 1 degree (0.442 mm per 25 mm of radius or 0.0177 mm per 1 mm), (0.0174 inch per inch of radius).

Figure 6: Angular key location

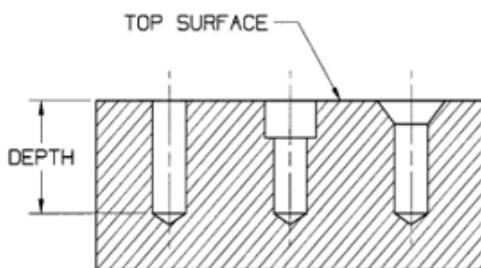


6 Holes

6.1 Depth

Hole depths must be measured from the top surface (including any spotface, countersink, or counterbore) to the depth of the full hole diameter (excluding the drill point depth).

Figure 7: Hole depth



6.2 Surface finish

Holes without a surface finish (roughness) symbol must receive the surface finish specified under the drawing Title Block tolerances.

6.3 Clearance holes

6.3.1 Holes up to 25 mm (1.000 inch) in diameter without drawing tolerances or holes called out in fractions are considered drilled holes and must adhere to the following tolerances.

Table 4: Drilled hole tolerances

Metric		Imperial	
Diameter	Tolerance	Diameter	Tolerance
Range (mm)		Range (in.)	
0 to 3	+0.140 -0.000	0.000 to 0.125	+0.004 -0.001
3 to 6	+0.180 -0.000	0.125 to 0.250	+0.005 -0.001
6 to 10	+0.220 -0.000	0.250 to 0.500	+0.006 -0.001
10 to 18	+0.270 -0.000	0.500 to 0.750	+0.008 -0.001
18 to 25	+0.330 -0.000	0.750 to 1.000	+0.010 -0.001

6.3.2 Unless otherwise specified, the drawing tolerances govern all other holes.

6.4 Hole shape

A hole can be round or tapered or have an irregular surface, providing:

- Every point in the hole is within the diametral limits.
- You can insert a minimum-size cylindrical plug gauge the full depth of the hole.

6.5 Hole squareness

6.5.1 Holes with 0.13mm (.005 inch) or greater diametral tolerance

The axis of a hole must be square with the hole surface in any direction or within the tolerance of the hole location, whichever is smaller.

Table 5: Squareness of holes (tolerance 0.13mm/.005 inch or greater)

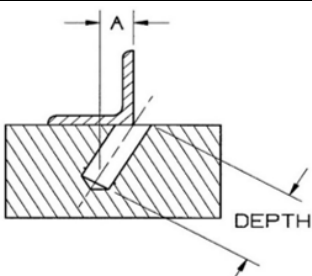
The diagram shows a cross-section of a hole in a block. A vertical dimension line labeled 'A' indicates the squareness variance at the top of the hole. A diagonal dimension line labeled 'DEPTH' indicates the depth of the hole. The hole is shown as a cylinder with a squareness tolerance zone.

Metric		Imperial	
Diameter	Variance (A)	Diameter	Variance (A)
Under $\varnothing 8$	0.2/25 mm of Depth	Under $\varnothing .250$	0.008/inch of Depth
$\varnothing 8$ and over	0.1/25 mm of Depth	$\varnothing .250$ and over	0.004/inch of Depth

6.5.2 Holes with diametral tolerance less than 0.13mm (.005 inch)

The axis of a hole must be square with the hole surface in any direction or within the tolerance of the hole location, whichever is smaller.

Table 6: Squareness of holes (tolerance less than 0.13mm/.005 inch)



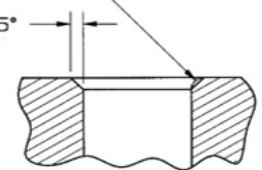
Metric		Imperial	
Diameter	Variance (A)	Diameter	Variance (A)
Under $\varnothing 8$	0.5 mm Total	Under $\varnothing .250$	0.002/inch Total
$\varnothing 8$ and over	0.03 mm Total	$\varnothing .250$ and over	0.001/inch Total

6.6 Machined hole and counterbore edge and corner condition

If a specific edge or corner break is not on a drawing, the edge must be made dull by any process that produces a radius, chamfer, or combination of these equivalent to the following values.

Table 7: Hole and counterbore edge and corner condition

CONFIGURATION OPTIONAL
WITHIN LIMITS OF RADIUS
AND CHAMFER.



Metric		Imperial	
Hole Size Range (mm)	Edge Break (A)	Hole Size Range (in.)	Edge Break (A)
0 to 6	0.1 to 0.4	0.000 to 0.250	0.004 to 0.016
6 to 12	0.1 to 0.5	0.250 to 0.500	0.004 to 0.020
12 and over	0.1 to 0.8	0.500 to over	0.004 to 0.030

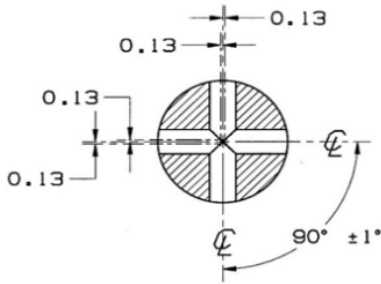
6.7 Multiple hole relation

Holes on a drawing that are 90 degrees radially from one another with no specified angle must be:

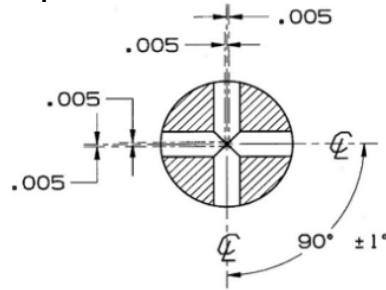
- On the centerline within 0.13 mm (0.005 inch)
- Located at 90 degrees within ± 1 degree (0.442 mm per 25 mm of radius or 0.0177 mm per 1 mm) (.0174 inch of radius)

Figure 8: Multiple hole relation

Metric



Imperial



6.8 Counterbores

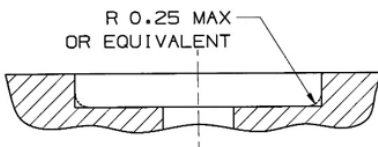
6.8.1 Counterbores must be concentric with the counterbored hole within 0.25 mm (.010 inch) TIR.

6.8.2 When a drawing shows a sharp internal corner on a counterbore with no fillet dimension the acceptable corner radius, or equivalent, must be a maximum of 0.25 mm (R.010 inch).

6.8.3 When applied to a curved surface, a specified counterbore depth must be interpreted as shown.

Figure 9: Counterbores

Metric



Imperial

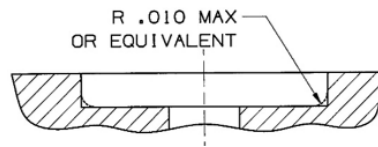
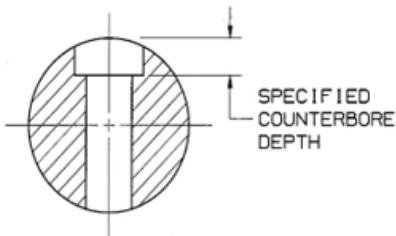


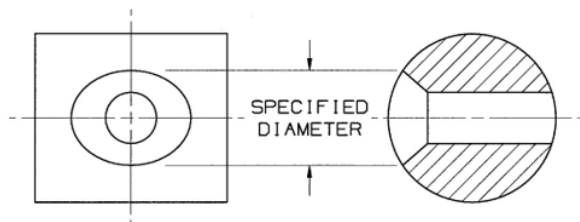
Figure 10: Counterbore depth on a curved surface



6.9 Countersinking holes in a curved surface

When countersinking a hole to a specific diameter when it intersects a curved surface, the dimension must be maintained relative to the smaller diameter of the countersunk portion.

Figure 11: Countersinking holes in a curved surface



7 Threaded parts

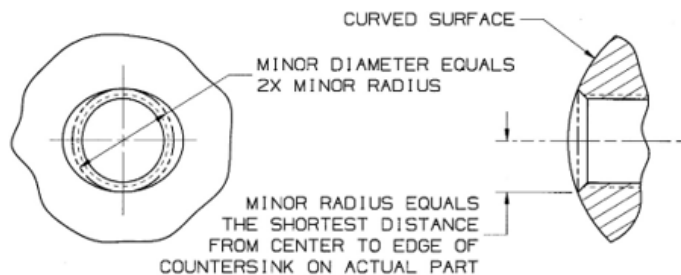
7.1 Metric screw thread designations called out on drawings without the pitch must be coarse pitch threads.

7.2 Tapped hole countersinks

7.2.1 All tapped holes must be countersunk 90 degrees ± 10 degrees included angle. The countersink diameter must be 0.5 mm to 1.5 mm (.020 inches to .060 inches) larger than the thread major diameter.

7.2.2 If a tapped hole is countersunk on a curved surface, the diameter specified on the drawing applies to the countersink minor diameter.

Figure 12: Countersink on a curved surface

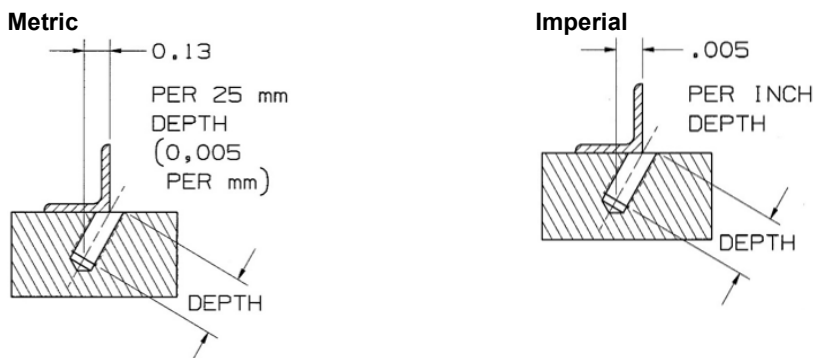


7.2.3 Where practical, tapped through-holes must be countersunk at both ends.

7.3 Tapped hole perpendicularity

The actual axis of threads must be square with the adjacent face within 0.13 mm per 25 mm or 0.005 mm per 1 mm (0.005 per inch) of thread depth. The depth must be measured from the top surface to the last fully formed thread (excluding drill extension).

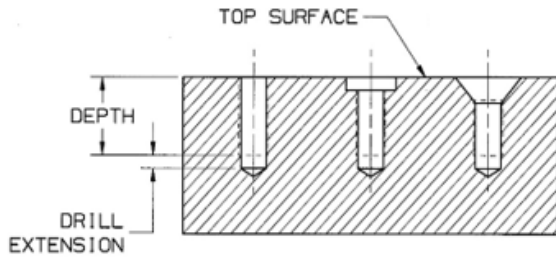
Figure 13: Tapped hole squareness



7.4 Tapped hole depth

The thread depth on a drawing indicates the expected length of full, perfect threads except for those lost by chamfering and counterboring. Thread length is measured from the surface of the base material (excluding drill extension).

Figure 14: Tapped hole depth

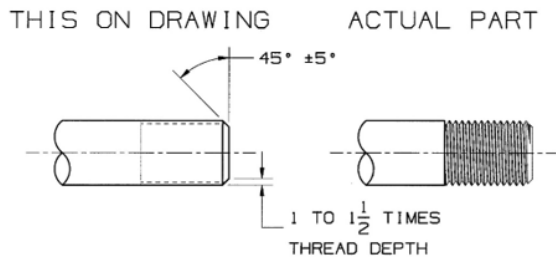


7.5 Chamfers

7.5.1 When there are no chamfer dimensions on the drawing, all threaded ends must be chamfered $45^\circ \pm 5^\circ$ from the end face.

7.5.2 The chamfer depth on the end of the thread must be from 1 to 1.5 times the full thread depth, maximum.

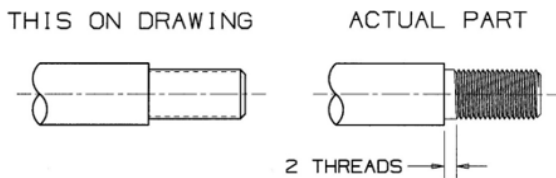
Figure 15: Thread end chamfers



7.6 External thread length

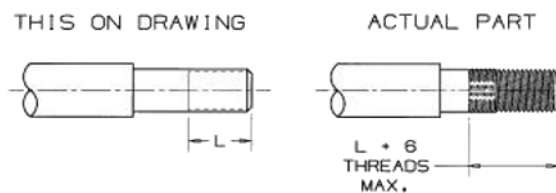
7.6.1 Parts threaded to a shoulder: the thread gauge must fit to within 2 threads from the shoulder. Necking is unnecessary unless specified on the drawing.

Figure 16: External thread length



7.6.2 Parts with definite thread lengths: if the thread does not end at a shoulder or undercut, the thread gauge must fit to the full definite thread. Up to 6 (six) additional threads, perfect or imperfect, are acceptable.

Figure 17: Definite thread length

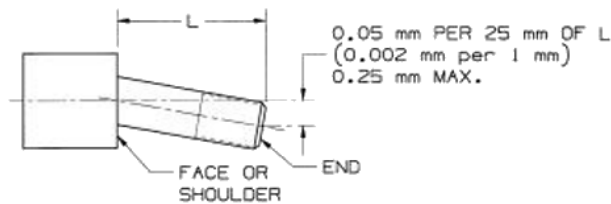


7.7 External perpendicularity

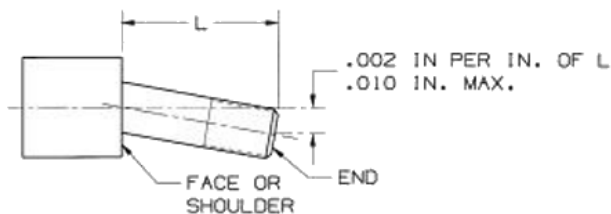
The actual axis of an external threaded end must be square with an adjacent face or shoulder within 0.05 mm per 25 mm or 0.002 mm per 1 mm (0.002 inch per 1.0 inch) of length (L), up to a maximum of 0.25 mm (.010 inch).

Figure 18: External perpendicularity

Metric



Imperial



7.8 External concentricity

Threads with a common centerline and adjacent cylindrical surface must be concentric with the axis of the surface within 0.25 mm (.010 inch) TIR runout.

7.9 Thread tolerance class designation

7.9.1 Metric: in accordance with ISO 965-1, unless otherwise specified, all threads must be:

- Class 6h (external thread) up to and including M1.4
- Class 6g (external thread) M1.6 and larger
- Class 5h (internal thread) up to and including M1.4
- Class 6h (internal thread) M1.6 and larger

7.9.2 Imperial: unless otherwise specified, all threads must be:

- Class 2A (external thread)
- Class 2B (internal thread)

7.9.3 The surface roughness finish limit of the drawing Title Block does not apply to threads.

7.10 Pipe threads

7.10.1 Metric pipe threads must be in accordance with:

- ISO 228-1 (G Series) where pressure-tight joints are not made on the threads.
- ISO 7-1 (Rp, Rc & R Series) where pressure-tight joints are made on the threads.
 - Rp = Parallel internal pipe thread
 - Rc = Taper internal pipe thread

- R = Taper external pipe thread

7.10.2 Imperial pipe threads must be in accordance with ANSI/ASME B1.20.1.

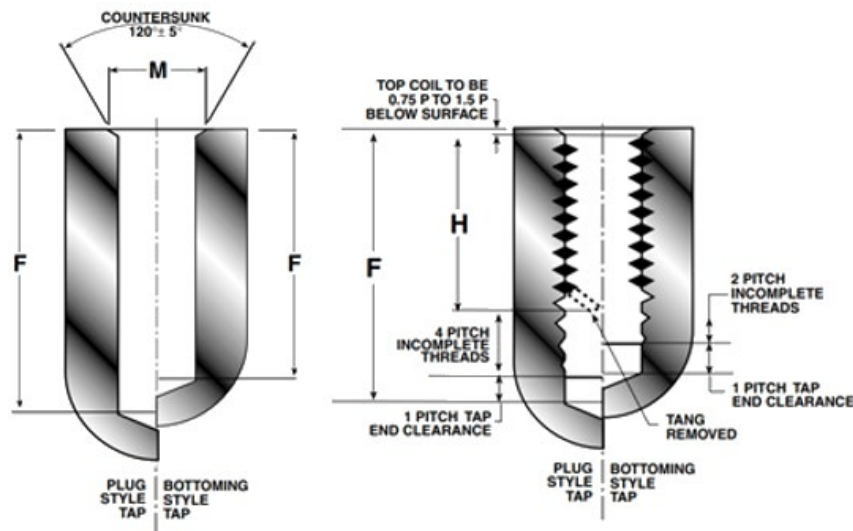
- NPT = American National Standard Taper Pipe Threads
- NPS = American National Standards Pipe Threads for Mechanical Joints
- NPSM = Free-Fitting Mechanical Joints for Fixtures (External and Internal)
- NPSL = Loose-Fitting Mechanical Joints with Locknuts (External and Internal)
- NPSH = Loose-Fitting Mechanical Joints for Hose Couplings
- NPSC = Straight Pipe Threads in Pipe Couplings for Pressure-tight Joints with Lubricant or Sealer
- NPTF = American National Standard Dryseal Pipe Threads for Pressure-tight Joints

7.11 Heli-Coil inserts

7.11.1 Heli-Coil inserts must be installed according to the manufacturer's instructions.

7.11.2 Tanged Heli-Coil inserts are approved for use when tangless Heli-Coil inserts or an insert tool is unavailable. All tangs must be removed from the part.

Figure 19: Heli-Coil installation



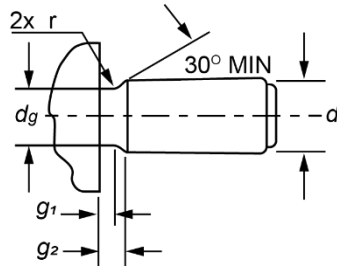
- F: minimum drill depth
- H: minimum tapping depth
- M: Countersink diameter

8 External thread relief (necking, undercut)

8.1 Metric external thread undercuts

When an external thread undercut is required for a part fully threaded to a shoulder, but the drawing does not provide dimensions, refer to the following table (which follows ISO 4755).

Table 8: External thread relief (metric)



Pitch of Thread P	D_g h12 (h13) ¹⁾	g_1 2) min	g_2 max (=3P)	r
0.25	d-0.4	0.4	0.75	0.12
0.3	d-0.5	0.5	0.9	0.16
0.35	d-0.6	0.6	1.05	0.16
0.4	d-0.7	0.6	1.2	0.2
0.45	d-0.7	0.7	1.35	0.2
0.5	d-0.8	0.8	1.5	0.2
0.6	d-1	0.9	1.8	0.4
0.7	d-1.1	1.1	2.1	0.4
0.75	d-1.2	1.2	2.25	0.4
0.8	d-1.3	1.3	2.4	0.4
1	d-1.6	1.6	3	0.6
1.25	d-2	2	3.75	0.6
1.5	d-2.3	2.5	4.5	0.8
1.75	d-2.6	3	5.25	1
2	d-3	3.4	6	1
2.5	d-3.6	4.4	7.5	1.2
3	d-4.4	5.2	9	1.6
3.5	d-5	6.2	10.5	1.6
4	d-5.7	7	12	2
4.5	d-6.4	8	13.5	2.5
5	d-7	9	15	2.5
5.5	d-7.7	11	17.5	3.2
6	d-8.3	11	18	3.2

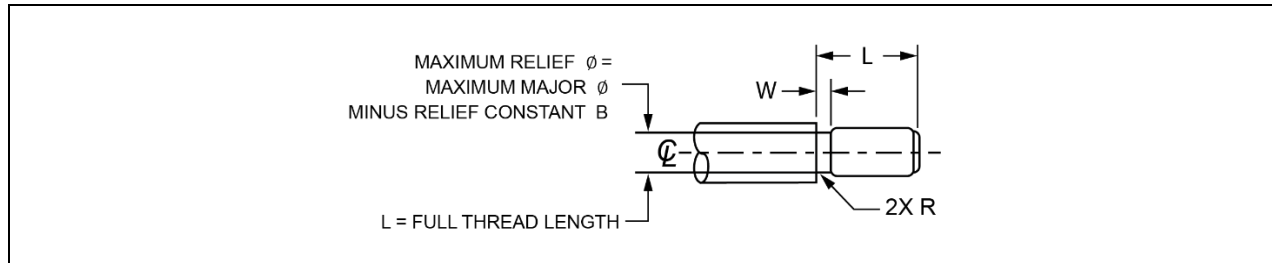
- 1) h12 up to and including 3 mm thread diameter.
- 2) g_1 min. based on a minimum transition angle of 30° .

8.2 Imperial external thread relief

When an external thread necking is required for parts fully threaded to a shoulder, but the drawing does not provide dimensions, refer to the following table.

The length of relief for pitch (W) must not exceed 3P.

Table 9: External thread relief (imperial)

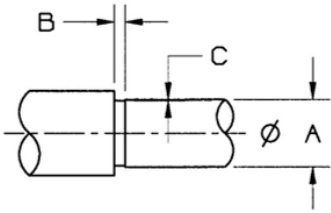


Threads per Inch	W = Length of Relief for Pitch					Relief Constant B	R
	1P	1 1/2P	2P	2 2/2P	3P		
80	.012	.019	.025	.031	.038	.020	.005 - .010
72	.014	.021	.028	.035	.042	.022	.005 - .010
64	.016	.023	.031	.039	.047	.024	.005 - .010
56	.018	.027	.036	.045	.054	.027	.005 - .015
48	.021	.031	.042	.052	.062	.032	.005 - .015
44	.023	.034	.045	.057	.068	.034	.010 - .020
40	.025	.038	.050	.062	.075	.037	.010 - .020
33	.028	.042	.056	.069	.083	.041	.010 - .020
32	.031	.047	.062	.078	.094	.046	.010 - .020
28	.036	.054	.071	.089	.107	.053	.02 - .04
24	.042	.062	.083	.104	.125	.061	.02 - .04
20	.050	.075	.100	.125	.150	.072	.02 - .04
18	.056	.083	.111	.139	.167	.081	.02 - .04
16	.062	.094	.125	.156	.188	.090	.02 - .04
14	.071	.107	.143	.179	.214	.103	.04 - .06
13	.077	.115	.154	.192	.231	.110	.04 - .06
12	.083	.125	.167	.208	.250	.120	.04 - .06
11	.091	.136	.182	.227	.273	.130	.04 - .06
10	.100	.150	.200	.250	.300	.143	.04 - .06
9	.111	.167	.222	.278	.333	.158	.04 - .06
6	.125	.188	.250	.312	.375	.178	.04 - .06
7	.143	.214	.286	.357	.429	.203	.06 - .08
6	.167	.250	.333	.417	.500	.237	.06 - .08
5	.200	.300	.400	.500	.600	.283	.06 - .08
4 1/2	.222	.333	.444	.556	.667	.314	.06 - .08
4	.250	.375	.500	.625	.750	.353	.06 - .08

8.3 Necking for grinding

Unless otherwise specified, a machined neck at shoulders is allowed. A neck must be machined at shoulders on ground diameters of 3 mm (.12 inch) or larger with dimensions as specified in the following table.

Table 10: Necking for grinding



Metric			Imperial		
Finished Diameter A	Width of Neck B	Depth of Neck C	Finished Diameter A	Width of Neck B	Depth of Neck C
3 to 12	2 ± 0.8	0.05 to 0.15	.12 to .50	.08 ±.03	.002 to .006
12 to 50	2 ± 0.8	0.15 to 0.3	.50 to 2.00	.08 ±.03	.006 to .012
Over 50	8 ± 0.8 0	0.05 to 0.8	Over 2.00	.12 ±.03	.020 to .030

9 Centers

9.1 Centers for turning shafts or other parts are permitted on a completed part except when the following note is on the drawing: Centers Not Permissible

9.2 Centers are not shown on drawings unless necessary for a machine function.

9.3 Normally, centers are equal to half the shaft diameter but do not exceed 19 mm (0.75 inch).

9.4 When the part end diameters differ, centers do not have to be the same size at both ends.

10 Parallelism

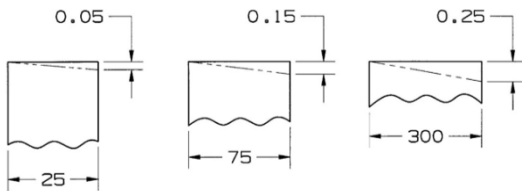
Machined surfaces shown parallel to one another must be parallel within 0.05 mm per 25 mm of length (.002 inch per inch of length), but not to exceed a total of 0.25 mm (.010 inch) or size tolerance.

11 Perpendicularity

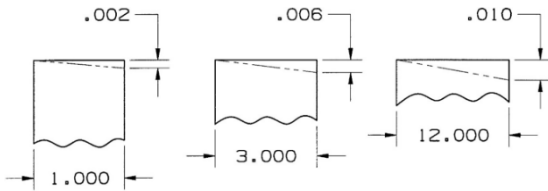
11.1 Machined surfaces shown square with one another on the drawing must be square within 0.05 mm per 25 mm of length or 0.002 mm per 1 mm (.002 inch per inch of length), to a maximum of 0.25 mm (.010 inch), but not to exceed the dimension of the surfaces.

Figure 20: Perpendicularity

Metric



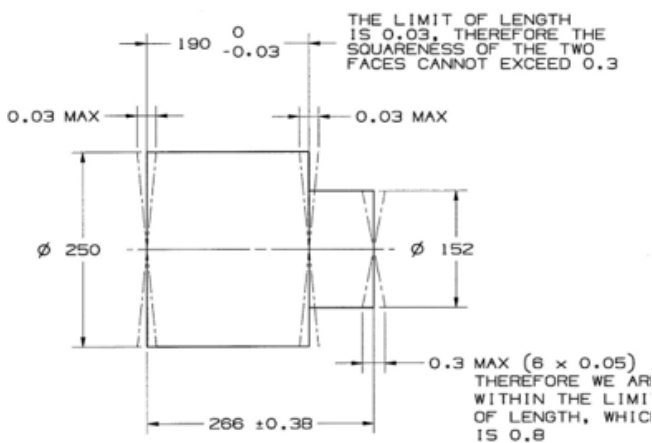
Imperial



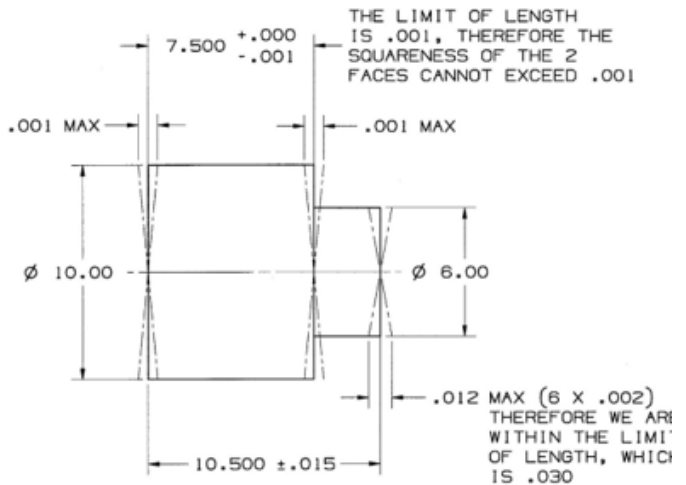
11.2 The squareness of ends, faces, and shoulders shown at right angles to the axis of rotation must be 0.05 mm per 25 mm or 0.002 mm per 1 mm (0.002 inch per inch) of diameter to a maximum of 0.25 mm (0.010 inch). No portion of an end, face, or shoulder shall be outside the limits of length or depth.

Figure 21: Faces (internal and external)

Metric



Imperial

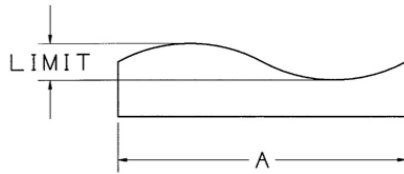


12 Flatness

The flatness tolerance of a machined surface is the total deviation permitted between two parallel planes. The entire surface must be within the tolerance.

Table 11: Flatness tolerance of a machined surface

Metric			Imperial		
Surface Roughness Up to and Including	Flatness mm per 25 mm (A)	Max Limit	Surface Roughness Up to and Including	Flatness in. per 1 in. (A)	Max Limit
0.8/	0.03	0.05	32/	.001	.002
1.6/	0.05	0.08	63/	.002	.003
3.2/	0.08	0.13	125/	.003	.005
6.3/	0.13	0.3	250/	.005	.012

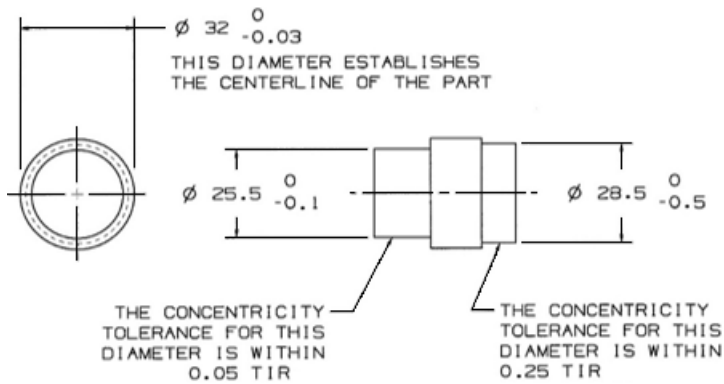


13 Quality Requirements

The diameter with the tightest tolerance establishes the centerline of the part. External (shaft) and internal (hole) cylindrical surfaces on the same part with a common centerline must be concentric with a TIR equal to one half the tolerance of the part diameter.

Figure 22: Establishing centerlines of external cylinders (shafts)

Metric



Imperial

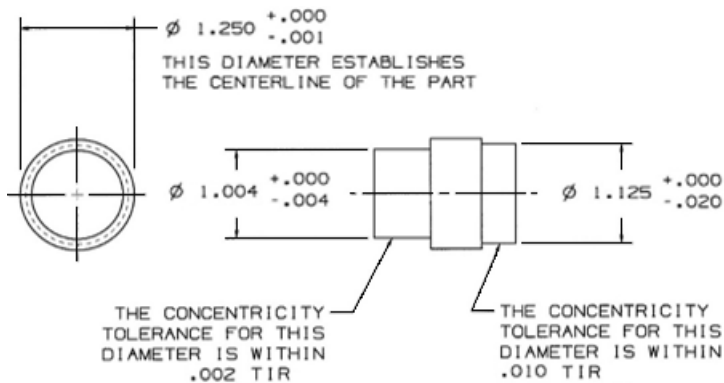
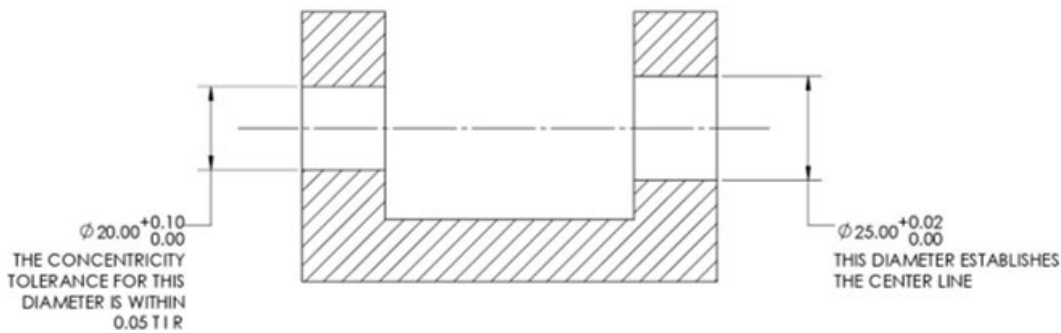
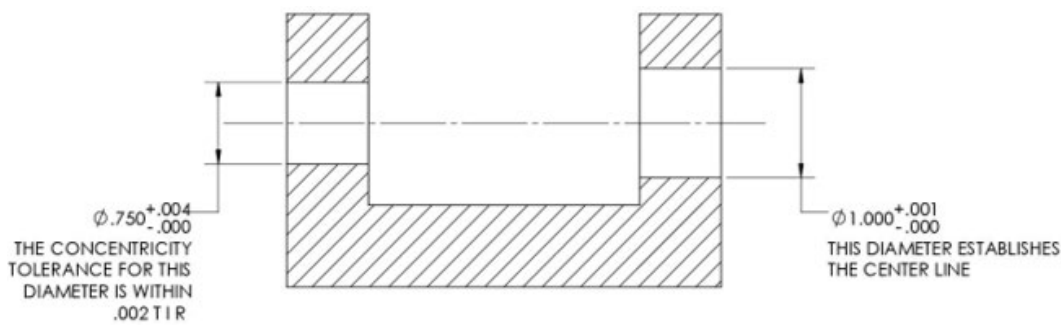


Figure 23: Establishing centerlines of internal cylinders (holes)

Metric



Imperial

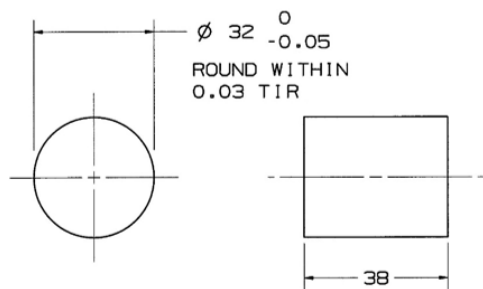


14 Circularity (roundness)

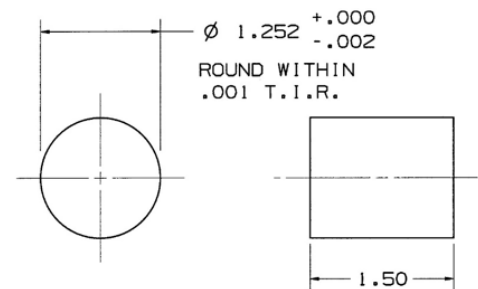
Internal and external cylindrical surfaces must be round within a TIR equal to one half the diameter tolerance.

Figure 24: Cylindrical surfaces

Metric



Imperial



15 Straightness

Surfaces shown on the drawing as straight with one another must be straight within 0.05 mm per 25 mm or 0.002 mm per 1 mm (0.002 inch per inch) of diameter to a maximum of 0.25 mm (0.010 inch) but less than the size tolerance.

16 Welding

16.1 Metric and imperial welding drawings indicate weld joint and welding instructions in accordance with American Welding Society, Standard Symbols for Welding, Brazing and Nondestructive Examination, ANSI/AWS A2.4.

16.2 Unless otherwise specified, all weldments must be stress relieved before machining.

16.3 When indicated by a note on the drawing, weldments that have a hanging load must undergo magnetic particle inspection (MPI).

16.4 All dimensions for the size and width of the weld are $\pm 10\%$ of the value in the following chart.

Figure 25: AWS Welding Symbol Chart

Basic Welding Symbols and Their Location Significance									
Location Significance	Fillet	Plug or Slot	Spot or Projection	Stud	Seam	Back or Backing	Surfacing	Edge	
Arrow Side									
Other Side				Not Used			Not Used		
Both Sides		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used		
No Arrow Side or Other Side Significance	Not Used	Not Used		Not Used		Not Used	Not Used	Not Used	
Location Significance	Groove							Scarf for Brazed Joint	
	Square	V	Bevel	U	J	Flare-V	Flare-Bevel		
Arrow Side									
Other Side									
Both Sides									
No Arrow Side or Other Side Significance		Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	Not Used	
Supplementary Symbols				Location of Elements of a Welding Symbol					
Weld-All-Around	Field Weld	Melt-Thru	Consumable Insert						
Backing/Spacer (Rectangular)	Contour								
Backing	Flush or Flat	Convex	Concave						
Spacer									
Basic Joints				Identification of Arrow Side and Other Side Joint					
Butt Joint		Corner Joint							
T-Joint		Lap Joint							
Edge Joint		Letter Designations							
					<p>Where letter designations are to be included in the tail of the welding symbol, reference is made to Table 1, Letter Designations of Welding and Allied Processes and Their Variations, of AWS A2.4-98.</p> <p>American Welding Society 550 N.W. LeJeune Road Miami, Florida 33126</p>				

17 Cleaning

17.1 All parts must be free of dirt, loose scale, metal chips, and other foreign matter when received, placed in stock, and when assembled. Special cleaning requirements must be specified on the drawing.

17.2 All parts delivered to Invio QMS must be protected from physical damage and corrosion.

18 Sheet metal

18.1 All parts must be free of dirt, loose scale, metal chips, and other foreign matter when received, placed in stock, and when assembled. Special cleaning requirements must be specified on the drawing.

18.2 All parts delivered to Invio QMS must be protected from physical damage and corrosion.

18.3 Unless otherwise specified, sheet metal part tolerances must be in accordance with the following table.

Table 12: Sheet metal part tolerances

Dimension	Description	Tolerance	
		Metric	Imperial
A	Hole to edge	±0.13	±.005
B	Hole to hole on one surface	±0.13	±.005
C	Hole to bend	±0.25	±.010
D	Hole to hole across 2 bends	±0.75	±.030
E	Hole to hole across 4 bends	±0.75	±.030
F	Edge to bend	±0.25	±.010
G	Bend to bend	±0.25	±.010
H	Edge to edge across 2 or more bends	±0.75	±.030
J	Bend angle	±1°	±1°

19 Castings and molded parts

19.1 Casting and molded part drawings must be prepared in accordance with ASME Y14.8 2009.

19.2 For all dimensions not shown in a drawing, you must use the approved 3D CAD model.

19.3 All values queried from the 3D CAD model are basic.

19.4 Gate, riser, vent, parting line, ejector pin locations, and other features for tooling considerations must be approved by Invio Engineering before tool construction.

19.5 All burrs, gates, fins, etc. must be removed flush within the profile tolerance.

19.6 The parts must be free of dirt, debris, oils, and other contaminants.

19.7 No through porosity, inclusions, non-fills, or flash are allowed.

19.8 Casting tolerances

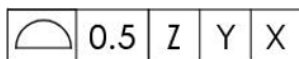
- Linear tolerance to datums X, Y, and Z
 - ± 0.25 mm (± 0.10 inch) up to 25 mm (1.00 inch)
 - ± 0.05 mm (± 0.002 inch) per additional 25 mm (1.00 inch)
- Shift or depth tolerance across parting line
 - ± 0.50 mm (± 0.10 inch) in addition to above linear tolerance.

19.9 Molded part tolerances

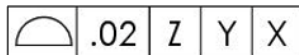
19.9.1 Unless otherwise specified, profile tolerances as shown in the following image.

Figure 26: Profile tolerance

Metric



Imperial



19.9.2 Parting line mismatch must be ± 0.25 mm (± 0.01 inch).

19.9.3 Ejector pin marks are acceptable to ± 0.25 mm (± 0.01 inch).

19.9.4 Unless otherwise specified, all molded surfaces must be 16 μ m (63 μ in) particulate (EDM) finish or better.

20 Symbology

20.1 Symbols that represent words or phrases are allowed on drawings that are not geometrically dimensioned and toleranced. Symbols must adhere to ASME Y14.5 2018, as shown in the following chart.

Table 27: ASME Y14.5 2018 dimension and tolerance symbols

SYMBOL FOR	ASME Y14.5	ISO
STRAIGHTNESS	—	—
FLATNESS		
CIRCULARITY		
CYLINDRICITY		
ANGULARITY		
PERPENDICULARITY		
PARALLELISM		
POSITION		
CONCENTRICITY and COAXIALITY	NONE	
SYMMETRY	NONE	
PROFILE OF A LINE		
PROFILE OF A SURFACE		
CIRCULAR RUNOUT		
TOTAL RUNOUT		
ALL AROUND		
ALL OVER		
AT MAXIMUM MATERIAL CONDITION		
AT MAXIMUM MATERIAL BOUNDARY		NONE
AT LEAST MATERIAL CONDITION		
AT LEAST MATERIAL BOUNDARY		NONE
PROJECTED TOLERANCE ZONE		
TANGENT PLANE		
FREE STATE		
UNEQUALLY DISPOSED PROFILE		UZ
ENVELOPE PRINCIPLE	DEFAULT	
INDEPENDENCY		DEFAULT
DYNAMIC PROFILE TOLERANCE		
TRANSLATION		NONE
FROM / TO		
DIAMETER		
BASIC DIMENSION (Theoretically Exact Dimension in ISO)		
REFERENCE DIMENSION (Auxiliary Dimension in ISO)	(50)	(50)
DATUM FEATURE		

* May be filled or not filled

C.3

SYMBOL FOR	ASME Y14.5	ISO
DIMENSION ORIGIN		
FEATURE CONTROL FRAME		
CONICAL TAPER		
SLOPE		
COUNTERBORE		NONE
SPOTFACE		NONE
COUNTERSINK		NONE
DEPTH/DEEP		NONE
SQUARE		
DIMENSION NOT TO SCALE	<u>15</u>	<u>15</u>
NUMBER OF PLACES	8X	8x
ARC LENGTH		
RADIUS	R	R
SPHERICAL RADIUS	SR	SR
SPHERICAL DIAMETER	S \emptyset	S \emptyset
CONTROLLED RADIUS	CR	NONE
BETWEEN	*	*
STATISTICAL TOLERANCE		NONE
CONTINUOUS FEATURE		NONE
DATUM TARGET		
MOVABLE DATUM TARGET		
TARGET POINT		
* May be filled or not filled		C,3

21 Painting and powder coating

21.1 Surface preparation:

- Surfaces to be painted:
 - Iron phosphate etch or equivalent process prior to painting.
 - Unless otherwise specified, paint must be RAL# 7035, semi-gloss, light texture.
- Surfaces to be powder coated:
 - Prior to coating, sandblast “Near White Blast” SSPC-10 zinc rich primer or equivalent process.

Mask the following:

- Holes, slots, and keyways with ± 0.13 mm (± 0.005 inch) tolerance or less.
- Tapped holes.
- External threads.
- Machined surfaces indicated with the finish symbol.