



Exceptional service in the national interest

Intro to Drawings and Geometric Dimensioning & Tolerancing (GD&T)

Per ASME Y14.5-2009

Caleb White

12/02/2021

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About Me



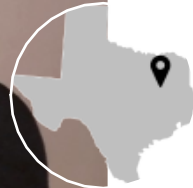
BS & MS in Mechanical Engineering



DPM on LMS19



Undergrad Intern (2017)



Virtual Worker in Tyler, TX



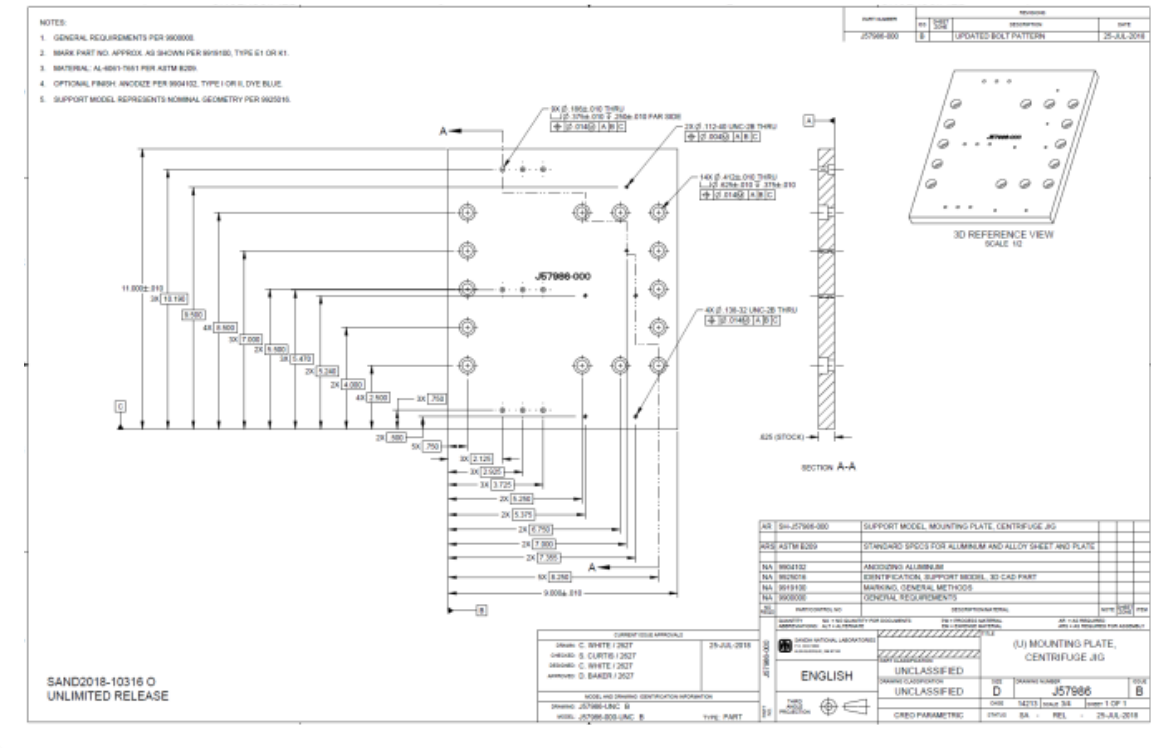
Y14.5-2009 Technologist Certification



The Secretary's Achievement Award
(2021)

Importance of Engineering Drawings

- Technical requirements document.
 - Fully defines all details critical to the *fit, form, or function* of the design/product.
 - Specifies: geometry, dimensions, tolerances, materials, finishes, specifications, Bill of Materials (BOM), instructions, additional processes, etc.
- Legal instrument in contractual agreement between designer and manufacturer.
 - Manufacturers are free from liability for faulty drawings, designers have legal recourse for manufacturing mistakes.



Incomplete/inaccurate drawings can cause severe production delays and increased costs.



Drawing Components

Notes

- NOTES:
1. GENERAL REQUIREMENTS PER 9900000.
 2. MARK PART NO. APPROX. AS SHOWN PER 9919100, TYPE E1 OR K1.
 3. MATERIAL: AL-6061-T651 PER ASTM B209.
 4. OPTIONAL FINISH: ANODIZE PER 9904102, TYPE I OR II, DYE BLUE.
 5. SUPPORT MODEL REPRESENTS NOMINAL GEOMETRY PER 9925016.

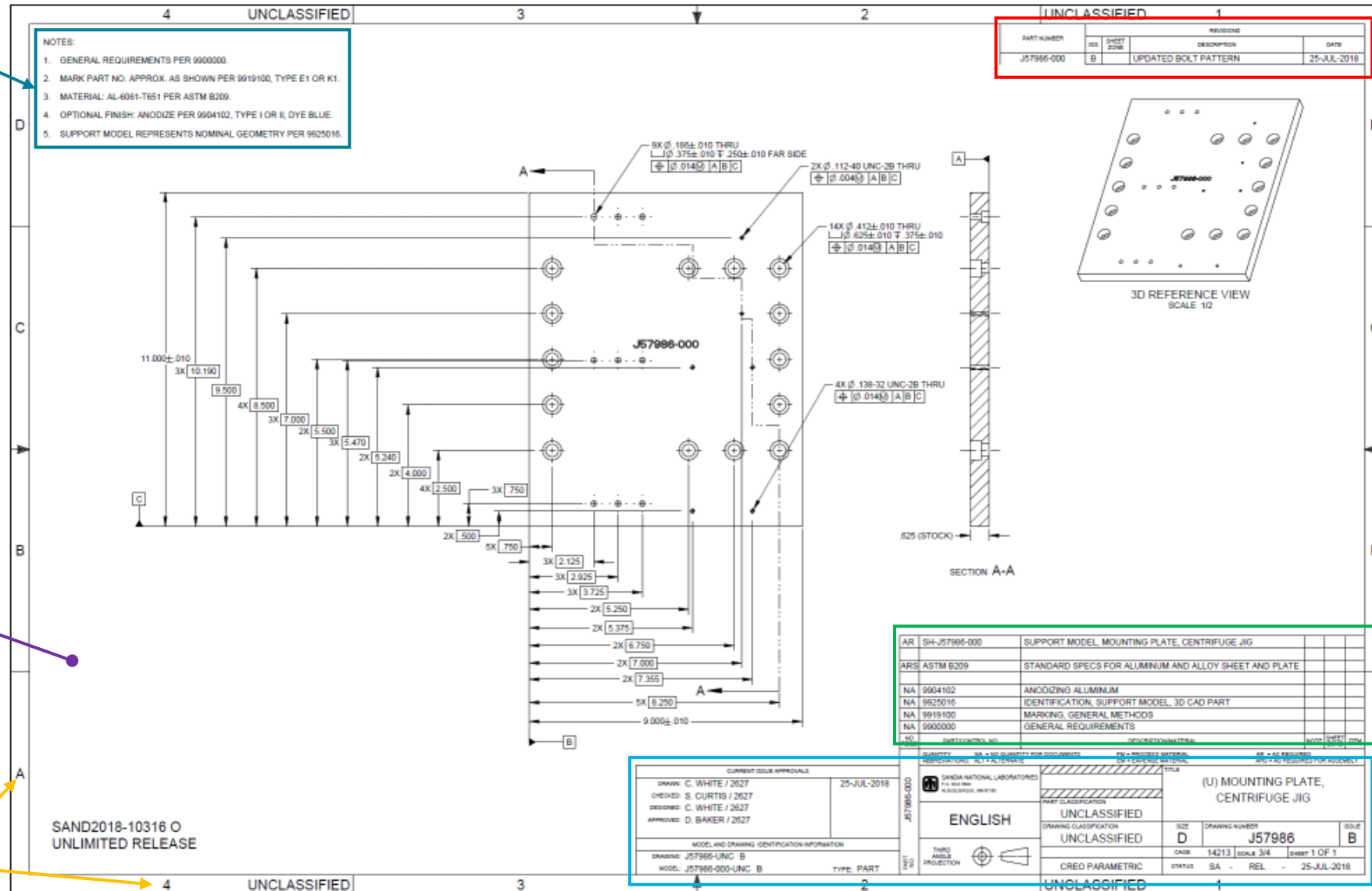
Field of the Drawing

Zones

Revisions Block

BOM/IPL

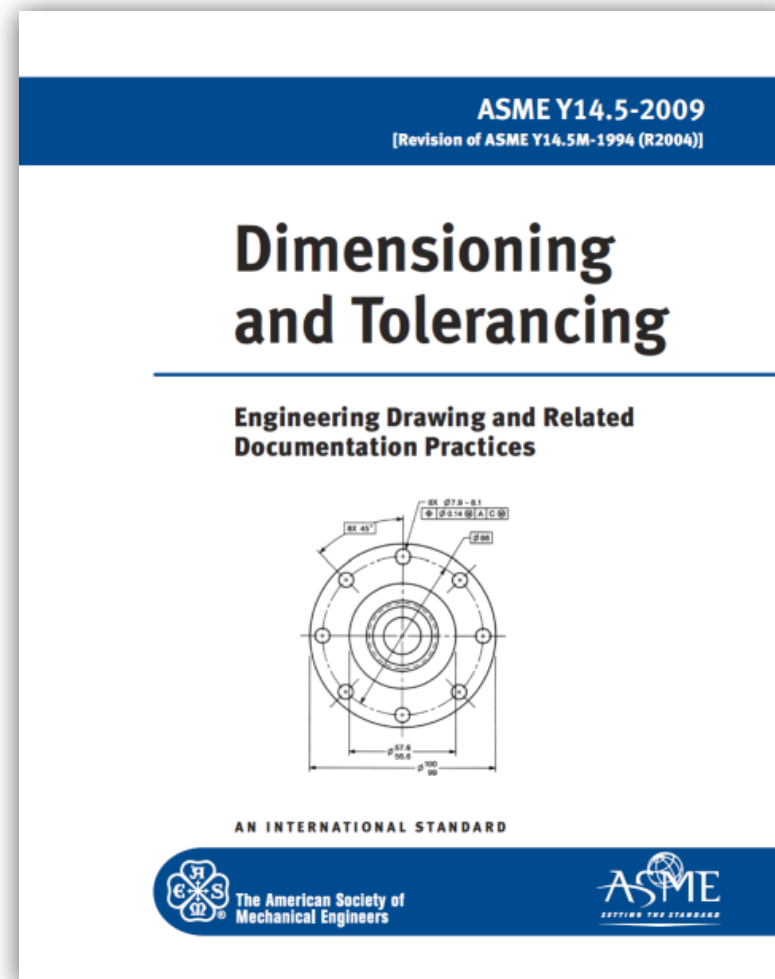
Title Block





Geometric Tolerancing & Dimensioning (GD&T)

- Credited to Stanley Parker in 1940.
- International standard that uses symbolic language on models and drawings to define nominal (theoretically perfect) geometry and the allowable variation in
 - 1) form and possible size of individual features,
 - 2) between features.
- Defines reference coordinate system(s) used throughout manufacturing and inspection; concisely describes complex requirements.
- Greatly simplifies tolerance analyses.
- Assures interchangeability.
- Related standards:
 - ASME Y14.5.1M *Mathematical Definition of Dimensioning and Tolerancing Principles*
 - ASME Y14.41 *Digital Product Definition Data Practices*



GD&T defines the theoretically exact part and the maximum amount of allowable variation—great emphasis on *design intent*.



Fundamental Rules

- All dimensions *shall* have a tolerance.
 - Applied directly, indirectly (basic), general note, or tolerance block.
 - Exceptions for reference, max, min, and stock.
- Dimensioning/tolerancing *shall* be complete for full understanding of every feature. Measurement and scaling of the drawing is disallowed*.
- All necessary dims *shall* be shown (no more than needed for completeness), reference dims should be minimized.
- Dims should be arranged to suit function/mating of part. Dims *shall* not be subject to more than one interpretation.
- Manufacturing methods should not be specified unless essential to requirements
- Non-mandatory processing dims are marked as such (NONMANDATORY), if final dims are given.
- Dims should be arranged for optimum readability and be applied in true profile views that refer to visible outlines.
- Geometry (i.e., wires, etc.) manufactured to gage or code numbers *shall* be specified by linear dimensions with the Gage or code numbers shown in following parentheses.
- $\angle(0^\circ, 90^\circ)$ basic angles are assumed for lines with no angular dim, tolerance is provided by feature control frames governing the feature.
- All dims/tolerances apply at 20°C (68°F) and 101.3 kPa (14.69 psi), unless stated.
- Unless specified, all tolerances apply to full depth, width, and length of feature.
- Dims only apply at specified drawing level.
- If coordinate system is shown: it *shall* be right-handed, show axis labels, and positive direction.

Standard must be invoked on drawing: DIMENSIONING AND TOLERANCING PER ASME Y14.5-2009.

Cannot mix standards (i.e., 1994 and 2009) on same drawing.



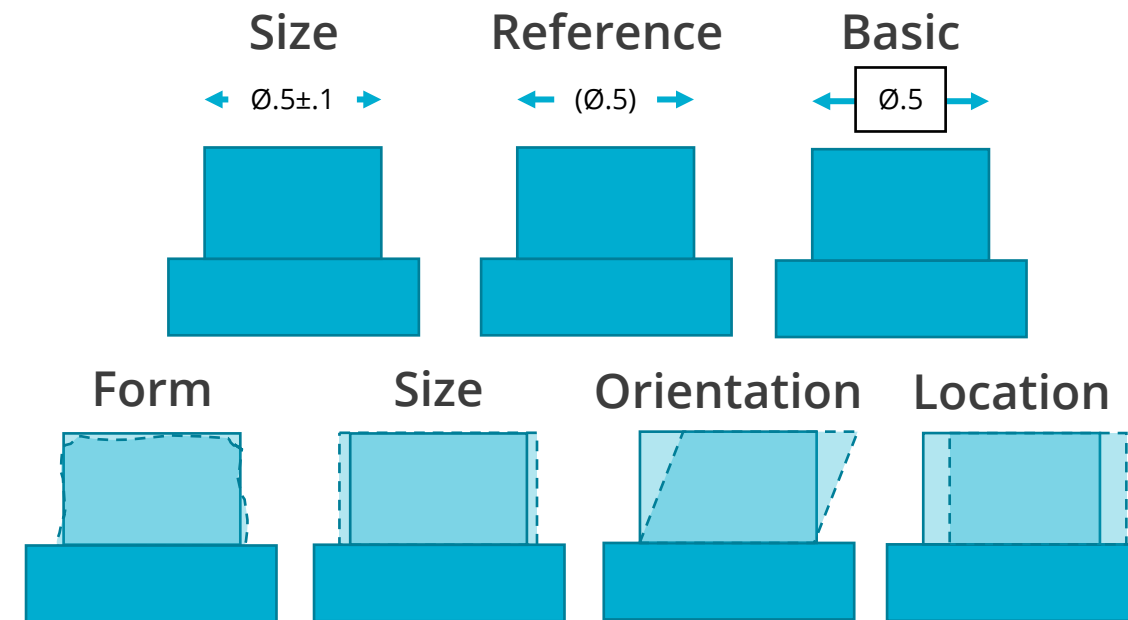
Dimensions & Tolerances

Dimension: a numerical value(s) or mathematical expression in appropriate units of measure used to define the form, size, orientation, or location, of a part or feature.

Tolerance: the total amount a specific dimension is permitted to vary. The tolerance is the difference between the maximum and minimum limits.

Feature: a physical portion of a part such as a surface, pin, hole, or slot or its representation on drawings, models, or digital data files.

Regular Feature of Size: one cylindrical or spherical surface, a circular element, and a set of two opposed parallel elements or opposed parallel surfaces, each of which is associated with a directly toleranced dimension.

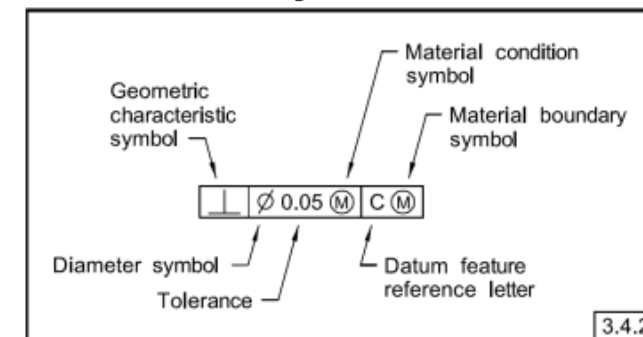


Directly Toleranced

Ø.5±.1 Ø.6 Ø.5⁰_{-.1}
Ø.4

~~UNLESS OTHERWISE SPECIFIED:
LINEAR TOLERANCE: ±.2
ANGULAR TOLERANCE: ±1°~~

Indirectly Toleranced



Rule #1: The form of an individual regular feature of size is controlled by its limits of size (perfect form at MMC).



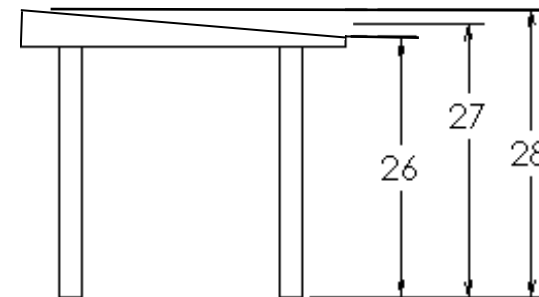
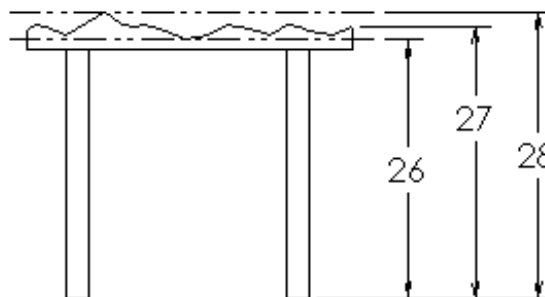
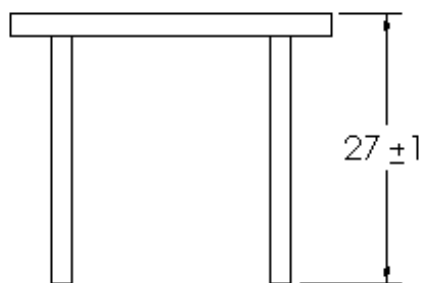
Table Design Example

Requirements

Design a table that stands between 26–28" high and is flat to within 1/16" ($\approx .06$ ").

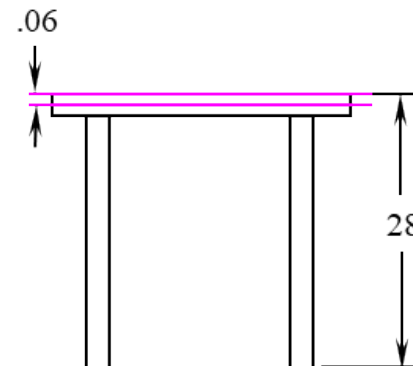
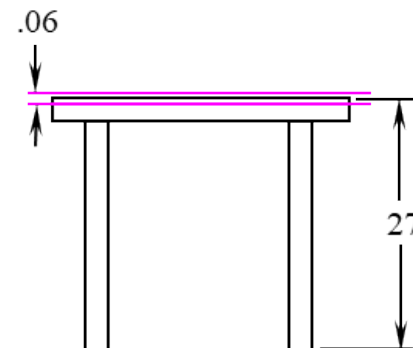
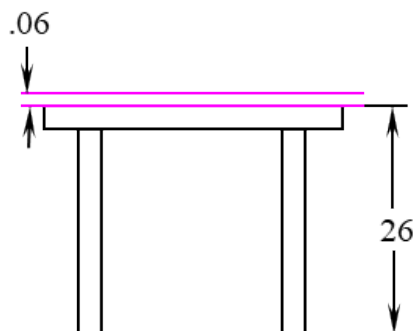
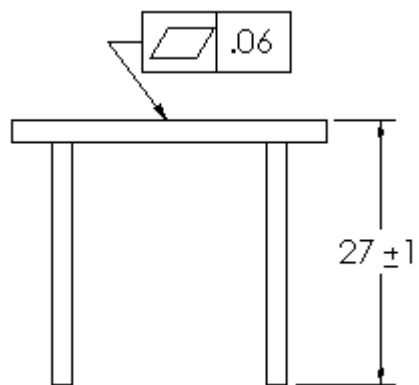
Direct Tolerancing

Per Rule #1, Form is given from Size tolerance.



Indirect with GD&T

Form and Size can be controlled separately.





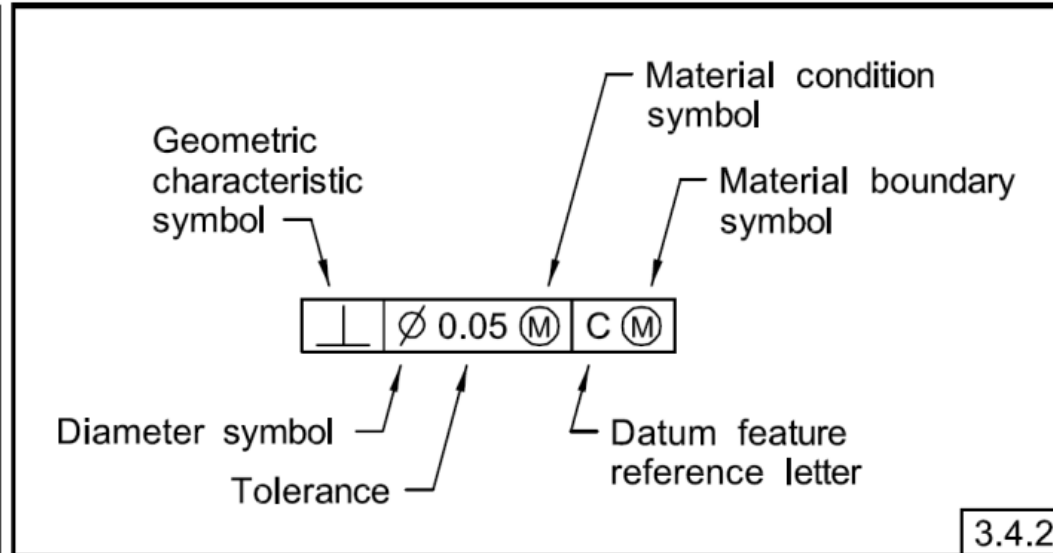
Geometric Symbols

APPLICATION	TYPE OF TOLERANCE	CHARACTERISTIC	SYMBOL	SEE:
INDIVIDUAL FEATURES	FORM	STRAIGHTNESS		5.4.1
		FLATNESS		5.4.2
		CIRCULARITY		5.4.3
		CYLINDRICITY		5.4.4
INDIVIDUAL OR RELATED FEATURES	PROFILE	PROFILE OF A LINE		8.2.1.2
		PROFILE OF A SURFACE		8.2.1.1
RELATED FEATURES	ORIENTATION	ANGULARITY		6.3.1
		PERPENDICULARITY		6.3.3
		PARALLELISM		6.3.2
	LOCATION	POSITION **		7.2
		CONCENTRICITY		7.6.4
		SYMMETRY		7.7.2
	RUNOUT	CIRCULAR RUNOUT		9.4.1
		TOTAL RUNOUT		9.4.2
* Arrowheads may be filled or not filled ** May be related or unrelated				3.3.1

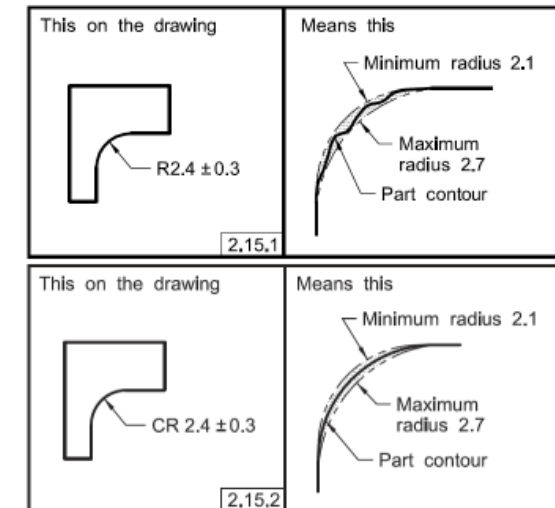
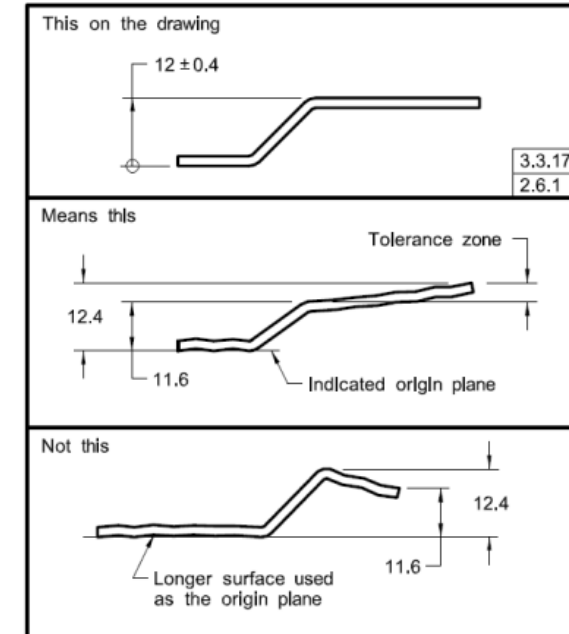


Modifying Symbols

TERM	SYMBOL	SEE:
AT MAXIMUM MATERIAL CONDITION (When applied to a tolerance value) AT MAXIMUM MATERIAL BOUNDARY (When applied to a datum reference)	\textcircled{M}	3.3.5
AT LEAST MATERIAL CONDITION (When applied to a tolerance value) AT LEAST MATERIAL BOUNDARY (When applied to a datum reference)	\textcircled{L}	3.3.5
TRANSLATION	\blacktriangleright	3.3.26
PROJECTED TOLERANCE ZONE	\textcircled{P}	3.3.6
FREE STATE	\textcircled{F}	3.3.20
TANGENT PLANE	\textcircled{T}	3.3.21
UNEQUALLY DISPOSED PROFILE	\textcircled{U}	3.3.22
INDEPENDENCY	\textcircled{I}	3.3.24
STATISTICAL TOLERANCE	\textcircled{ST}	3.3.10
CONTINUOUS FEATURE	\textcircled{CF}	3.3.23
DIAMETER	\varnothing	3.3.7
SPHERICAL DIAMETER	$S\varnothing$	3.3.7
RADIUS	R	3.3.7
SPHERICAL RADIUS	SR	3.3.7



CONTROLLED RADIUS	CR	3.3.7
SQUARE	\square	3.3.16
REFERENCE	()	3.3.8
ARC LENGTH	\frown	3.3.9
DIMENSION ORIGIN	$\oplus \rightarrow$	3.3.17
BETWEEN	\longleftrightarrow	3.3.11
ALL AROUND	$\rightarrow \oplus$	3.3.19
ALL OVER	$\rightarrow \oplus \rightarrow$	3.3.25



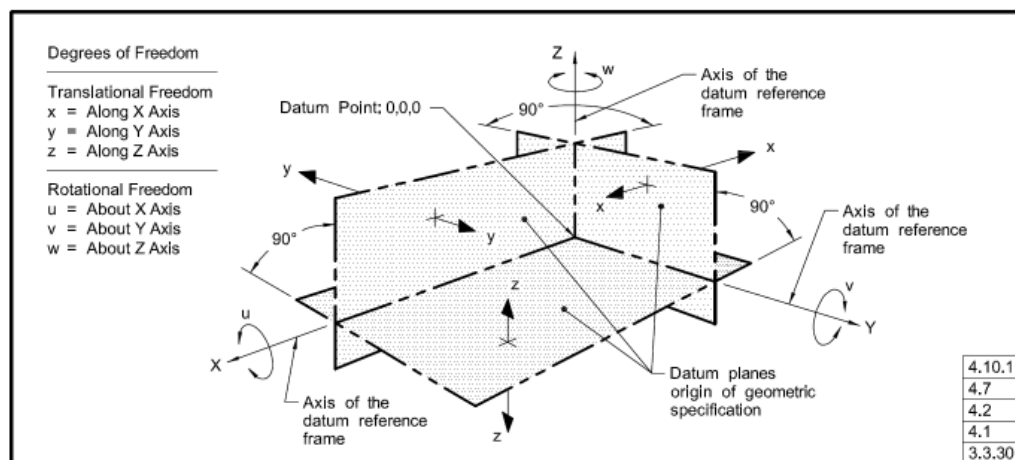


Datums & Datum Features

Datum: a theoretically exact point, axis, line, plane, or combination thereof derived from the theoretical datum feature simulator.

Datum Feature: a feature that is identified with either a datum feature symbol or a datum target symbol.

Datum Feature Simulator: the physical boundary used to establish a simulated datum from a specified datum feature.

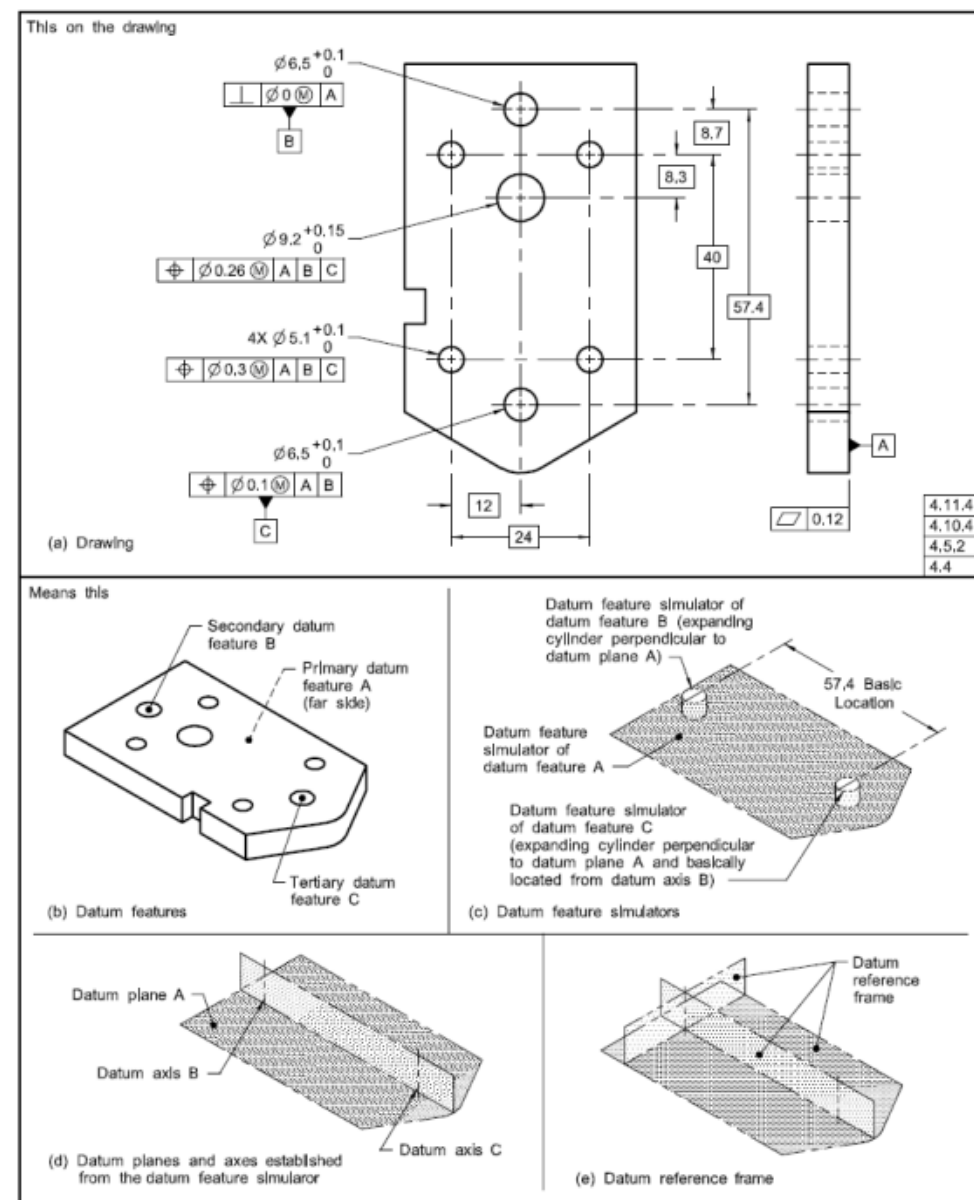
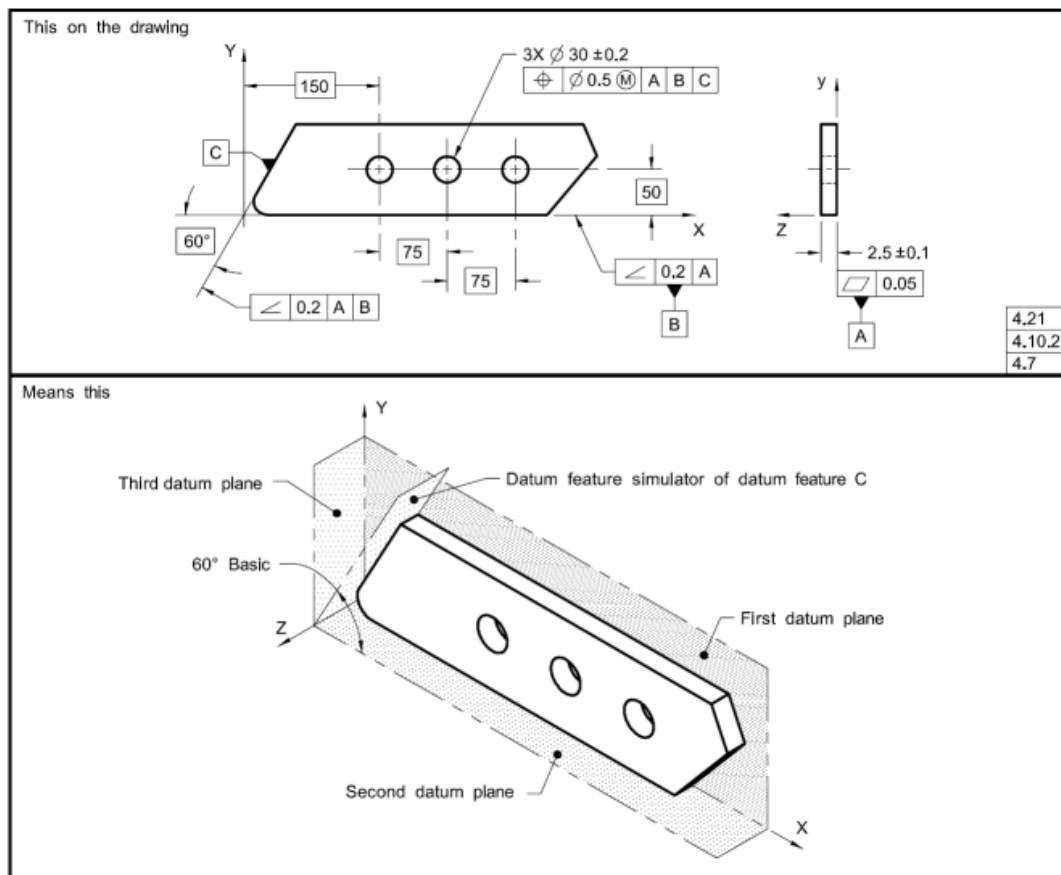


FEATURE TYPE	ON THE DRAWING	DATUM FEATURE	DATUM AND DATUM FEATURE SIMULATOR	DATUM AND CONSTRAINING DEGREES OF FREEDOM
PLANAR (a)				
WIDTH (b)				
SPHERICAL (c)				
CYLINDRICAL (d)				
CONICAL (e)				
LINEAR EXTRUDED SHAPE (f)				
COMPLEX (g)				<div>4.23 4.3 4.11.4 4.2</div>



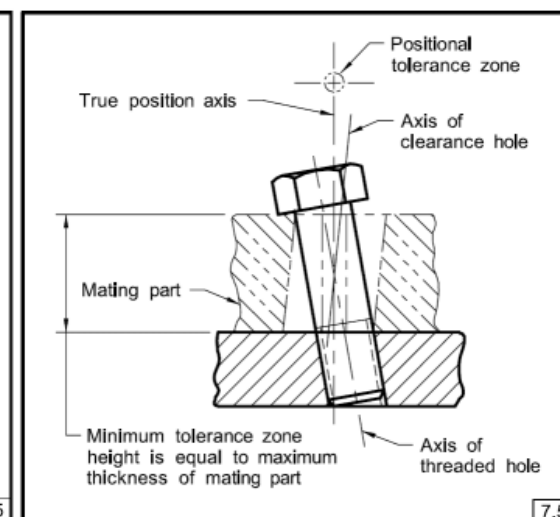
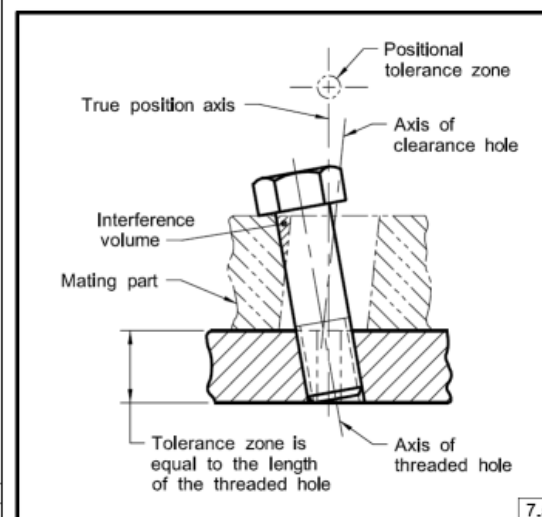
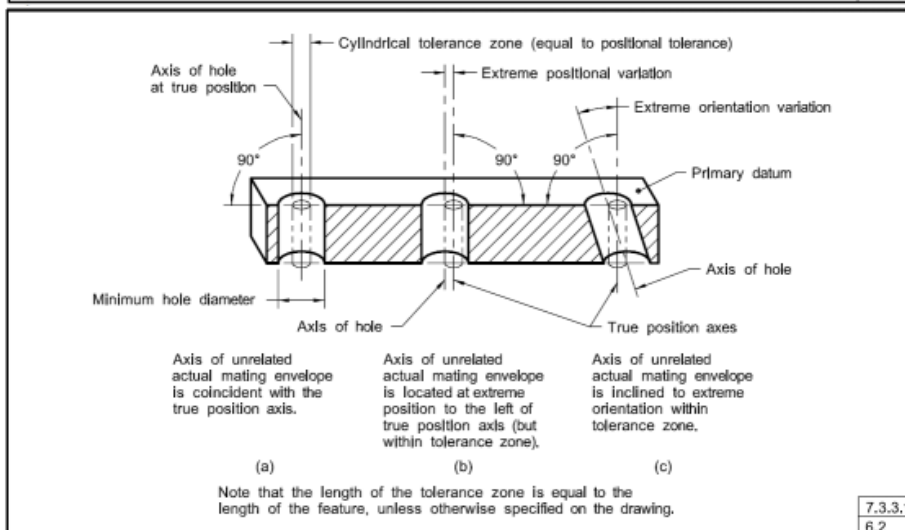
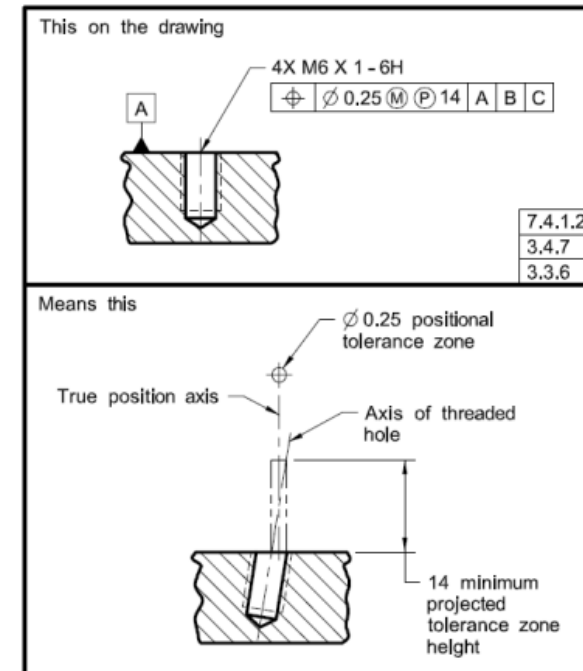
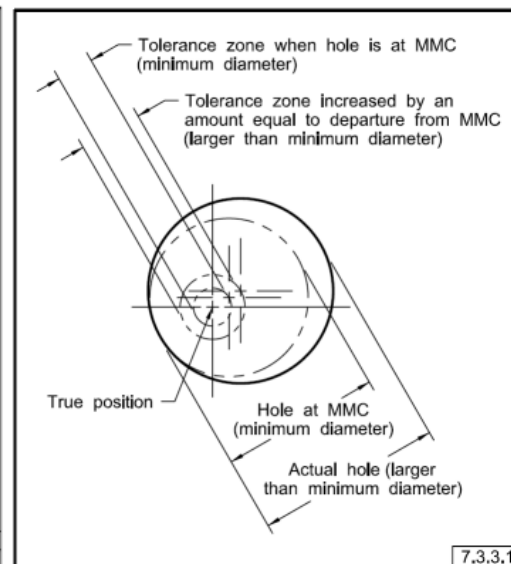
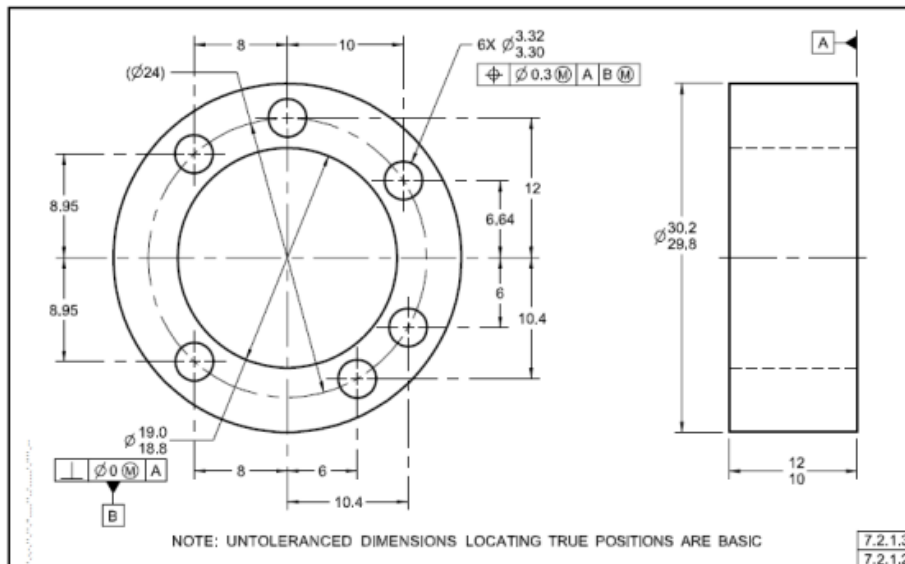
Developing Datum Reference Frame

1. Identify datum features.
2. Relate (control) datum features to each other.
3. Locate surfaces and features of size.
4. Refine orientation and form if necessary.





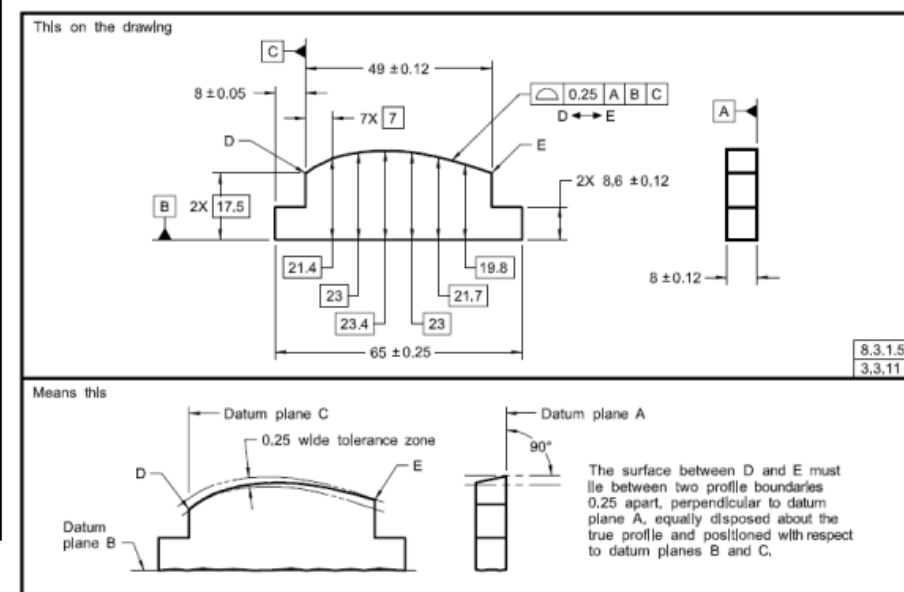
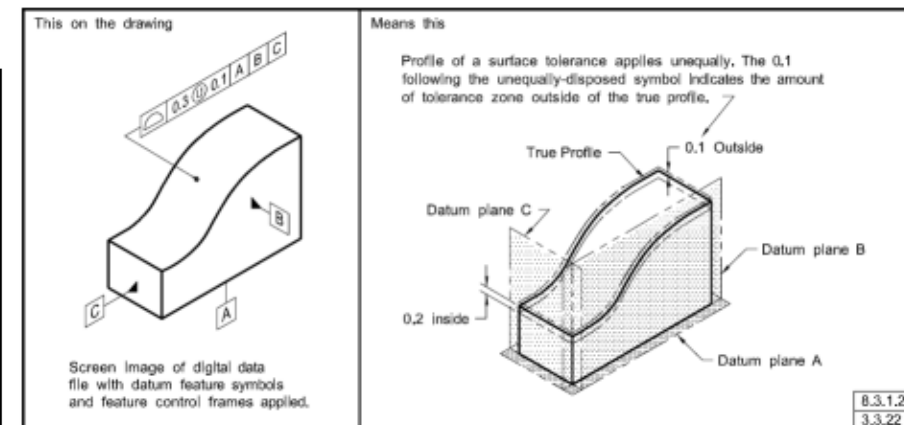
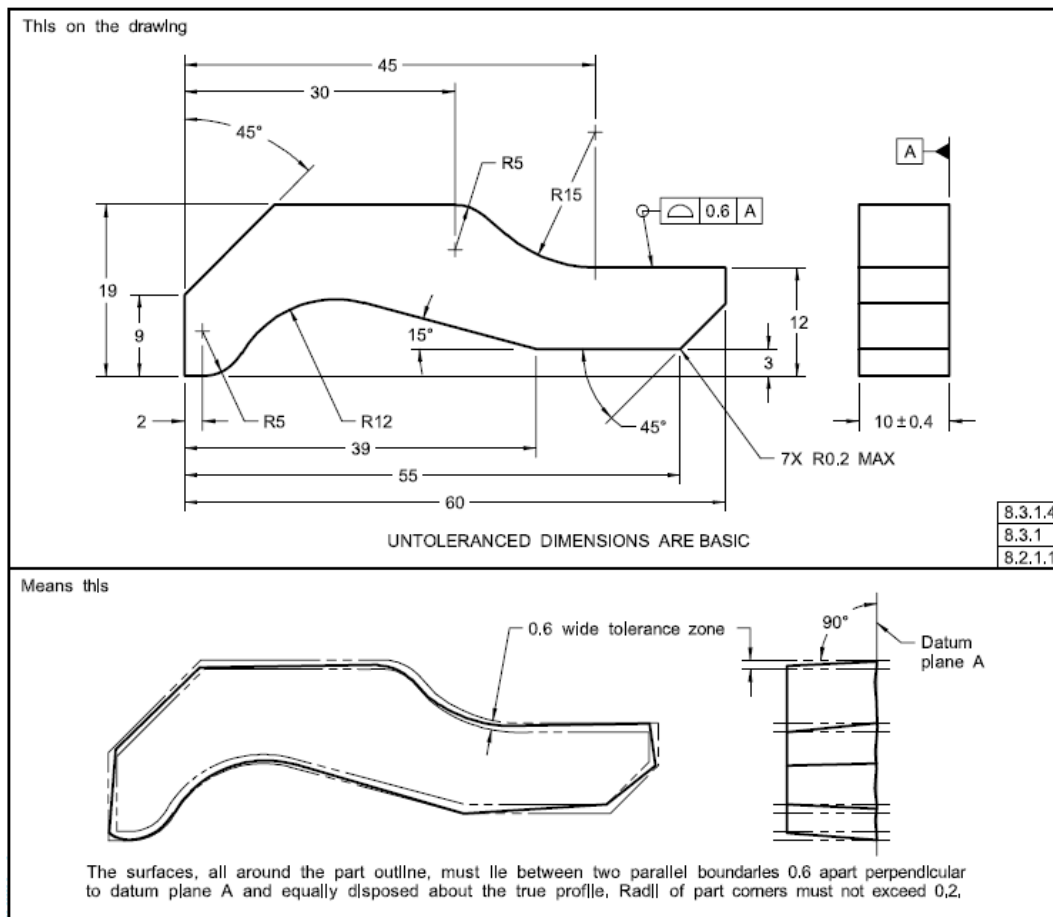
Position (Location)



Formulas for positional tolerances.
Fixed: $T = (H - F)/2$ Floating: $T = H - F$



Profile of a Surface



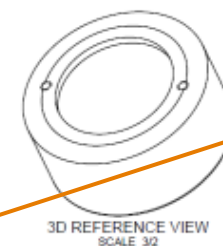
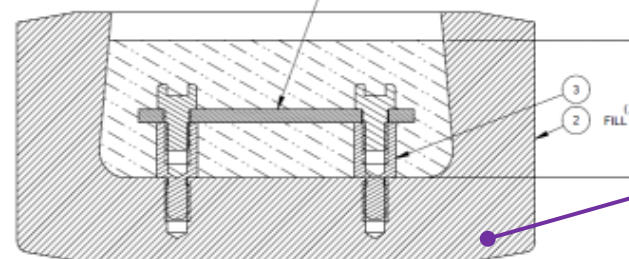
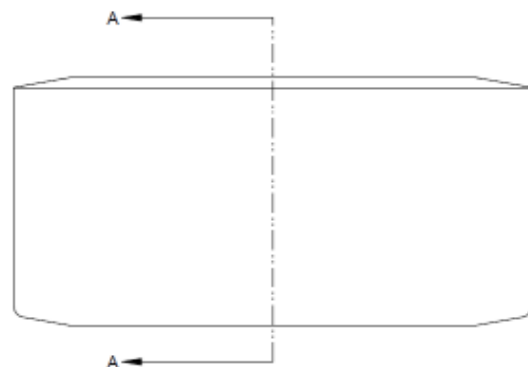
Unequally disposed profile tolerance always adds material.



Assembly Drawing

Assembly Instructions

- NOTES:
1. GENERAL REQUIREMENTS PER 9900000.
 2. ENCAPSULATE PER 9927085.
 - 2.1 USE THE FOLLOWING CURE SCHEDULE:
 - 2.1.1 PRESSURIZE TO 70-90 PSIG IN 20 MINUTES MAXIMUM.
 - 2.1.2 HOLD AT 25 10 C FOR 2 HOURS MINIMUM AND 24 HOURS MAXIMUM.
 - 2.1.3 RAISE THE TEMPERATURE LINEARLY TO 50 6 C IN 2 HOURS 30 MINUTES.
 - 2.1.4 HOLD THE CURE TEMPERATURE AT 50 6 C FOR 12 HOURS 30 MINUTES.
 - 2.1.5 RAISE THE TEMPERATURE LINEARLY TO 71 6 C IN 5 HOURS 30 MINUTES.
 - 2.1.6 HOLD THE CURE TEMPERATURE AT 71 6 C FOR 5 HOURS 30 MINUTES.
 - 2.1.7 RAMP DOWN TO 25 10 C IN 30 MINUTES MINIMUM AND 24 HOURS MAXIMUM.
 - 2.1.8 REDUCE THE PRESSURE TO 0-5 PSIG IN 20 MINUTES MAXIMUM.
- ENSURE POTTING EXCEEDS FILL HEIGHT.



BOM
Balloons

Flag notes

Section, detail views. Never explode.

SAND2018-10316 O
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CURRENT ISSUE APPROVALS

DRAWN: S. CURTIS / 02627	15-JUN-2018
CHECKED: C. WHITE / 02627	
DESIGNED: S. CURTIS / 02627	
APPROVED: C. HETTLER / 02627	

MODEL AND DRAWING IDENTIFICATION INFORMATION

DRAWING: J45482-UNC A	MODEL: J45482-000-UNC A	TYPE: ASSEM
-----------------------	-------------------------	-------------

1	828-DEA-GMB	ENCAPSULATION			5
4	95868a255	SCH. 112-40UNC-2A, 188 L. NYLON, MCMASTER			4
4	92745A371	POST ELEC.MIF, 112-40 X .25 L, 188 HEX, NYLON, MCMASTER			3
1	J45483-000	HOUSING			2
1	J45486-100	PRINTED CIRCUIT BOARD			1
NA	9927085	ENCAPSULATION, GLASS MICROSPHERE-FILLED EPOXY			
NA	9900000	GENERAL REQUIREMENTS			
NO REQ					
PART CONTROL NO.					
QUANTITY	NA = NO QUANTITY FOR DOCUMENTS	PM = PROCESS MATERIAL	AR = AS REQUIRED	NOTE	SHEET
ABBREVIATIONS	ALT = ALTERNATE	REQ = EXCESSIVE MATERIAL	AND = AS REQUIRED FOR ASSEMBLY	ZONE	ITEM
SANDIA NATIONAL LABORATORIES					
J45482-000					
ENGLISH					
UNCLASSIFIED					
UNCLASSIFIED					
CREO PARAMETRIC					
THIRD ANGLE PROJECTION					
(U) ASSEMBLY, TEST ARTICLE					
SIZE D					
DRAWING NUMBER J45482					
PAGE 14213 SCALE 4/1					
SHEET 1 OF 1					
STATUS SA - REL - 15-JUN-2018					



3D Print Drawing

Do not
inspect
tolerances

Reference
Dimensions

4 UNCLASSIFIED 3 2 1 UNCLASSIFIED

NOTES:

1. GENERAL REQUIREMENTS PER 9900000.
2. MARK PART NUMBER PER 9919100, CLASS H1.
3. SUPPORT MODEL REPRESENTS NOMINAL GEOMETRY PER 9925016.
4. PART DESIGNED TO BE 3D PRINTED VIA ADDITIVE MANUFACTURING. ALL DIMENSIONS MAY BE HELD TO PRINTER TOLERANCES AND ARE NOT INSPECTABLE.

3D REFERENCE VIEW
SCALE 5/1

(.450) (.225) (.125) (.325) (R.063) (.400)

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CURRENT ISSUE APPROVALS

DESIGNED: C. WHITE / 2627	25-JUL-2018
CHECKED: S. CURTIS / 2627	
DESIGNED: C. WHITE / 2627	
APPROVED: C. HETTLER / 2627	

MODEL AND DRAWING IDENTIFICATION INFORMATION

DRAWING: J59475-UNC A	TYPE: PART
MODEL: J59475-000-UNC A	

AR	SH-J59475-000	SUPPORT MODEL, BRACKET, LEFT			
ARS	ABSplus	THERMOPLASTIC, FUSED DEPOSITION MODELING			
NA	9925016	IDENTIFICATION, SUPPORT MODEL, 3D CAD PART			
NA	9919100	MARKING, GENERAL METHODS			
NA	9900000	GENERAL REQUIREMENTS			
NO	NO	PART CONTROL NO	DESCRIPTION/MATERIAL	NOTE	CHG
QUANTITY	NA - NO QUANTITY FOR DOCUMENTS	PI - PROCESS MATERIAL	AR - AS REQUIRED		
ABBREVIATIONS	ALT - ALTERNATE	EN - EXPENSE MATERIAL	ARE - AS REQUIRED FOR ASSEMBLY		
SANDIA NATIONAL LABORATORIES P.O. BOX 5800 ALBUQUERQUE, NM 87116		(U) BRACKET, LEFT			
ENGLISH		UNCLASSIFIED			
THIRD ANGLE PROJECTION		UNCLASSIFIED			
		QTY	D	DRAWING NUMBER	ISSUE
		CNDR	14213	SCALE 9/1	J59475 A
		STATUS	SA	REL	25-JUL-2018

4 UNCLASSIFIED 3 2 1 UNCLASSIFIED



References

- ASME Y14.5-2009, Dimensioning and Tolerancing
- Pat McQuiston, Geometric Dimensioning and Tolerancing (GD&T)
- Don Day, The GD&T Hierarchy Y14.5-2009, Tec-Ease Inc.



Questions?