AGI and CAM Logic Present:

Geometric Dimensioning & Tolerancing
(GD&T– an Overview)

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Geometric Dimensioning and Tolerancing

GD&T

A Means of Dimensioning and Tolerancing a Part With Respect to **Relationship** and **Function**

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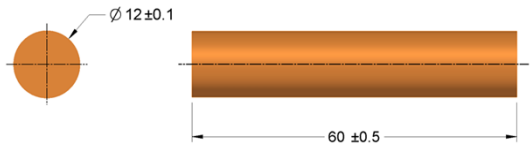
The Simplest Drawing In The World



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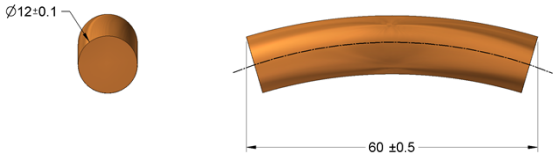
The Problem with The Simplest Drawing



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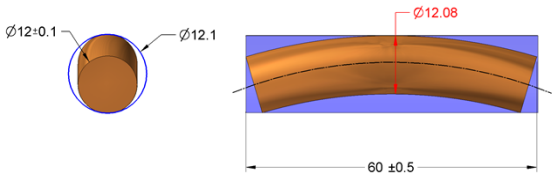
The ASME Y14.5 Interpretation



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Mil-Std. 8 1949 Established Rule #1

- Unless otherwise specified, the limits of size of an individual feature of size control the form of the feature as well as the size.

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What can be controlled?

- Size
- Form
- Orientation
- Location

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Size Controls

- Features of size are usually controlled with nominal dimensions and size tolerances – plus or minus tolerancing.
- It is also possible, and even desirable in some instances, to control size using basic dimensions (for "nominal" size) and defining a profile tolerance zone for the tolerancing.

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Form Controls

- Flatness ----------
- Straightness ----------
- Cylindricity ----------
- Circularity ----------

Form controls define the tolerances for the shape of features.

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Orientation Controls

- Perpendicularity ----------
- Angularity ----------
- Parallelism ----------

Orientation controls define the tolerances for the shape of features relative to datums.

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Orientation Controls

All orientation controls are essentially the same.
Perpendicularity is angularity at 90°
Parallelism is angularity at 0°

Note that each of these things COULD be controlled using Profile (but don't if you don't need to do so).

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Location Controls

- Position ----------
- Concentricity ----------
- Symmetry ----------

Location controls are relational controls.

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Location Controls

Concentricity and Symmetry are often misunderstood by people from Design to Manufacturing to Inspection. Take special care to understand these controls so that you actually measure the data set that the print requires.

The ASME Y14.5 standard states that these controls should be avoided and Position or Runout used instead.

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Combination Controls

- Total Runout ----------
- Circular Runout ----------
- Profile of a surface ---------
- Profile of a line ----------

Profile can be used as a combination control or just a form control.

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Basic Dimension

- A numerical value used to describe the theoretically exact size, profile, orientation or location of a feature or datum target. Basic Dimensions establish the perfect orientation and location (and sometimes the size of) tolerance zones within which variations are allowed.
- Basic dimensions perfectly **orient** and **locate** (and occasionally size) ***tolerance zones***.

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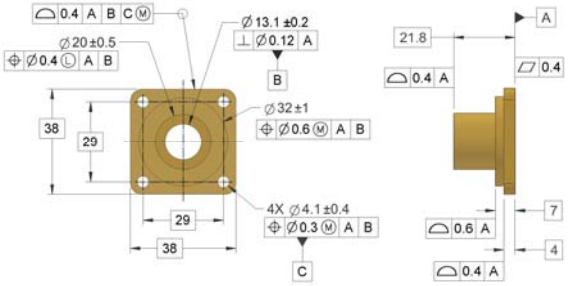
Three BASIC Dimension Methods



BASIC dimensions shown boxed

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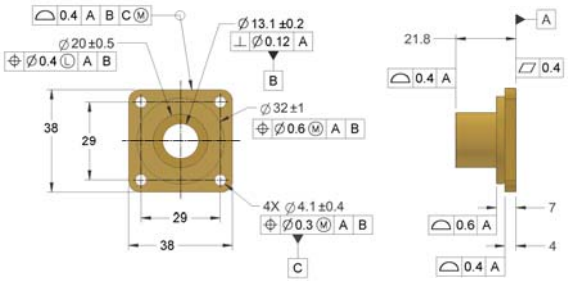
Three BASIC Dimension Methods



NOTE: UNTOLERANCED DIMENSIONS ARE BASIC

*When this method is used, a plus/minus general tolerance is not allowed.

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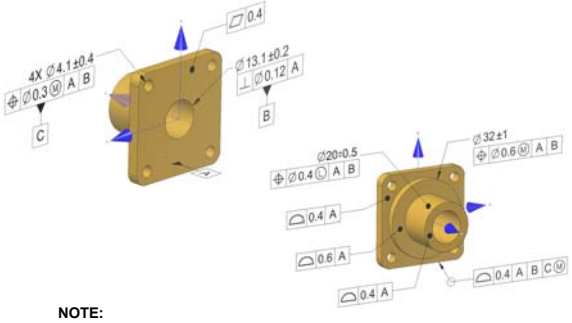
Three BASIC Dimension Methods



NOTE:
QUERY BASIC DIMENSIONS ON CAD MODEL PER ASME Y14.41-2012

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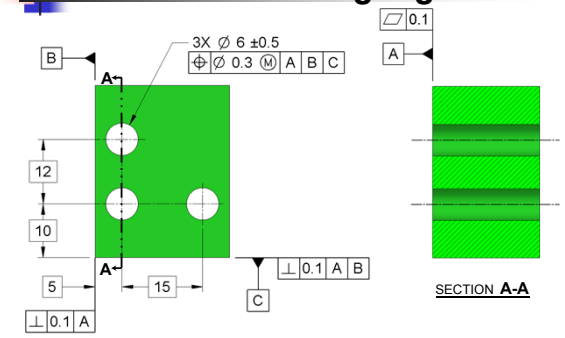
The GD&T Language



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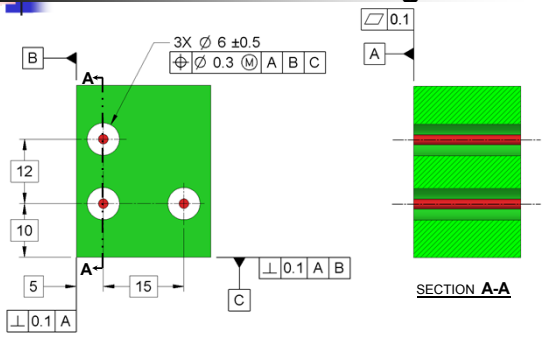
Tolerance Zone Length



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Reading a Feature Control Frame

1. What is the size of the tolerance zone?
2. What is the shape of the tolerance zone?
3. What is the orientation of the tolerance zone?
4. What is the location of the tolerance zone?
5. What entity must lie within the tolerance zone?

This is our method for "reading" the information that was "written" by the designer. Consider it a checklist to help you understand what you are to measure as an inspector.

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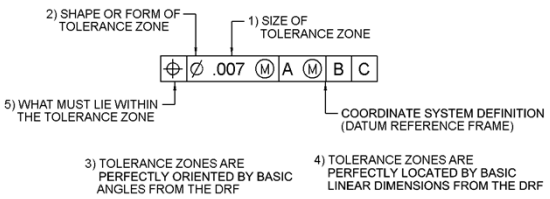
Reading a Feature Control Frame



Read Inside Out

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What must lie within?

- The key concept to understand with any one of the GD&T symbols is that the definition of each symbol answers the question, "What entity must lie within the tolerance zone?"
  - What is the significance of the answer to this question; to the inspector – EVERYTHING!
  - The ability to successfully answer that question means that you, as the inspector, understand the data set you are seeking – i.e. what you need to measure
  - The answer will always be one of the following: a point; a collection of points (e.g. a surface or a derived median line or derived median plane); an axis; or a plane.

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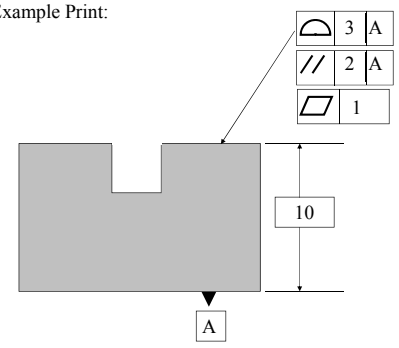
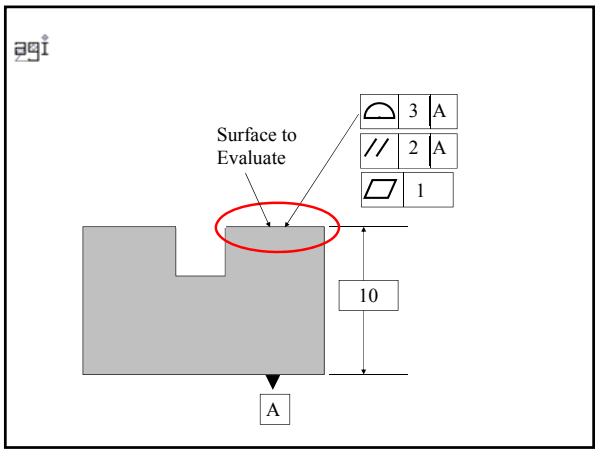
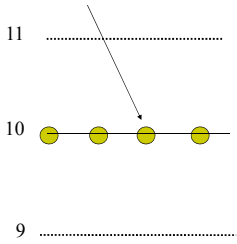
Example Print:





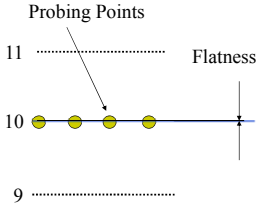
Flatness

Actual Probing
Points



Flatness

Actual
Probing Points



Why The Answer?

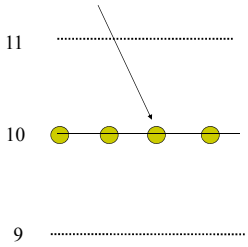
For a plane, if all points lay on a perfectly flat plane, regardless of orientation or position, the result will be zero.

A perfect form result is zero.

Flatness = 0

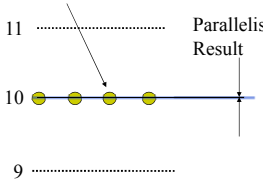
Parallelism

Actual Probing
Points



Parallelism

Actual
Probing Points



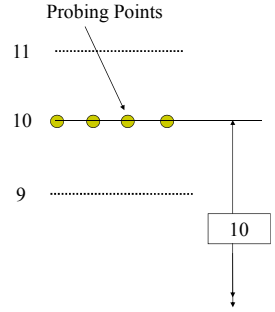
Why The Answer?

If all the points lay in a perfectly flat plane AND that plane is perfectly oriented to match the datum, the result will be zero.

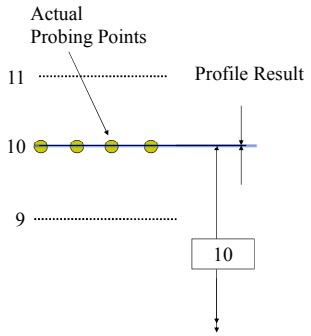
Parallelism = 0

Profile

Actual
Probing Points



Profile



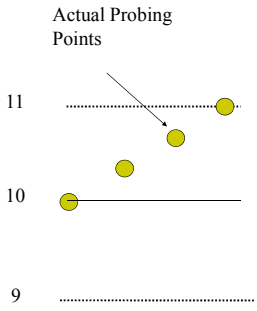
Why The Answer?

Since Profile is the thickness of a zone centered on the nominal geometry, if all measured points are exactly on the nominal, the thickness of the zone would be zero.

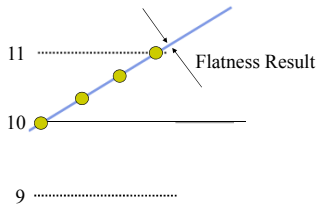
A perfect Profile result is zero.

Profile = 0

Flatness



Flatness



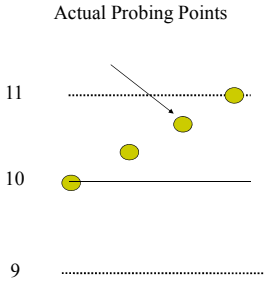
Why The Answer?

For a plane, if all points lay on a perfectly flat plane, regardless of orientation or position, the result will be zero.

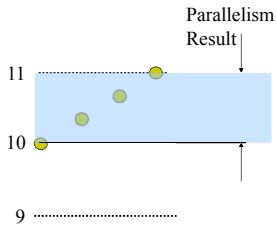
A perfect form result is zero.

Flatness = 0

Parallelism



Parallelism



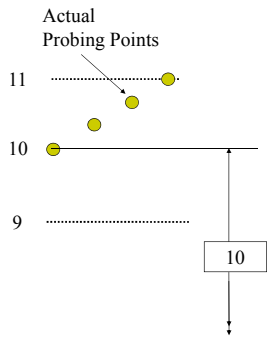
Why The Answer?

In this case, a perfectly flat plane shows Parallelism deviation due to the angle of the plane relative to the Datum.

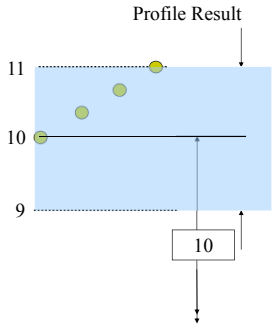
The result is the distance between two planes, parallel to the datum, that contains all the measured points.

Parallelism = 1

Profile



Profile

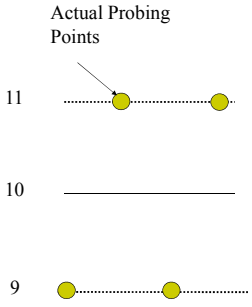


Why The Answer?

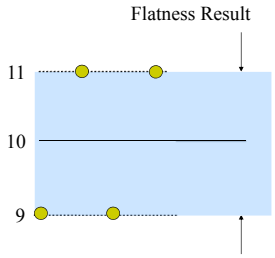
Since Profile is the thickness of a zone centered on the nominal geometry, the result will be two times the distance of the most distant point from the nominal geometry.

Profile = 2

Flatness



Flatness

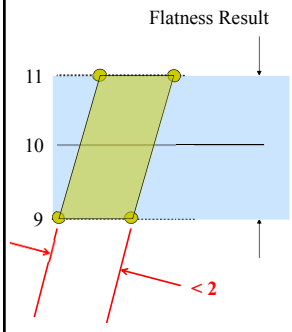


Why The Answer?

In this case, the distance between two perfect planes parallel to each other that contain the measured points is 2.0.

Flatness = 2

Flatness

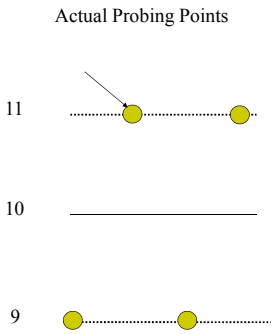


Why The Answer?

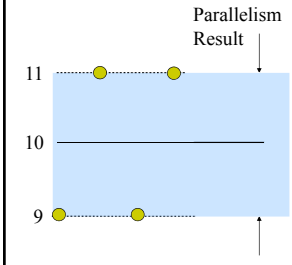
In this case, the distance between two perfect planes parallel to each other that contain the measured points is something less than 2mm.

Flatness < 2

Parallelism



Parallelism



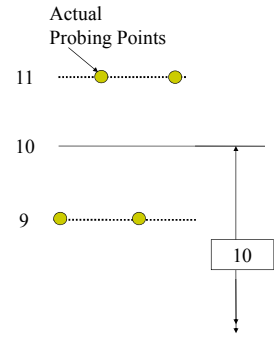
Why The Answer?

In this case, a plane which is perfectly parallel to the datum shows a high amount of parallelism deviation. This is because of the form error of the feature.

The result is the distance between two planes, parallel to the datum, that contains all the measured points.

Parallelism = 2

Profile



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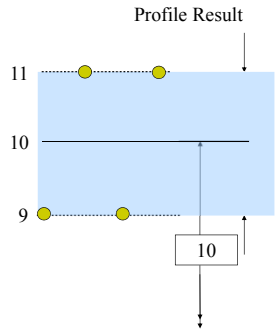


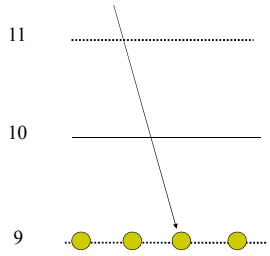
Why The Answer?

Since Profile is the thickness of a zone centered on the nominal geometry, the result will be two times the distance of the most distant point from the nominal geometry.

Profile = 2

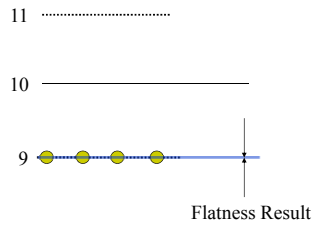
Flatness

Actual Probing Points



Flatness

Why The Answer?



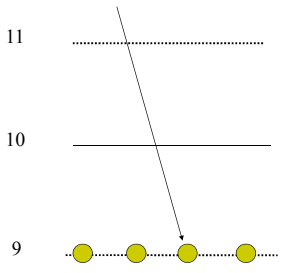
For a plane, if all points lay on a perfectly flat plane, regardless of orientation or position, the result will be zero.

A perfect form result is zero.

Flatness = 0

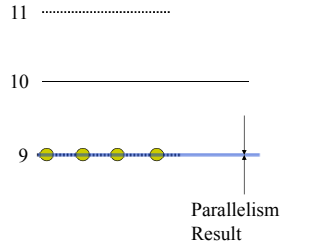
Parallelism

Actual Probing Points



Parallelism

Why The Answer?

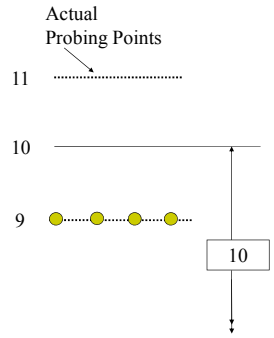


If all the points lay in a perfectly flat plane, perfectly oriented to match the datum, the result will be zero.

Note that position error does not effect the Parallelism result.

Parallelism = 0

Profile



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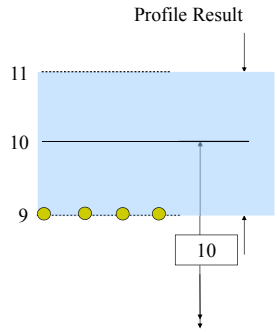
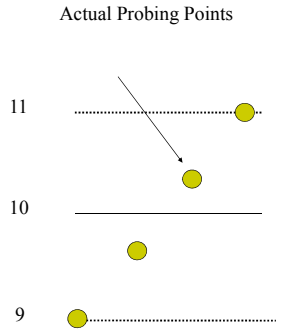


Why The Answer?

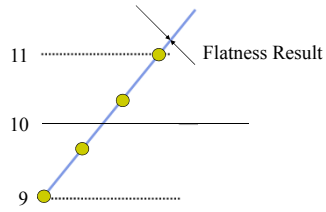
Since Profile is the thickness of a zone centered on the nominal geometry, the result will be two times the distance of the most distant point from the nominal geometry.

Profile = 2

Flatness



Flatness



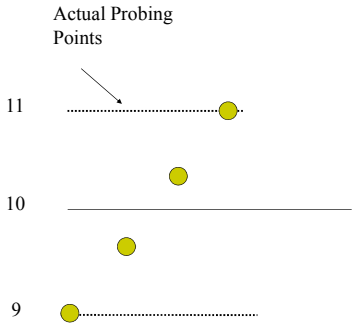
Why The Answer?

For a plane, if all points lay on a perfectly flat plane, regardless of orientation or position, the result will be zero.

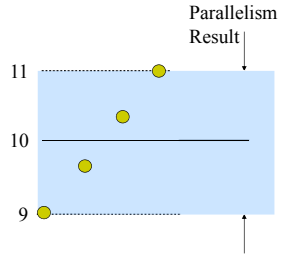
A perfect form result is zero.

Flatness = 0

Parallelism



Parallelism



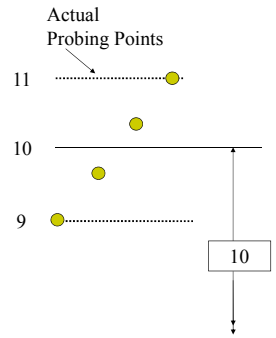
Why The Answer?

In this case, a perfectly flat plane shows Parallelism deviation due to the angle of the plane relative to the Datum.

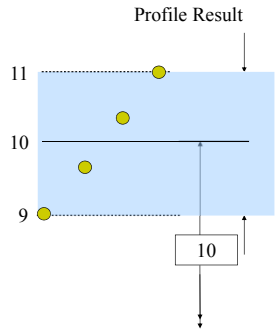
The result is the distance between two planes, parallel to the datum, that contains all the measured points.

Parallelism = 2

Profile



Profile



Why The Answer?

Since Profile is the thickness of a zone centered on the nominal geometry, the result will be two times the distance of the most distant point from the nominal geometry.

Profile = 2

Profile:

- **Definition:** Profile tolerancing is a method used to specify a uniform amount of variation of a surface or line elements of a surface.
- **Tolerance Zone:** Profile tolerance specifies a tolerance zone confined by two equidistant profiles within which the entire surface must lie.

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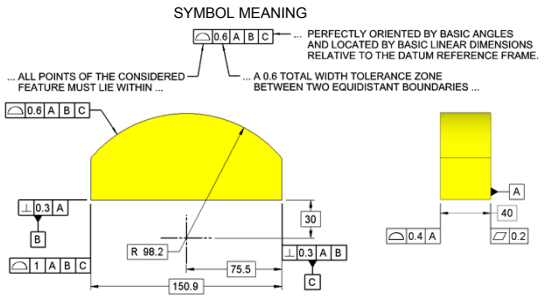
Profile

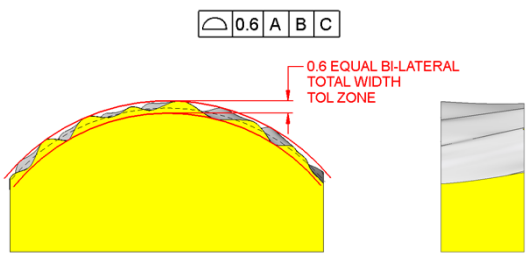
(Surface and Line)



Applied Geometrics Inc. Copyright

Profile

(Surface and Line)



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Unequally & Unilateral Disposed Tolerance Zones

- For an unequally disposed profile tolerance zone a basic dimension is added to illustrate the tolerance zone distribution.
- For a unilateral disposed profile tolerance zone a single phantom curve is shown either inside or outside of the material.

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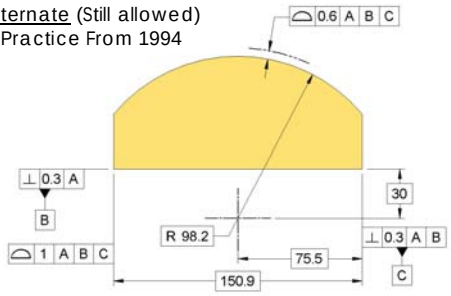
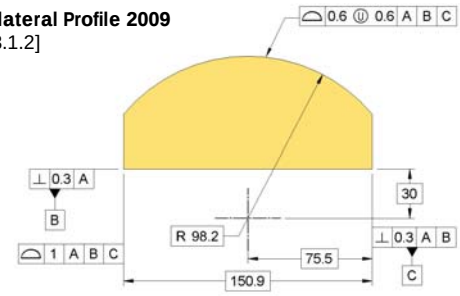
Unilateral Profile
Alternate (Still allowed)
Practice From 1994



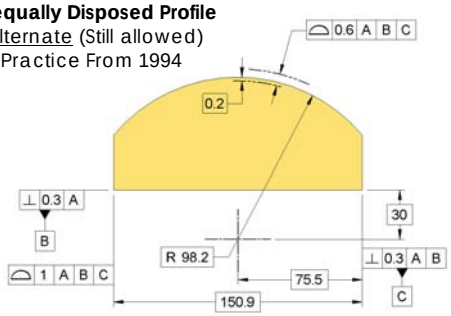
Applied Geometrics Inc. Copyright

Unilateral Profile 2009
[8.3.1.2]



Applied Geometrics Inc. Copyright

Unequally Disposed Profile
Alternate (Still allowed)
Practice From 1994



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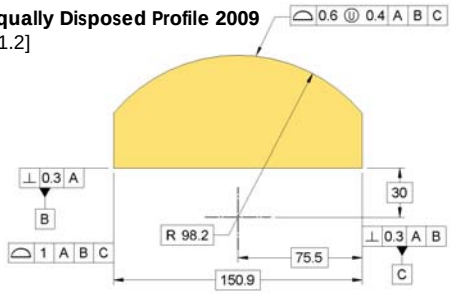
Unequally Disposed Profile 2009
[8.3.1.2]



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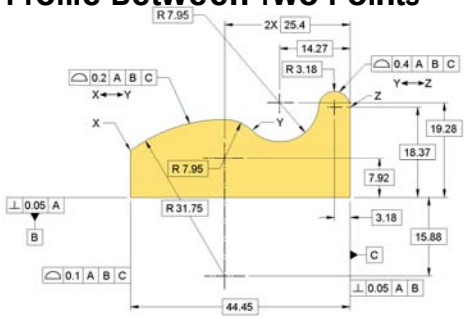
Profile Between Two Points

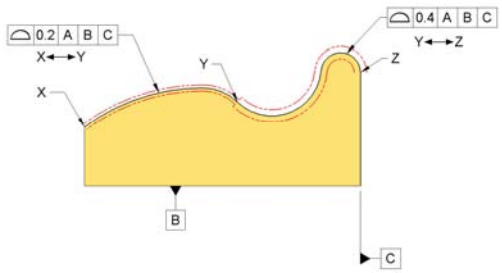
- A Symbol (# ⟷ #) is used to indicate a tolerance applies to a limited segment of a surface between designated extremes.

Applied Geometrics Inc. Copyright

Profile Between Two Points

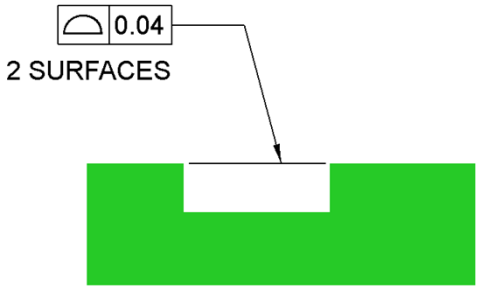


Applied Geometrics Inc. Copyright



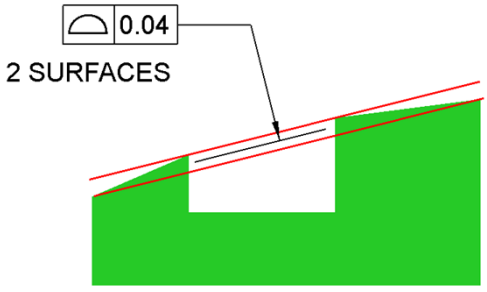
Applied Geometrics Inc. Copyright

Profile Can Control Co-planarity



Applied Geometrics Inc. Copyright

Profile Can Control Co-planarity



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Technical Terminology – ASME

- **Datum**
- **Datum Feature**
- **Theoretical Datum Feature Simulator**
  - **Formerly "True Geometric Counterpart"**
- **Physical Datum Feature Simulator**
- **Simulated Datum**

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Technical Terminology – ASME

- **Datum - Theoretical, Perfect**
- **Datum Feature - Real, Imperfect**
- **Theoretical Datum Feature Simulator**
- **Physical Datum Feature Simulator - Real**
  - Best approximation of the TDFS
- **Simulated Datum - Real (Derived from real)**
  - Best approximation of the Datum

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Datum – ASME

- A theoretically exact point, axis, plane or combination thereof derived from the theoretical datum feature simulator and the specified datum feature.
- A datum is the origin from which the location or geometric characteristics of features of a part are established.

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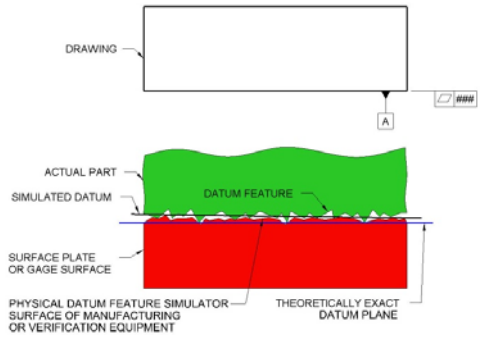
Datum Theory vs. Reality



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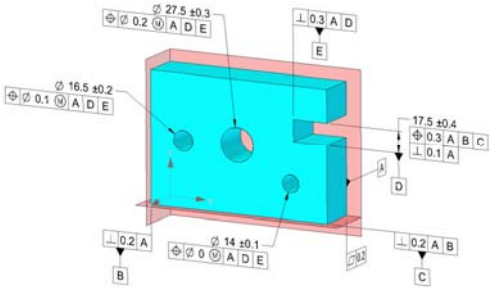
Theoretical Datum Feature Simulators
A|B|C

(Datums in This Example)



Formally "True Geometric Counterpart" in 1994

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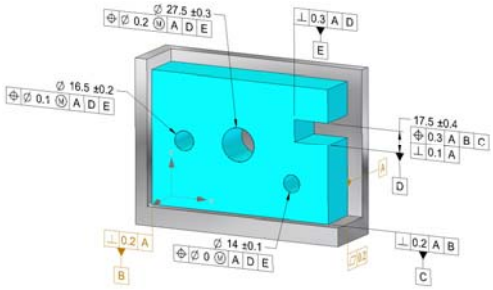
Physical Datum Feature Simulators
A|B|C



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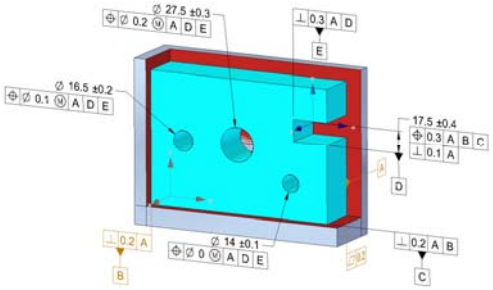
Simulated Datum Planes



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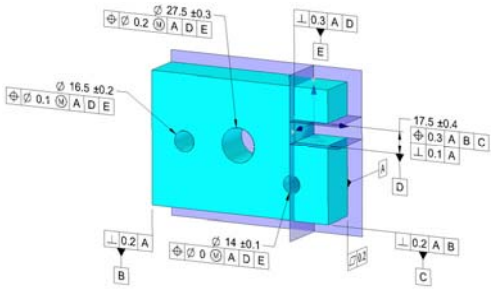
Theoretical Datum Feature Simulators
A|D|E



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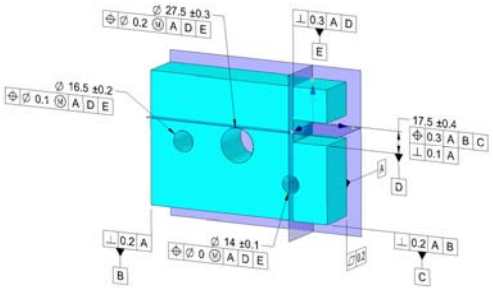
Theoretical Datum Planes
A|D|E



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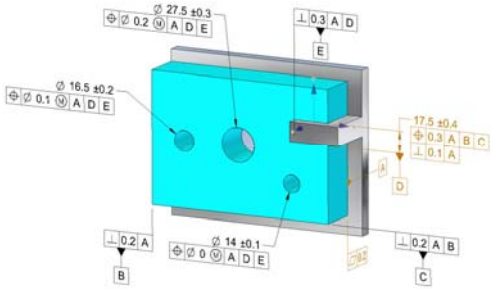
Physical Datum Feature Simulators A|D|E



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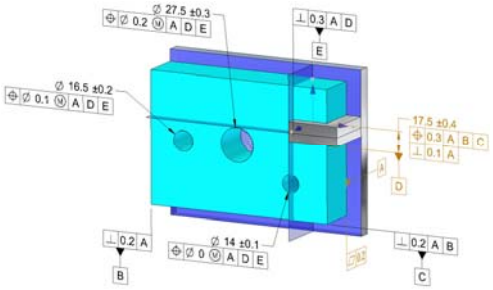
Simulated Datum Planes



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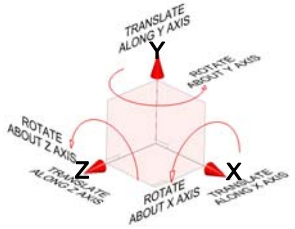
Degrees of Freedom

- There are six degrees of freedom.
  - Three degrees of rotation
  - Three degrees of translation



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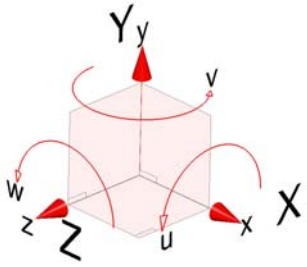
Axis and Degrees of Freedom Labels



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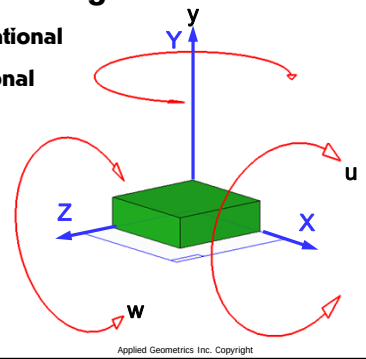
Planar Features Can Constrain 3 Degrees of Freedom

1 Translational

2 Rotational



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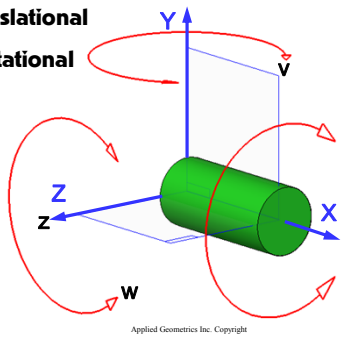
Pins & Holes Can Constrain 4 Degrees of Freedom

- 2 Translational
- 2 Rotational



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In *Reality*, Can / May / Must

- **Physically Establishing a Datum Reference Frame**
  - If a Datum Feature ***CAN*** Stop a Particular D.O.F.,
  - ***AND*** that Datum Feature ***MAY*** Stop that D.O.F.,
  - Then that Datum Feature ***MUST*** Completely Stop that D.O.F.
    - (Unless Otherwise Specified – e.g. MMB)

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Maximum Material Condition

- Condition of a part feature wherein it contains the **maximum amount** of **material**.
- Symbol: Ⓜ
- Abbreviation: MMC
  - (MMB in the DRF)

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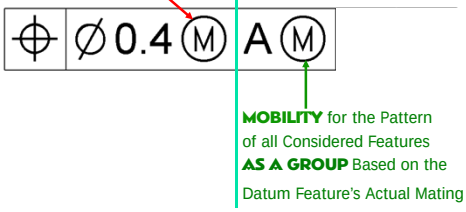
More vs. Mobility

MORE Positional Tolerance for **EACH CONSIDERED FEATURE** Based on the Actual Mating Size



MOBILITY for the Pattern of all Considered Features **AS A GROUP** Based on the Datum Feature's Actual Mating Size

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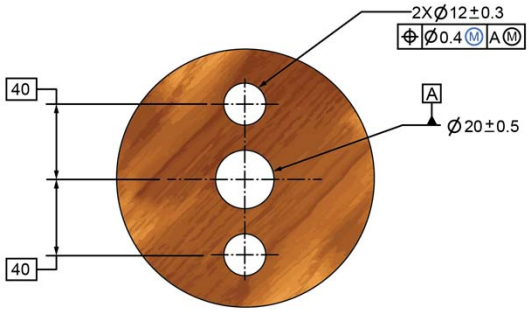
Considered Feature Bonus Tolerance Gives "MORE TOLERANCE" to Each Individual Considered Feature



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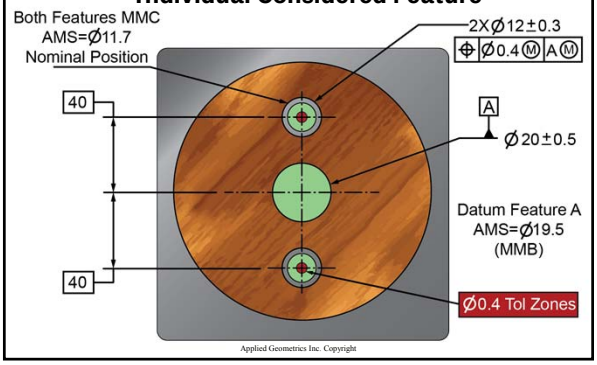
Considered Feature Bonus Tolerance Gives "MORE TOLERANCE" to Each Individual Considered Feature



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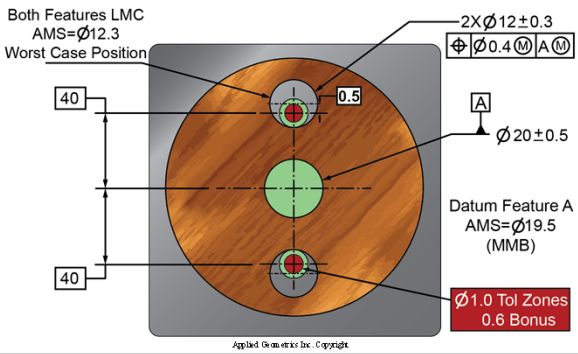
Considered Feature Bonus Tolerance Gives "MORE TOLERANCE" to Each Individual Considered Feature



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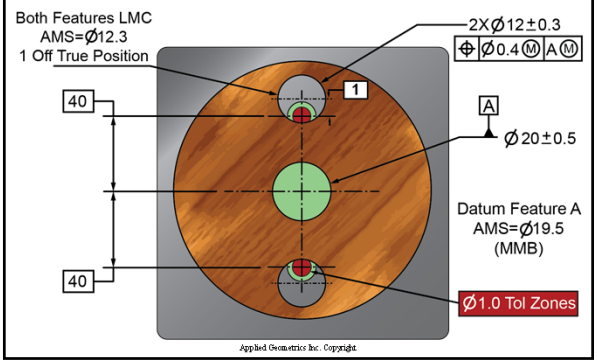
No "MOBILITY TOLERANCE" Available When Datum Feature A is at MMB



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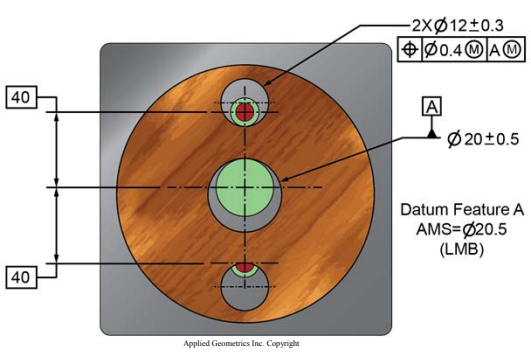
Potential "MOBILITY TOLERANCE" is NOT Simply Added to the Tolerance Value



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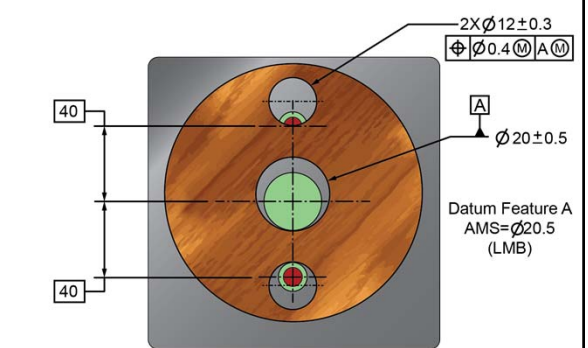
Potential "MOBILITY TOLERANCE" is NOT Simply Added to the Tolerance Value



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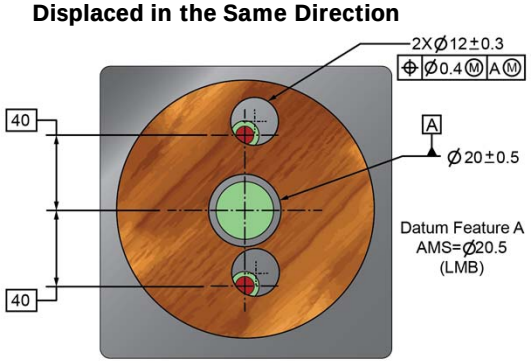
Maximum "Mobility" Tolerance is Realized When the Features of the Pattern are Displaced in the Same Direction



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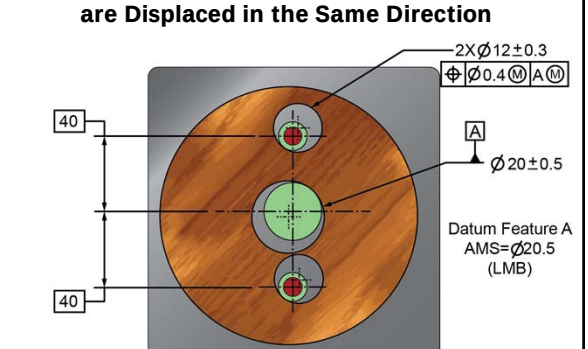
Maximum "Mobility" Bonus Tolerance is Realized When the Features of the Pattern are Displaced in the Same Direction



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Characteristics of "Maximum Material Modifiers"

- Allows **BONUS TOLERANCE**
  - Maximum allowable tolerances promotes **LOWEST MANUFACTURING COSTS!**
- Allows **FUNCTIONAL GAUGING**
- Allows **DATUM FEATURE SHIFT OR MOBILITY**
- Common Usage: **100% INTERCHANGEABILITY**
  - **Parts Assembled with Clearance Fits**
- Must apply to a Regular or Irregular **FEATURE OF SIZE**
  - MMB may be applied to a Surface Feature in certain scenarios.

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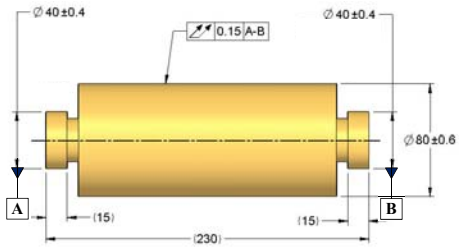
Datum Axis Definition
Two (or More) "Short" Diameters Sufficiently Separated



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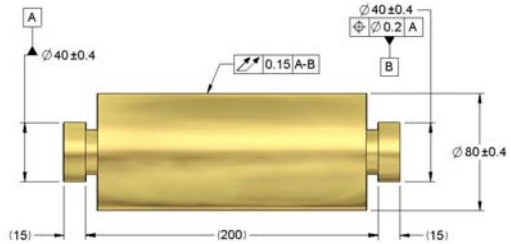
Coaxial Control
Positioning One Datum Feature To an Unconstrained Datum Feature Primary



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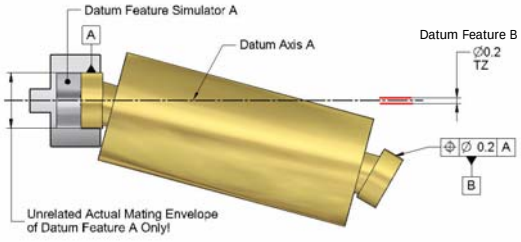
Coaxial Control
Positioning One Datum Feature To an Unconstrained Datum Feature Primary Means This



Datum Feature B Fails Position Requirement

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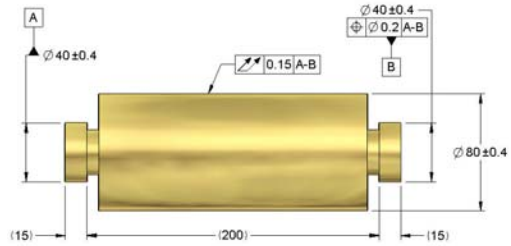
Coaxial Control
Position Datum Feature B Only to the A-B Axis



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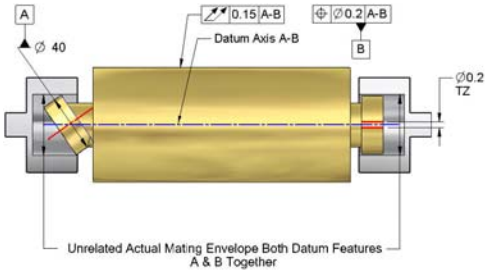
Coaxial Control
Position Datum Feature B Only to the A-B Axis Means This



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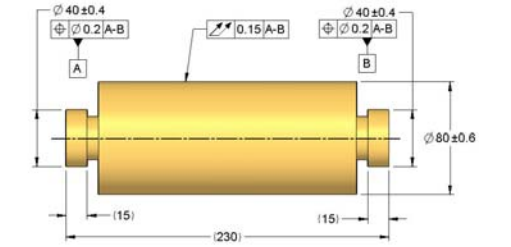
Coaxial Control
Best Practice to Specify Control to the A-B Axis



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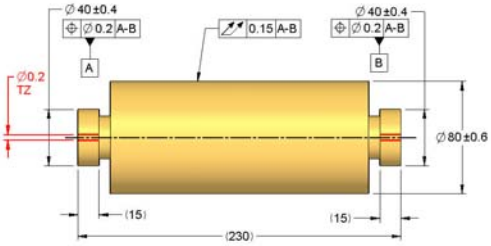
Coaxial Control

Locate and Orient TWO Tolerance Zones To the A-B Datum Axis



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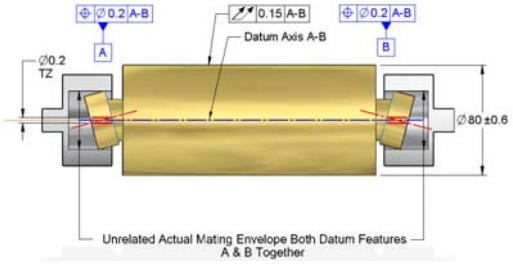
Coaxial Control

Coaxial Control to the A-B Axis MEANS THIS



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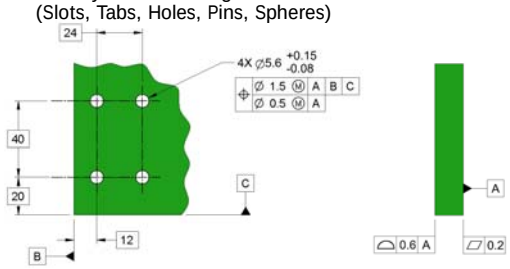
Composite Feature Control Frames

Composite Feature Control Frames Are Often Used to Control Patterns of Holes, But They Can Also Be Used For Any Pattern of Regular Features of Size. (Slots, Tabs, Holes, Pins, Spheres)



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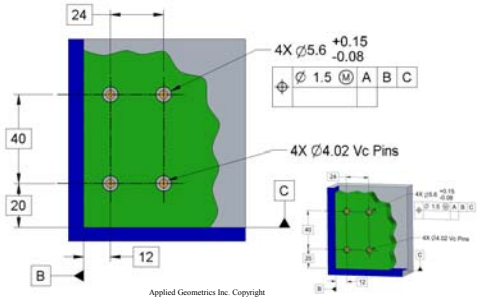
Composite FCF PLTZF

The PLTZF Controls the ***Location of the Pattern*** to the Datums Referenced in the Upper Tier of the Feature Control Frame.



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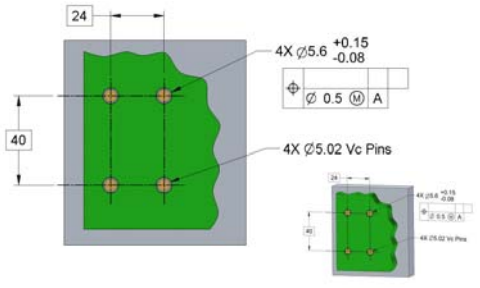
Composite FCF FRTZF - (One Datum)

The FRTZF Controls the Feature to Feature Relationships, And ***Orientation Only*** to the Datums Referenced in the Lower Tier of the Feature Control Frame.



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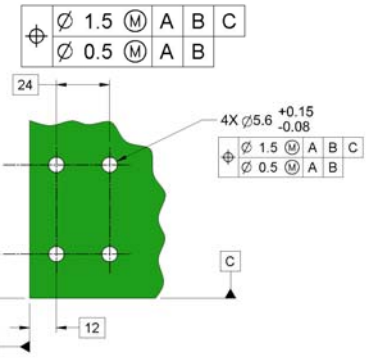
Composite FCF - (Two Datums)



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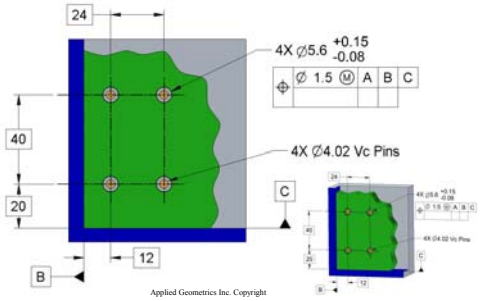
Composite FCF PLTZF

The PLTZF Controls the ***Location of the Pattern*** to the Datums Referenced in the Upper Tier of the Feature Control Frame.



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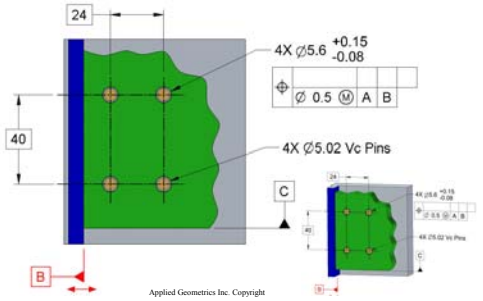
Composite FRTZF - (Two Datums)

The FRTZF Controls the Feature to Feature Relationships, And ***Orientation Only*** to the Datums Referenced in the Lower Tier of the Feature Control Frame.



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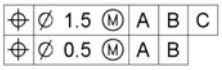
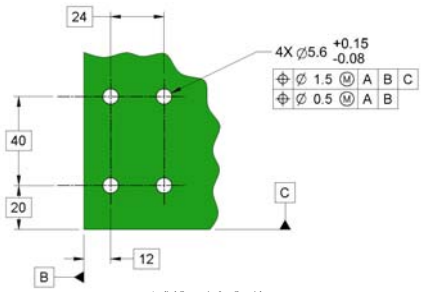
Multiple Single Segment FCF





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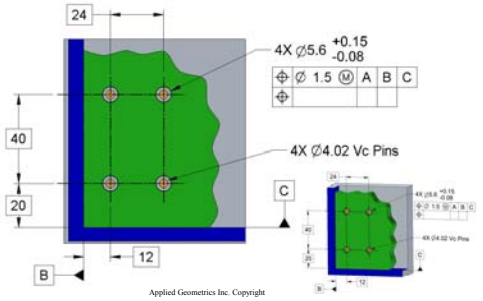
Multiple Single Segment FCF – PLTZF

The Top Tier Controls the ***Location of the Pattern*** to the Datums Referenced in the Upper Entry of the Feature Control Frame.



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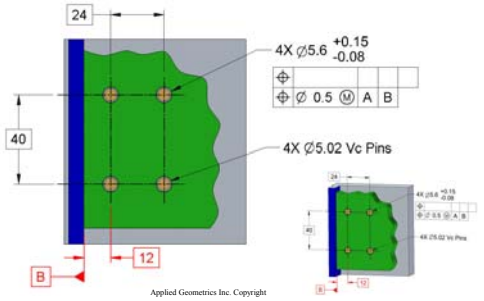
Multiple Single Segment FCF – FRTZF

The Lower Tier Controls the Feature to Feature Relationships, And ***Orientation & Location*** to the Datums Referenced in the Lower Entry of the Feature Control Frame.



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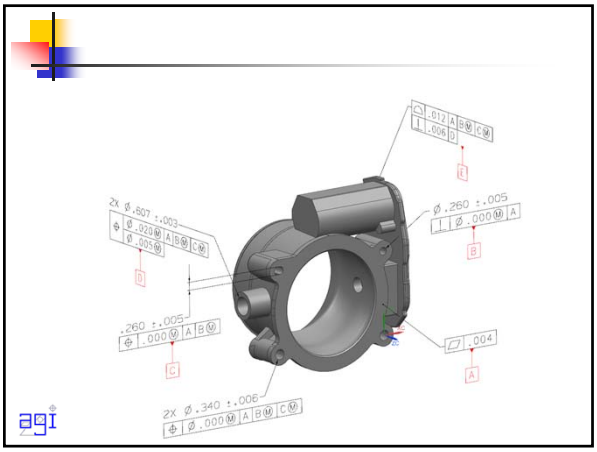
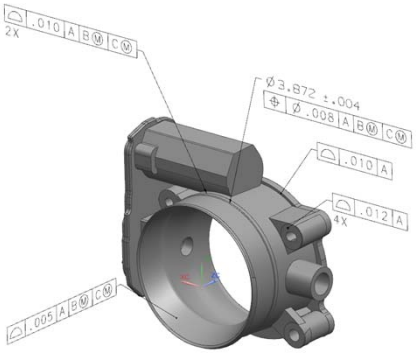
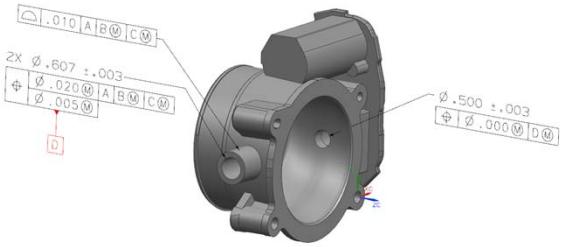


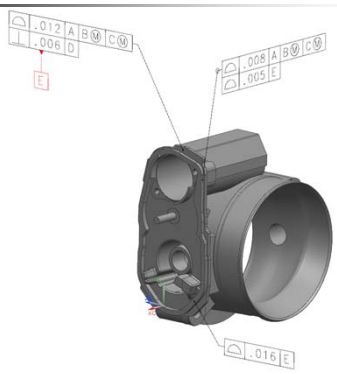
Model View: MBD_Intake_Side



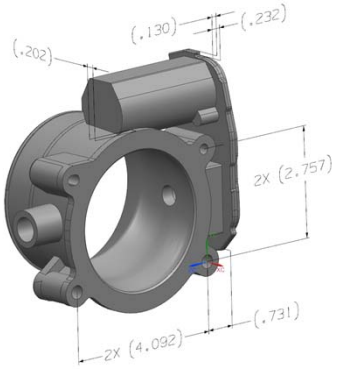
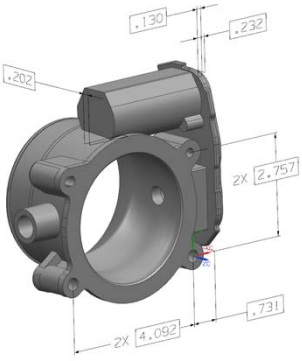
Model View: MBD_Shaft_Holes



Model View: MBD_Control_Module



Model View: MBD_References



Model View: MBD_Basic