BiTS™
Burn-in & Test Socket Workshop

ARCHIVE 2006
Tutorial

"Geometric Dimensioning And Tolerancing:
A Primer For The BiTS Professional"

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BiTS
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●2006

Geometric Dimensioning and Tolerancing: A Primer for the BiTS Professional

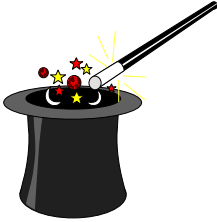**Thomas Allsup**
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Why Are We Here?

- Many will believe that a class on Geometric Dimensioning and Tolerances is like taking a high school English again.
- Those people are 100% correct.
- Learning GD&T is exactly like learning a new language.

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Tricks?

- Teaching people who don't want to learn or think they don't need to is a difficult task.
- Here's some concepts that might help you teach / learn GD&T.

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There Are No Stupid Questions
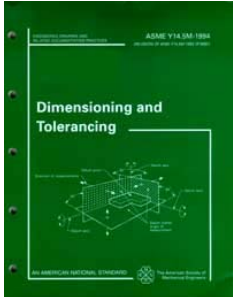
- Although the presentation is "canned", questions aren't just encouraged - they are expected.
  - Will this be on the test?
- You didn't learn English by keeping your mouth shut.
  - However our time is short today so please hold your long questions until each break.

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The Standard

- ASME Y14.5M-1994
  - Softbound: $135
  - PDF: $156
  - CD-ROM: $780
- Everything we talk about today is from this standard.

Dimensioning and Tolerancing
ASME Y14.5M-1994
AN AMERICAN NATIONAL STANDARD · The American Society of Mechanical Engineers

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ISO 1101:2004

- *Official Title: Geometrical Product Specifications (GPS) -- Geometrical tolerancing -- Tolerances of form, orientation, location and run-out*
- Every revision of the American standard has brought more harmony with the ISO equivalent.
  - And vice versa as well.
- Everyone has heard of ISO9000 but little is said about ISO1101 because it is very close to ASME Y14.5M-1994.

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FOPRL?

- This section starts looking at the 14 GD&T control symbols.
- We will use a technique that I developed based on a concept similar to the Periodic Table of Elements in Chemistry.
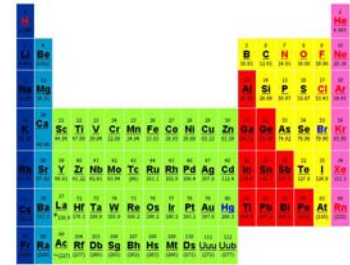
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Periodic Table of Elements

- Remember high school chemistry?
- Columns and rows both group elements.
- Each box has information about just that element.

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Element Information
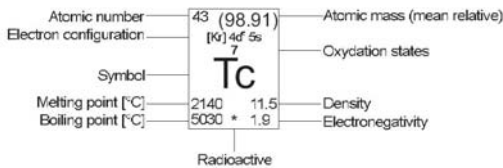
In each element, the chart makers place information so someone "skilled in the arts" will have all the information they need to work with the element.

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Periodic Table of GD&T

- Columns and rows both group controls.
- Each box has information about just that control.
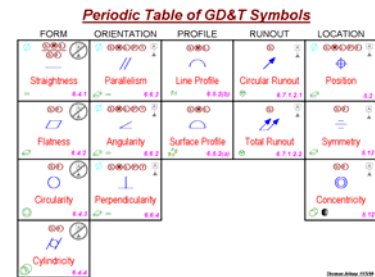
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FOPRL Legend
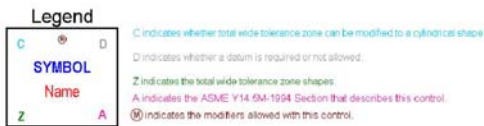
In each control, we place information so someone "skilled in the arts" will have all the information they need to work with the control.

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Five Kinds of Geometric Control

- All of these controls act just like they sound like:
  - Form
  - Orientation
  - Profile
  - Runout
  - Location
- This is how we get F O P R L.

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Form Controls

- First kind of geometric control we look at is the simplest: Form.
- Form control is just like it sounds, they control the acceptable variance in the shape of a feature.
- There are four kinds of form control - I remember them by saying 2D-3D-2D-3D - let's see why.

Form
Straightness

- What geometry is two dimensional and linear?
  - Answer: A straight line
- Let's call the control of a straight line, the STRAIGHTNESS.
- The icon to represent a straight line would be a line –

Form
Flatness

- What geometry is three dimensional and linear?
  - Answer: A flat plane
- Let's call the control of a flat plane, the FLATNESS.
- The icon to represent a flat plane would be the shape of a plane ▱

Form
Circularity

- What geometry is two dimensional and rotary in nature?
  - Answer: A circle
- Let's call the control of a circle, the CIRCULARITY.
- The icon to represent a circle would be a circle ○

Form
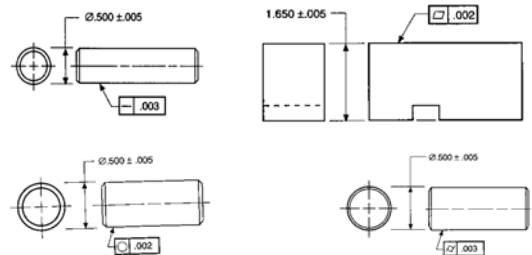### Cylindricity

- What geometry is three dimensional and rotary in nature?
  - Answer: A cylinder (Don't guess sphere)
- Let's call the control of a cylinder, the CYLINDRICITY.
- The icon to represent a cylinder would be a made up symbol ⌭
  - More on why this makes sense later.

Form Callouts

2006

FOPRL
In Process

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
STRAIGHTNESS —				
FLATNESS ▱				
CIRCULARITY ○				
CYLINDRICITY ⌭				

We can cheat and see that there must be three orientation controls.

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Orientation Controls

- Second kind of geometric control we look at is the next simplest: Orientation.
- Orientation control is just like it sounds, they control the acceptable variance in the direction of a feature.
- There are three kinds of orientation control - I remember them thinking about my arm swing from horizontal to vertical.

Aerobics Time!

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Orientation Angles

- When your arm is horizontal, what is the angle it forms with the ground?
  - Zero, it is parallel with the ground.
- As you rotate you arm, the angle is some arbitrary angle.
- When your arm in pointing up, what is the angle it forms with the ground?
  - Ninety degrees, it is perpendicular with the ground.

Since the ground is our reference, let's call it a datum. There'll be much more on these later.

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Orientation
Parallelism

- What orientation is at zero degrees from the reference?
  - Parallelism
- The icon to represent when things should be parallel would be a two parallel lines ∥

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Cylindricity Revisited

- Two dimensional rotational form control Circularity ○ plus Parallel orientation of the sides ∥ equals three dimensional rotational form control Cylindricity ⌭
- It kind of all makes sense, doesn't it?

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Orientation
Angularity

- What orientation is any angle?
  - Answer: Angularity
- The icon to represent when two things are at an arbitrary angle looks like an angle ∠

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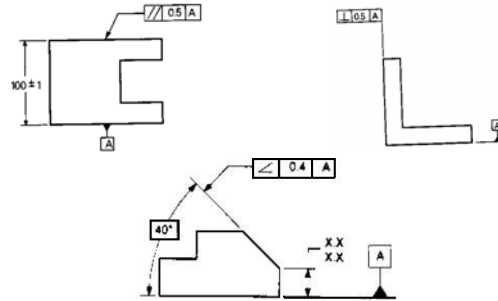

Orientation
Perpendicularity

- What orientation is at ninety degrees from the reference?
  - Answer: Perpendicularity
- The icon to represent when things should be perpendicular would be something that looks like ⊥

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Orientation Callouts

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FOPRL
In Process

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
STRAIGHTNESS —	PARALLELISM //			
FLATNESS ▱	ANGULARITY ∠			
CIRCULARITY ◯	PERPENDICULARITY ⊥			
CYLINDRICITY				

We can cheat and see that there must be two profile controls.

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Profile Controls

- Now let's start looking at the complicated geometric controls: Profile Controls.
- Profile control is just like it sounds, they control the acceptable variance in the profile of a feature.
- There are two kinds of profile control - I remember them by thinking 2D-3D.

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Complex Profiles?

- Most people think of complex shapes like the contour of a car but the profile can be as simple as a line or circle.
- Inspectors love checking profile controlled features because they can place a clear overlay on the feature and simply say pass or fail.

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Profile Control
Line

- We call the two dimensional profile control "*line profile*" or "*profile of a line*".
  - The line in question can be any shape, or any number of lines, arcs, or splines.
- The icon used to represent a line profile is ⌒ *Don't turn that frown upside down!*

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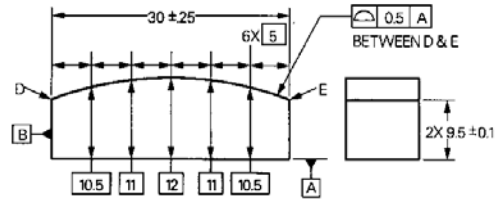
Profile Control
Surface

- We call the three dimensional profile control "*surface profile*" or "*profile of a surface*".
  - The surface in question can be any shape, or any number of planes or surfaces.
- The icon used to represent a surface profile is ⌓

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Profile Callout

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FOPRL
In Process

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
STRAIGHTNESS —	PARALLELISM //	LINE PROFILE ⌒		
FLATNESS ▱	ANGULARITY ∠	SURFACE PROFILE ⌓		
CIRCULARITY ○	PERPENDICULARITY ⊥			
CYLINDRICITY				

We can cheat and see that there must be two runout controls as well.

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Runout Controls

- Let's continue looking at the complicated geometric controls: Runout Controls.
- Runout control is just like it sounds, they control the acceptable variance in a revolved feature.
- There are two kinds of profile control - I remember them by thinking 2D-3D.

You getting tired of 2D-3D? Last time I use it, promise.

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Runout Control
Circular

- We call the two dimensional runout control "*circular runout*".
- The icon used to represent circular runout is ↗
- Note this symbol looks like the needle from a dial indicator and that's exactly how we measure it.

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Runout Control
Total

- We call the three dimensional runout control "*total runout*".
- The icon used to represent circular runout is ↗↗
- This is a perfect time to talk about what we call the rotation of the dial indicator over a feature.

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Runout Callout

∅1.000 +.000 / −.002

∅.500 +.000 / −.002

.001 | A

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FOPRL
In Process

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
STRAIGHTNESS	PARALLELISM	LINE PROFILE	CIRCULAR RUNOUT	
FLATNESS	ANGULARITY	SURFACE PROFILE	TOTAL RUNOUT	
CIRCULARITY	PERPENDICULARITY			
CYLINDRICITY				

There's a reason that we put profile and runout next to each other. All these controls could replace all the other controls.

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Location Controls

- The last kind of geometric control we look at is the next most complicated: Location.
- Location control is just like it sounds, they control the acceptable variance in the location of a feature.
  - These controls are so important that entire chapter of the standard deals with these controls and entire seminars are based on understanding true position theory and practice.
- There are three kinds of location control - I have a hard time remembering the last two of these and don't have a good way of helping you so it's memorization time.

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Location
Position

- The obvious location control for features is position.
- The icon to represent where a feature should be, we use a target symbol ⊕
- *This reminds me of one of my favorite military sayings:*
  - *Mechanical engineers build weapons.*
  - *Civil engineers build targets.*

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Location
Symmetry

- The first non-obvious location control is called symmetry.
- The icon to represent when two things should be symmetric is ⌯
- Note the icon shows a mirror reference line (the datum) and two little symmetric lines. *I have never placed a symmetric tolerance on a drawing or checked a drawing that had it (correct).*

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Location
Concentricity

- The second non-obvious location control is called concentricity.
- The icon to represent when two things should have the same center axis is ◎
- Most GD&T newbies love hearing about this symbol and are anxious to use it although they probably should be using runout - this is hard to inspect.

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Position Callout

4X .262 $^{+.005}_{-.000}$

⊕ | .012 Ⓜ | A | B

.500

1.000

2.880 ±.020   2X .55 ±.01

B

A

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FOPRL
Complete

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
STRAIGHTNESS —	PARALLELISM //	LINE PROFILE ⌒	CIRCULAR RUNOUT ↗	POSITION ⊕
FLATNESS ▱	ANGULARITY ∠	SURFACE PROFILE ⌓	TOTAL RUNOUT ↗↗	SYMMETRY �
CIRCULARITY ○	PERPENDICULARITY ⊥			CONCENTRICITY ◎
CYLINDRICITY ⌭				

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FOPRL Legend

Legend
C ⌖ D
SYMBOL
Name
Z   A

C indicates whether total wide tolerance zone can be modified to a cylindrical shape.
D indicates whether a datum is required or not allowed.
Z indicates the total wide tolerance zone shapes.
A indicates the ASME Y14.5M-1994 Section that describes this control.
Ⓜ indicates the modifiers allowed with this control.

In each control, we place information so someone "skilled in the arts" will have all the information they need to work with the control.

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FOPRL Legend
C

Legend
C ⌖ D
SYMBOL
Name
Z   A

C indicates whether total wide tolerance zone can be modified to a cylindrical shape.
D indicates whether a datum is required or not allowed.
Z indicates the total wide tolerance zone shapes.
A indicates the ASME Y14.5M-1994 Section that describes this control.
Ⓜ indicates the modifiers allowed with this control.

We'll leave this area blank except for the controls that can have cylindrical tolerance zone and then we'll put ⌀.

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FOPRL Legend
D

Legend
C ⌖ D
SYMBOL
Name
Z   A

C indicates whether total wide tolerance zone can be modified to a cylindrical shape.
D indicates whether a datum is required or not allowed.
Z indicates the total wide tolerance zone shapes.
A indicates the ASME Y14.5M-1994 Section that describes this control.
Ⓜ indicates the modifiers allowed with this control.

Three options:
- Datums not allowed
- Datums required
- Datums are allowed but not required is just left blank

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FOPRL Legend
Z

Legend
C ⌖ D
SYMBOL
Name
Z   A

Between two lines
Between two planes
Between two curves
Between two curved surfaces
Between two circles
Between two cylinders
Within a cylinder
Within a sphere
Full Indicator Movement

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FOPRL Legend A

Everyone turn in your standard to page number …

Until you have a standard, you'll just to trust me.

FOPRL Legend Ⓜ

- Ⓜ MMC   Ⓣ Tangent Plane
- Ⓛ LMC   Ⓕ Free State
- Ⓢ RFS   Ⓟ Projected Tolerance Zone

Periodic Table of GD&T Symbols

What's Coming Up

- We now have the preliminary information on the FOPRL chart.
- Let's start talking about features of size, tolerance zones, and datums.

10 Minute Break

Features of Size

- We will now go deeper into the concepts of GD&T by starting to look at features of size.
- This conversation will led us to discussing modifiers.
  - Modifiers are the little letters in circles.
- Along the way, we'll learn Rule #2 of GD&T.
- We'll finish by starting to talk about tolerance zones & shapes of all the geometric controls.

What's a Feature?

- ASME Y14.5M-1994 Section 1.3.12 Defines a Feature as the general term applied to a physical portion of a part, such as a surface, pin, tab, hole, or slot.
- In other words, any distinctive portion of a part that might be dimensioned is a "feature".

What is Size?

- 1.3.24 Actual Size : The general term for the size of a produced feature.
  - This is what you measure on a part.
- 1.3.27 Limits Of Size : The specified maximum and minimum sizes.
  - This is the numbers found on the drawing.
- 1.3.28 Nominal Size : The designation used for purposes of general identification.
  - 28 Gauge wire, 1" Schedule 40 pipe, 2x4

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Size Isn't Important

Physical features are grouped into two distinct regimes:

- Features that do not depend on size
  - Single surfaces, lines, arcs
  - Sometimes called "Not Related Features"
- "Features of size"
  - Plates, holes, slots, balls
  - Sometimes called "Related Features"

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Feature of Size Examples

- One cylindrical surface
- One spherical surface
- Set of two opposed elements
- Set of opposed parallel surfaces

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The "Caliper" Check

Things that you are measure with a pair of calipers are features of size:

- Inside Jaws
- Outside Jaws
- Depth Gauge

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Why Are Features of Size Important?

- Geometric tolerances for features of size can be *modified* according to the "size of the feature".
- Everyone knows that engineers love to modify things.

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What Does the Circled Letters Stand For?

Ⓢ Ⓜ Ⓛ Ⓕ

- The geometric tolerance for features of size can be modified in several methods but the two most important are:
  - Regardless of Feature Size (RFS)
  - Maximum Material Condition (MMC)
- There is also LMC and Free State
  - For a good time, ask an ISO1101 person for an explanation of the Envelope modifier.

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Regardless of Feature Size

- This is the default if no modifier is given.
- The tolerance zone is not affected by the actual size of the feature.
- You don't see the symbol Ⓢ anymore except in GD&T training sessions.
- Just because you don't see the symbol doesn't mean the concept isn't used all the time.

Ⓢ

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Second Rule of GD&T

- Remember the first rule of GD&T states the limits of size are the first magnitude of control.
- The second rule of GD&T states that if the geometric tolerance is applied to a feature of size then it is assumed to be regardless of feature size.

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Maximum Material Condition

- The stated tolerance applies when the most material is there.
  - The tolerance zone increases when there is less material – you get a "***bonus tolerance***" if a hole is large.
- Examples:
  - Thickest plate
  - Smallest hole

Ⓜ

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"Worst Case Scenario"

MMC is normally valid only when all of these conditions exist:

- Two or more features are interrelated with position or orientation.
- At least one of the features is a feature of size.
- The feature with which MMC is to be applied must be a feature of size with a axis or center plane.

Note: We used to call MMC, the "worst case".

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Least Material Condition

- The stated tolerance applies when the least material is there.
  - This is a rarely used modifier.
- Examples:
  - Thinnest plate
  - Largest hole

Ⓛ

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Why is LMC rare?

- Most tolerance analysis is checking whether part will go together.
- If you are checking if a male part will go into a hole, you need to know the largest male part and the smallest hole - both of which are MMC.
- LMC can be used to see what the maximum clearance is in a system but that analysis is pretty rare.

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Free State

- Free State Variation : A term used to describe distortion of a part after removal of forces applied during manufacture.
- You see this on lots of flexible parts, like rubber gaskets, wire forms, and some thin walled plastic components.

Ⓕ

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Two More Modifiers

- Technically, the following two modifiers do not affect features of size.
- However, there is no good place to put them in this seminar.
- So, here's Tangent Plane and Projected Tolerance Zone.

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Tangent Plane

- This modifier tells the inspector to place a tangent plane on a surface and measure the gauge plate, not the part.
- This modifier is commonly used by orientation controls.
    - It will become clear a little later when we look at tolerance shapes.

Tangent Plane
Part

Ⓣ

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Projected Tolerance Zone

- Used only with position & orientation tolerances.
- Mainly position and perpendicularity.
- Circled P appears after any modifiers and is itself followed by the projected height.
- The words are "**with a projected tolerance zone of …** "
- For clarification, a chained line can be drawn and dimensioned with a minimum height dimension (not a basic dimension).

Ⓟ

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Tolerance Zones and Shapes

- The next stop on the GD&T primer train is the Tolerance Zones and Shapes station.
- These sound like the same thing but they are two separate but related items for tolerances.
- Let's start with the easy one - zones.

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Tolerance Zones

- All controls can have **TOTAL WIDE TOLERANCE ZONES**.
    - Except Concentricity.
- Only five can have a **CYLINDRICAL TOLERANCE ZONES**:   *Position tolerance zones for holes and bosses are always cylindrical tolerance zones.*
    - Position ←
    - Orientation
        - Parallelism, Angularity, Perpendicularity
    - Straightness
- Concentricity requires **CYLINDRICAL TOLERANCE ZONE.**

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Tolerance Zone Symbology

// .014 Ⓜ U

Total wide zone is default
UNLESS...
You put the diameter symbol here.

⊕ Ø.002 Ⓛ Y

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Tolerance Zone Shapes

- Cylindrical zone sounds easy - it's a circle or cylinder within with which the feature must reside to be acceptable.
- What shape is a total wide zone?
- Here's where it gets complicated and one of the reasons I originally built the FOPRL chart - let's look at the shapes.

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Tolerance Zone Shape: Form Total Wide

- Each geometric control has it's own total wide tolerance shape that is suggested by it's name.
- Form
  - Straightness: between two lines
  - Flatness: between two planes
  - Circularity: between two circles
  - Cylindricity: between two cylinders

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Tolerance Zone Shape: Orientation Total Wide

- For all three orientation controls, the surfaces must lie between two planes.
  - Parallel
  - Angularity
  - Perpendicular
- Hold it a second, we just said flatness control was between two planes.

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Tolerance Zone Shape: Profile / Runout Total Wide

- Profile
  - Line: between two curves that are the shape of the feature
  - Surface: between two surfaces that are the shape of the feature
- Runout
  - Full indicator movement

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Tolerance Zone Shape: Location Controls Total Wide

- Position: depends on the geometry it controls
  - Between resultant and virtual conditions and fixed / floating fastener theory, there's a day's worth of topics on positional tolerances.
- Symmetry: two planes
- Concentricity: cylindrical

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Datums

- Datums do one simple thing:
  - *Datums are a way for the part designer to tell the part inspector how to hold and immobilize the part during inspection.*
- Datums are a reference for geometric dimensions.

Datum Definitions

- A Datum is a theoretically exact
  - point
  - axis
  - plane
  - derived from the true geometric counterpart of a specified datum feature.
- A datum is the origin from which the location or geometric characteristics of features of a part are established.

Datum Reference Frame

- 4.1 Datum Reference Frame: Datums that exist within a framework of three mutually perpendicular intersecting planes.
- Framework datums called: Primary - secondary - tertiary

Dimensioning and Tolerancing

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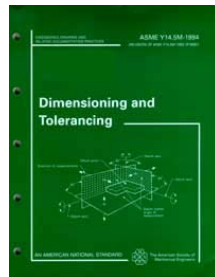
Points of Contact

- A primary datum feature usually has three points of contact
  - Don't use the word ***must***.
- A secondary datum feature usually has two points of contact
  - Don't use the word ***must***.
- A tertiary datum feature usually has one point of contact
  - Don't use the word ***must***.
- The largest surface on a part doesn't always have to be the primary datum feature.
  - The designer dictates primary datum feature.
  - Usually it is a good design idea for the largest surface to be the primary datum feature.

Clarification of Feature Control Frame

- Draw vertical lines between separate datums:
  - *Section 3.4.3 "Where more than than one datum is required, the datum reference letters (each followed by a material condition symbol where applicable) are entered in separate compartments in the desired order of precedence, from left to right."*

  A-B

- Draw a horizontal dash between datums to indicate a compound datum.
  - *Pre-ASME Y14.5-1994, the dashes could have meant a datum callout.*

  -A-

Missing in Action

- The standard only calls out three letters that cannot be used as datums.
  - **I, O, or Q**
- The standard does not say you have to start with A and go in any particular order.
  - I prefer to never use S or Z

2006

What Does it Mean #1?

- This datum is the bottom surface.
- This datum is not a feature of size.
- The datum simulator can be a gauge plate.
  - Gauge plate needs to be 10X flatter than what you want to check.
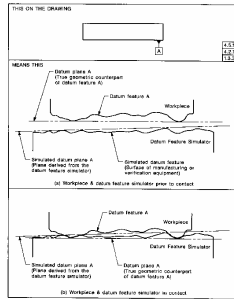
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What Does It Mean #2?

- This datum is the center axis.
- This datum is a feature of size.
- The datum simulator is a two piece "clamp".
  - RFS - clamp squeezes
  - MMC - clamp is fixed size
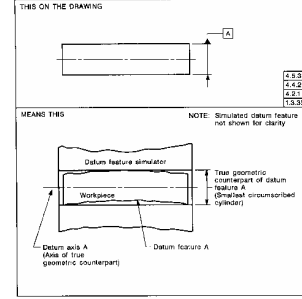
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Basic Dimensions

- If you think of datums as a method of immobilizing a part then basic dimensions are just offsets from that reference frame.
- Basic dimensions are boxed dimensions.   .500
- Basic dimensions don't have tolerances, they are used by other geometric dimensions.

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Angularity Basic Dimensions
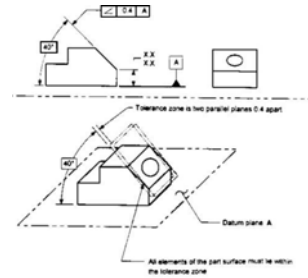
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Position Basic Dimensions
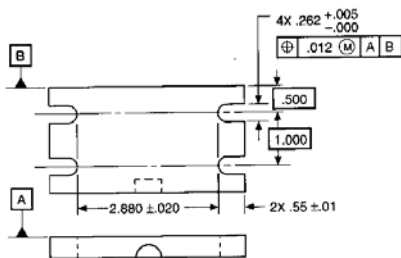
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Profile Basic Dimensions
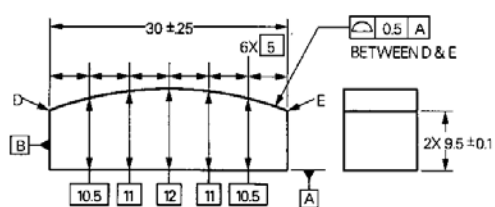
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Form
Straightness Exception

- Today, I've been careful not to mention that almost every rule in GD&T has exceptions.
  - This really disrupts the GD&T learning process.
- Rule 1 has four (count'em four) exceptions:
  - Stock parts : Bars, sheets, tubing, structural shapes
  - Parts subject to free state variation
  - Add note to a surface or feature: PERFECT FORM AT MMC NOT REQUIRED.
  - *Straightness tolerance on features of size with MMC applied.*
- Straightness is the important exception at the end.

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Straightness Tolerance
on Features of Size with MMC Applied

- Pretty much, just like it sounds.
- The shaft shown below can be shaped like a "smiley face" and still be acceptable.

Ø.500 ± .002

⌀.015 Ⓜ

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Form
With Exception

- Adding a second set of rules just for straightness yields the first column of the FOPRL chart.
- The rest of the controls are unchanged from this exception to Rule #1.

FORM

ØⓈⓂⒹⓅⓉ ⌀
Straightness   6.4.1
ⓈⓂⒹⓅⓉ ▱
Flatness   6.4.2
ⓈⓂⒹⓅⓉ ○
Circularity   6.4.3
ⓈⓂⒹⓅⓉ ⌭
Cylindricity   6.4.4

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Orientation

- **C** - Orientations can have total wide or cylindrical tolerance zones.
- **D** - Orientations have to have datums.
- **Z** - Each zone shape is driven by what is being directed toward.
- **A** - All part of section 6.6.
- Ⓜ - Size affects orientation so we get MMC & LMC, Projected Tolerance, and Tangent Plane.

ORIENTATION

Ø ⓈⓂⒹⓅⓉ Ⓐ
// Parallelism
⌀ =   6.6.3
Ø ⓈⓂⒹⓅⓉ Ⓐ
∠ Angularity
⌀ =   6.6.2
Ø ⓈⓂⒹⓅⓉ Ⓐ
⊥ Perpendicularity
⌀ =   6.6.4

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Profile

- **C** - Profile can only have total wide tolerance zones.
- **D** - Profiles can use datums but don't have to have datums.
- **Z** - Each zone shape is between curves or curved surfaces.
- **A** - All part of section 6.5.2.
- Ⓜ - Size can affect profile so we get MMC & LMC.

PROFILE

ⓈⓂⓁ
⌒ Line Profile
≈   6.5.2(b)
ⓈⓂⓁ
⌓ Surface Profile
⌔   6.5.2(a)

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Runout

- **C** - Runout can only have full indicator movement (FIM).
- **D** - Runout have to have datums.
- **Z** - Each zone shape can only have full indicator movement (FIM).
- **A** - All part of section 6.7.1.2.
- Ⓜ - Size can't affect runout so we only get RFS.

RUNOUT

Ⓢ   Ⓐ
↗ Circular Runout
⌰   6.7.1.2.1
Ⓢ   Ⓐ
↗↗ Total Runout
⌰   6.7.1.2.2

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Location
Position

LOCATION

C - Position can (and usually does) have cylindrical tolerance zones.
D - Runout have to have datums.
Z - Each zone shape can have .
A - All part of section 5.2.
Ⓜ - Size can affect position so we get MMC & LMC, Projected Tolerance, and Tangent Plane.

Position 5.2

Symmetry 5.13

Concentricity 5.12

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Location
Symmetry & Concentricity

LOCATION

C - Symmetry & Concentricity can only have total wide tolerance zones.
D - Symmetry & Concentricity have to have datums.
Z - Each zone shape is driven by what is being directed toward.
A - Section 5.12 & 5.13
Ⓜ - Size can't affect Symmetry & Concentricity so we only get RFS & Free State.

Position 5.2

Symmetry 5.13

Concentricity 5.12

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- Finally we have everything filled in.
- Later, as a review exercise, you should try to complete as much of the FOPRL chart as possible.

Periodic Table of GD&T Symbols

FORM	ORIENTATION	PROFILE	RUNOUT	LOCATION
Straightness 6.4.1	Parallelism 6.6.3	Line Profile 6.5.2(b)	Circular Runout 6.7.1.2.1	Position 5.2
Flatness 6.4.2	Angularity 6.6.2	Surface Profile 6.5.2(a)	Total Runout 6.7.1.2.2	Symmetry 5.13
Circularity 6.4.3	Perpendicularity 6.6.4			Concentricity 5.12
Cylindricity 6.4.4				

Thomas Allsup TI/SM

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What's Coming Up

Let's spend our remaining time with examples of "saying" feature control frames and some practical examples.

10 Minute Break

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Feature Control Frame

⌒ | .003 | C B Ⓜ D

- The fourteen geometric control symbols are applied to features by placing them in a feature control frame.
- Let's start our reading lessons by learning how to interpret feature control frames.

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Reading A Feature Control Frame

Read everything left to right! Don't skip anything!

FIRST BAR: The feature shall
  {be or have a} **BLANK** {geometric characteristic}
SECOND BAR: within a
  {total wide tolerance zone of
  cylindrical tolerance zone of,
  or full indicator movement} **BLANK**
  {geometric tolerance}
    [at {modifier}]
THREE BAR: with respect to datum(s) {datum name(s)} **BLANK**
LAST BAR: Period

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Example 1

The feature shall be
angular
within a
total wide tolerance zone of
.014"
at least material condition
with respect to
datum G

∠ .014 Ⓛ G ▷

Example 2

The feature shall be
flat
within a
total wide tolerance zone of
.018".

▱ .018

How To Say Anything
Form

Form: The feature shall be {straight, flat, circular, or cylindrical} within a {total wide or cylindrical} tolerance zone of {geometric tolerance} [at {modifier}].

How To Say Anything
Orientation

Orientation: The feature shall be {perpendicular, angular, or parallel} within a {total wide or cylindrical} tolerance zone of {geometric tolerance} [at {modifier}] with respect to datum(s) {datum name(s)}.

How To Say Anything
Profile

Profile: The feature shall have a {line or surface} profile within a total wide tolerance zone of {geometric tolerance} [at {modifier}] [with respect to datum(s) {datum name(s)}].

How To Say Anything
Runout

Runout: The feature shall have a {circular or total} runout within a full indicator movement of {geometric tolerance} with respect to datum axis {datum}.

How To Say Anything Location

Location: The feature shall be {positioned, concentric, or symmetric} within a {total wide or cylindrical} tolerance zone of {geometric tolerance} [at {modifier}] [with respect to datum(s) {datum name(s)}].

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Verbal Tests

- The upcoming 10 slides are all feature control frames that you might see on a drawing.
- In this exercise, I imagine I am on the telephone and trying to verbally communicate my required tolerance.
- Later, when you are reviewing this material, try the reverse operation by covering up the symbol, read the description, and draw the feature control frame.

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Verbal Test #1

$$\boxed{\boxed{\diagdown} \mid .002}$$

The feature shall be flat within a total wide tolerance zone of .003".

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Verbal Test #2

$$\boxed{\angle \mid .008 \mid D \mid F}$$

The feature shall be angular within a total wide tolerance zone of .008" with respect to datams D and F.

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Verbal Test #3

$$\boxed{\cap \mid .002}$$

The feature shall have a surface profile within a total wide tolerance zone of .002".

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Verbal Test #4

$$\boxed{= \mid .004 \mid F}$$

The feature shall be symmetric within a total wide tolerance zone of .004" with respect to datam F.

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Verbal Test #5

⊕	⌀.001 Ⓢ	B

The feature shall be positioned within a cylindrical tolerance zone of .001" regardless of feature size with respect to datam B.

The above Feature Control Frame is drawn incorrectly, the regardless of feature size symbol has been removed from the standard.

Verbal Test #6

—	.002

The feature shall be straight within a total wide tolerance zone of .002".

Verbal Test #7

↗	.005	M

The feature shall have a total runout within a full indicator movement of .005" with respect to datum axis M.

Verbal Test #8

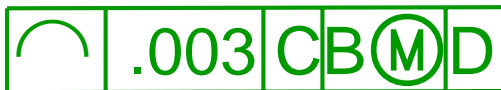| ⊥	.007 Ⓜ	C

The feature shall be perpendicular within a total wide tolerance zone of .007" at maximum material condition with respect to datum C.

Verbal Test #9

⌒	.003	C	B Ⓜ	D

The feature shall have a line profile within a total wide tolerance zone of .003" with respect to datums C, B at maximum material condition, and D.

Verbal Test #10

//	.009 Ⓜ	E

The feature shall be parallel within a total wide tolerance zone of .009" at maximum material condition with respect to datum E.

Practical Examples

- Well that was fun...
- We should now be comfortable with the all the symbols of GD&T and how they are used in feature control frames.
- Let's take a look at some practical examples and see how we interpret them.

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Practical Example #1

The slot is eighth inch (+/- .020"). The two inner walls of the slot are to be parallel to within .002".

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Practical Example #2

There are two .040" square something's that have a positional tolerance within a total wide tolerance zone of .005".

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Practical Example #3

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Practical Example #4

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Practical Example #5

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Practical Example #6

- The pads on this device are "**c**" wide.
- They are positioned within "**d**" when "**c**" is at MMC.

$\oplus$ | d Ⓜ | A | B
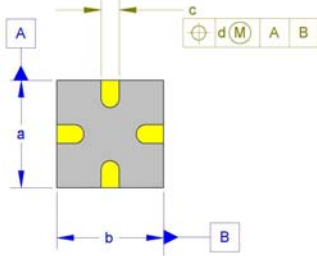
What's Wrong

- Let's finish this session with seeing some typical screw-ups.
- These sketch portions and feature control frames are from actual drawings and other class material.
  - Some of them are actually mine.
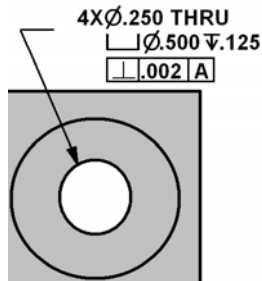- Try and see what's wrong with these...

What's Wrong #1

Four - quarter inch diameter holes through a plate with half inch diameter, eighth inch deep counter-bores that are perpendicular to within a total wide tolerance zone of 2 mils to a datum A. Right?
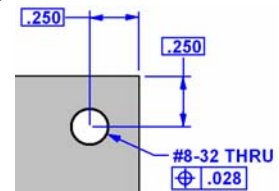
Tolerance zone is circular not total wide.

4X∅.250 THRU
⌴∅.500 ▾.125
⊥ | .002 | A

What's Wrong #2

This appears to be a #8-32 tapped hole positioned within a .028 inch total wide tolerance zone at a quarter of an inch from a corner. Right?

The tolerance zone should have been a circular tolerance zone.

.250   .250

#8-32 THRU
$\oplus$ | .028

What's Wrong #3

This appears to be a feature having a circular runout within a full indicator movement of .005" at maximum material condition with respect to datum axis G. Right?

⟋ | .005 Ⓜ | G

The runout tolerance zone is only RFS and cannot be modified.

What's Wrong #4

⟋ | ∅.005

Isn't this telling us there is a feature that shall be cylindrical within a cylindrical tolerance zone of .005"?

The tolerance zone can't be a circular tolerance zone.

What's Wrong #5

The feature shall be concentric within a cylindrical tolerance zone of .002" with respect to datam A. Right?

◎ | Ø.002 | A

The tolerance zone can't be a circular tolerance zone.

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What's Wrong #6

○ | Ø.004 Ⓕ

The feature shall be circular within a cylindrical tolerance zone of .004" in its free state.
The tolerance zone can't be a circular tolerance zone.

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Wrap Up

- 14 GD&T Symbols
  - FOPRL Chart
- Features of Size
- Datums
- Tolerance Zone Shapes
- Reading Feature Control Frames

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To Learn More…

- This has been a short introduction to Geometric Dimensioning and Tolerances.
  - There are many excellent books on the subject.
- Information is also available on the web from:
  - www.asme.org
  - www.anidatech.com

- **Good Luck!**

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