

# **RULES AND CONCEPTS OF GD&T**

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# RULES AND CONCEPTS OF GD&T

## Sections:

1. Rules
2. Introduction to Basic Dimensions
3. Introduction to Virtual Condition and Boundary Conditions
4. Introduction to Bonus Tolerance

# RULES

There are two general rules in ASME Y14.5M-1994. The first rule establishes default conditions for features of size. The second rule establishes a default material condition for feature control frames.

## **Rule #1**

Rule #1 is referred to as the “Individual Feature of Size Rule.” It is a key concept in geometric tolerancing. Rule #1 is a dimensioning rule used to ensure that features of size will assemble with one another. When Rule #1 applies, the maximum boundary (or envelope) for an external FOS is its MMC. The minimum envelope for an internal FOS is its MMC. To determine if two features of size will assemble, the designer can then compare the MMCs of the features of size.

# RULES

**Rule #1: Where only a tolerance of size is specified, the limits of size of an individual feature prescribe the extent to which variations in its form – as well as in its size – are allowed.**

In industry, Rule #1 is often paraphrased as “perfect form at MMC” or the “envelope rule.”

There are two components to Rule #1: the envelope principle and the effects on the form of a FOS as it departs from MMC. When Rule #1 applies, the limits of size define the size as well as the form of an individual FOS.

For example, let's look at how Rule #1 affects the diameter of a pin. When the pin diameter is at MMC, the pin must have perfect form. For a pin diameter, perfect form means perfect straightness and perfect roundness. This would allow the pin to fit through a boundary equal to its MMC. If the size of the pin was less than its MMC, the pin could contain form error (straightness and roundness error) equal to the amount the pin departed from MMC.

# RULES

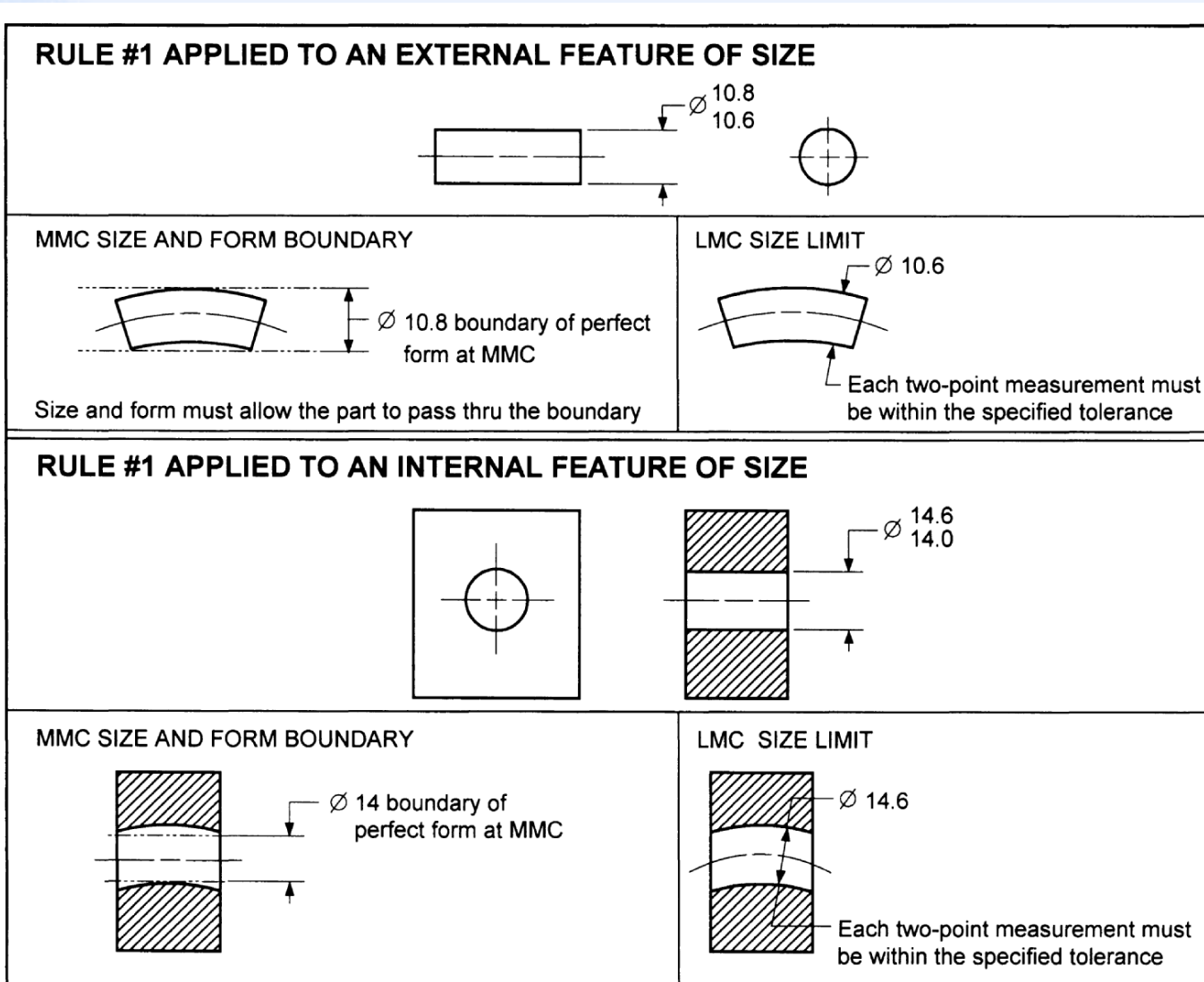
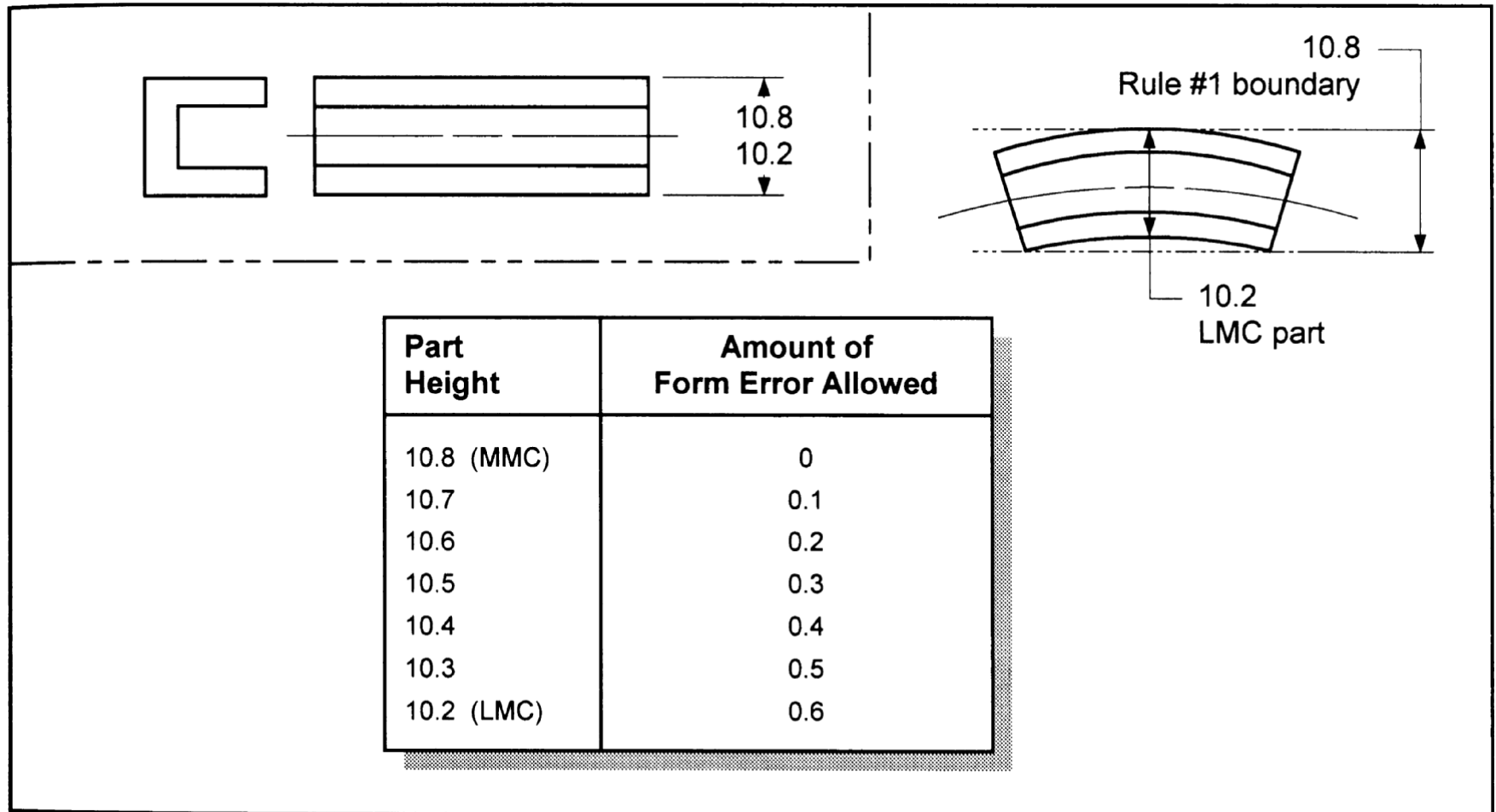


FIGURE 3-1 Rule #1 Examples

# RULES



**FIGURE 3-2 Rule #1 Boundary**



# RULES

## How to Override Rule #1

Rule #1 applies whenever a feature of size is specified on a drawing. There are two ways Rule #1 can be overridden:

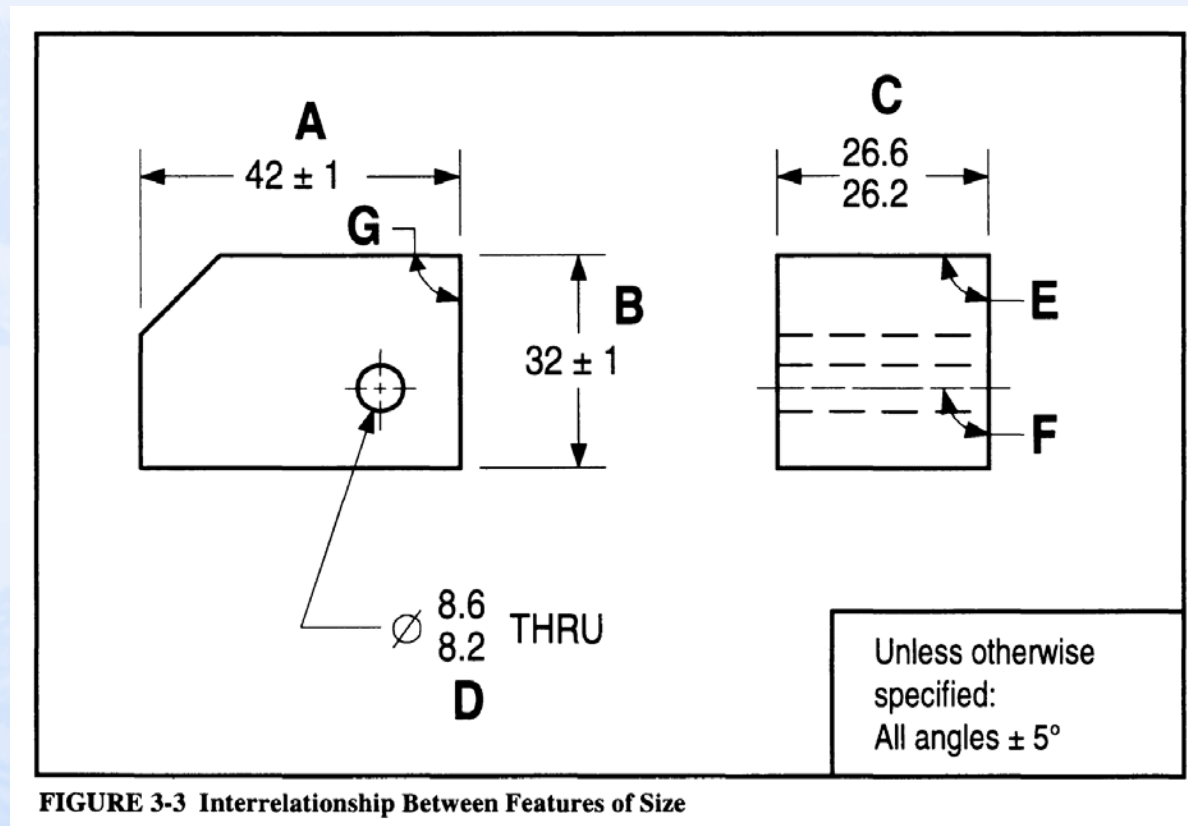
**If a straightness control is applied to a feature of size, Rule #1 is overridden.**

If a note such as “Perfect Form at MMC Not Required” is specified next to a FOS dimension, it exempts the FOS dimension from Rule #1.

## Rule #1 Limitation

A part often contains multiple features of size. Rule #1 does not affect the location, orientation, or relationship between features of size. Features of size shown perpendicular, symmetrical, or coaxial must be controlled for location or orientation to avoid incomplete drawing specifications. Often, implied 90° angles are covered by a general angular tolerance note or by an angular tolerance in the drawing titleblock.

# RULES



In this figure there are four features of size, marked A, B, C, & D. Rule #1 applies independently to each FOS. The angles between these features of size (angles E, F, & G) are not controlled by Rule #1.



# RULES

## Exceptions to Rule #1

Rule #1 does not apply to a FOS on a part subject to free-state variation in the unrestrained condition. In simple terms, Rule #1 does not apply to flexible parts that are not restrained.

Rule #1 does not apply to stock sizes, such as bar stock, tubing, sheet metal, or structural shapes. Paragraph 2.7.1.3 in ASME Y14.5M-1994 explains why. It states, “. . . standards for these items govern the surfaces that remain in the as-furnished condition on the finished part.”

# RULES

## **Inspecting a Feature of Size**

When inspecting a FOS that is controlled by Rule #1, both its size and form need to be verified.

The MMC size and the Rule #1 envelope can be verified with a Go gage. A Go gage is a gage that is intended to fit into (for an internal FOS) or fit over (for an external FOS) the FOS. A Go gage is made to the MMC limit of the FOS and has perfect form. A Go gage can verify the MMC limit and Rule #1 form envelope of a FOS. To fully verify the Rule #1 effects, a Go gage must be at least as long as the FOS it is verifying.

The minimum size (LMC) of a FOS can be measured with a No-Go gage. A No-Go gage is a gage that is not intended to fit into or over a FOS. A No-Go gage is made to the LMC limit of the FOS. A No-Go gage makes a two-point check; a caliper or snap gage could be used as a No-Go gage. The two-point check is made at various points along the cross section to insure that the FOS does not violate the LMC limit.

# RULES

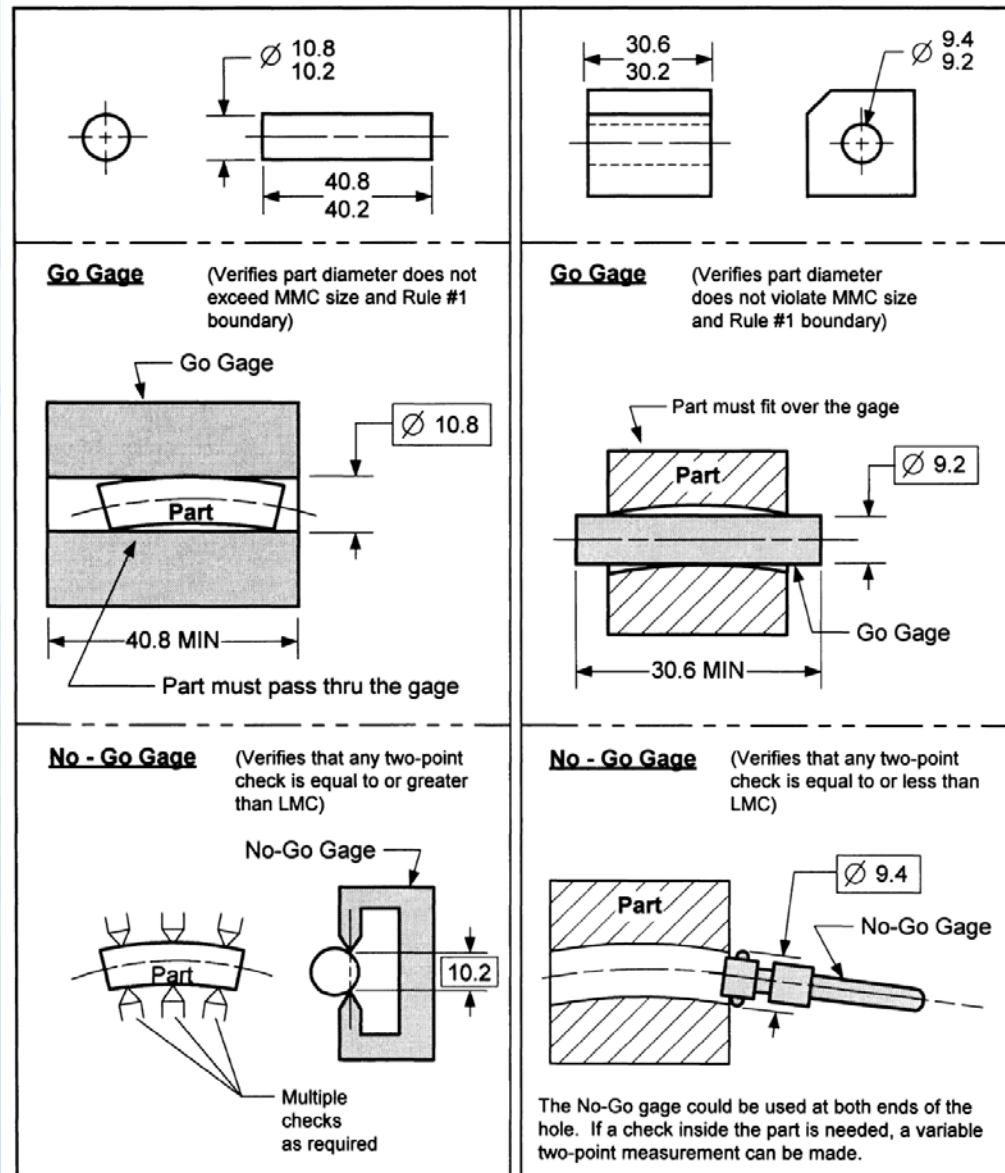


FIGURE 3-4 Go Gage and No-Go Gage Examples

# RULES

## Rule #2

Rule #2 is called “the all applicable geometric tolerances rule.”

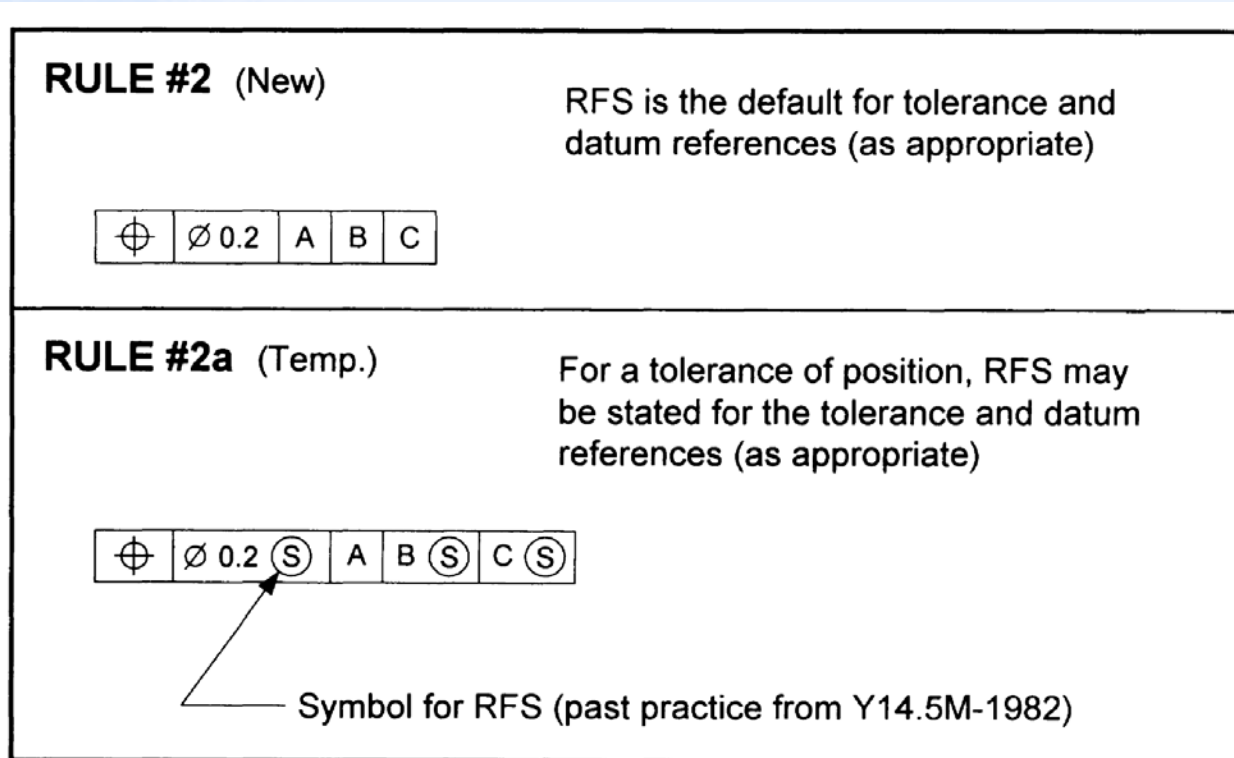
Rule #2: RFS applies, with respect to the individual tolerance, datum reference, or both, where no modifying symbol is specified. MMC or LMC must be specified on the drawing where required.

Certain geometric tolerances always apply RFS and cannot be modified to MMC or LMC.

Where a geometric tolerance is applied on an RFS basis, the tolerance is limited to the specified value regardless of the actual size of the feature.

Rule #2a is an alternative practice of Rule #2. Rule #2a states that, for a tolerance of position, RFS may be specified in feature control frames if desired and applicable. In this case, the RFS symbol would be the symbol from the 1982 version of Y14.5.

# RULES



**FIGURE 3-5 Rule #2 and Alternate Rule #2a**



# INTRODUCTION TO BASIC DIMENSIONS

A **basic dimension** is a **numerical value** used to describe the theoretically exact size, true profile, orientation, or location of a feature or gage information (i.e., datum targets). On engineering drawings there are two uses for basic dimensions. One is to define the theoretically exact location, size, orientation, or true profile of a part feature; the other use is to define gage information (example: datum targets). When a basic dimension is used to define part features, it provides the nominal location from which permissible variations are established by geometric tolerances.

# INTRODUCTION TO BASIC DIMENSIONS

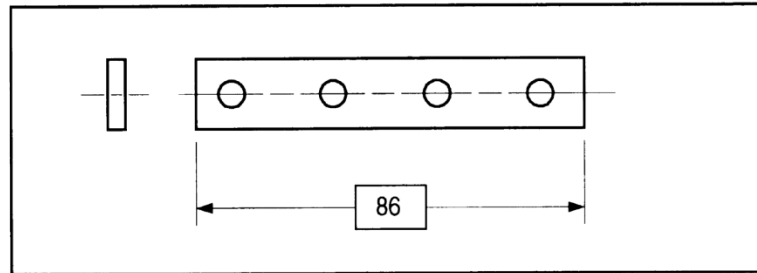


FIGURE 3-6 Basic Dimension Symbol

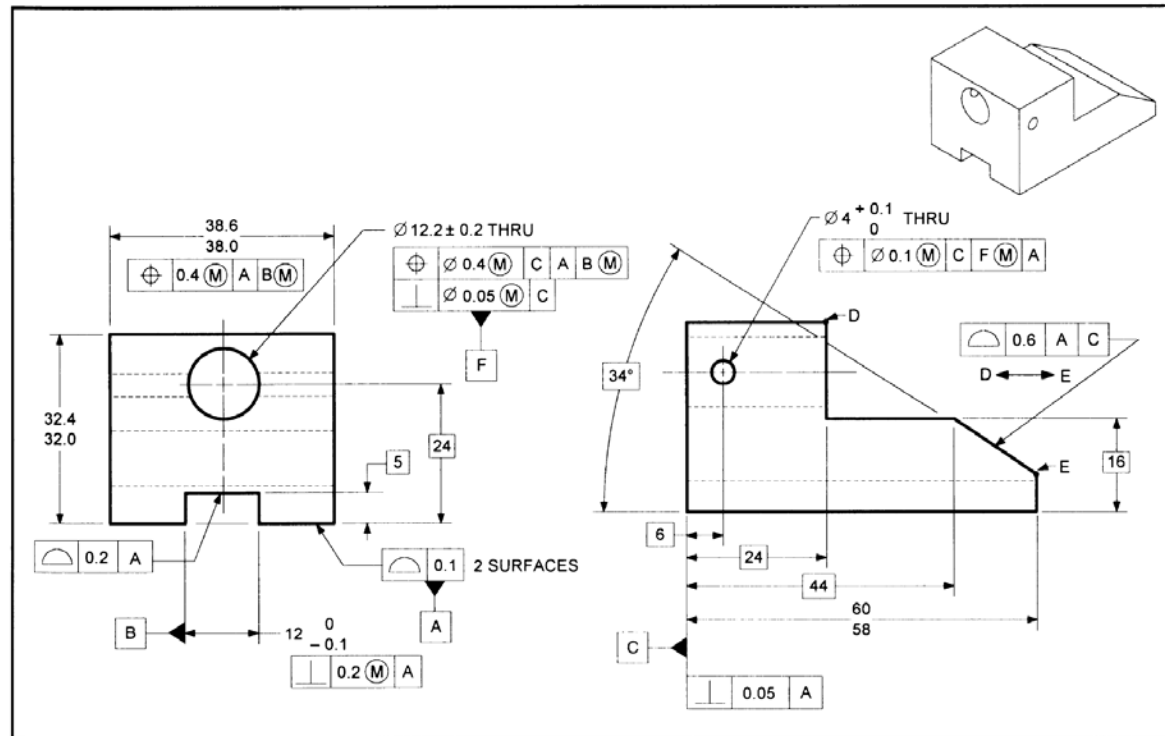


FIGURE 3-7 Basic Dimension Examples



# INTRODUCTION TO BASIC DIMENSIONS

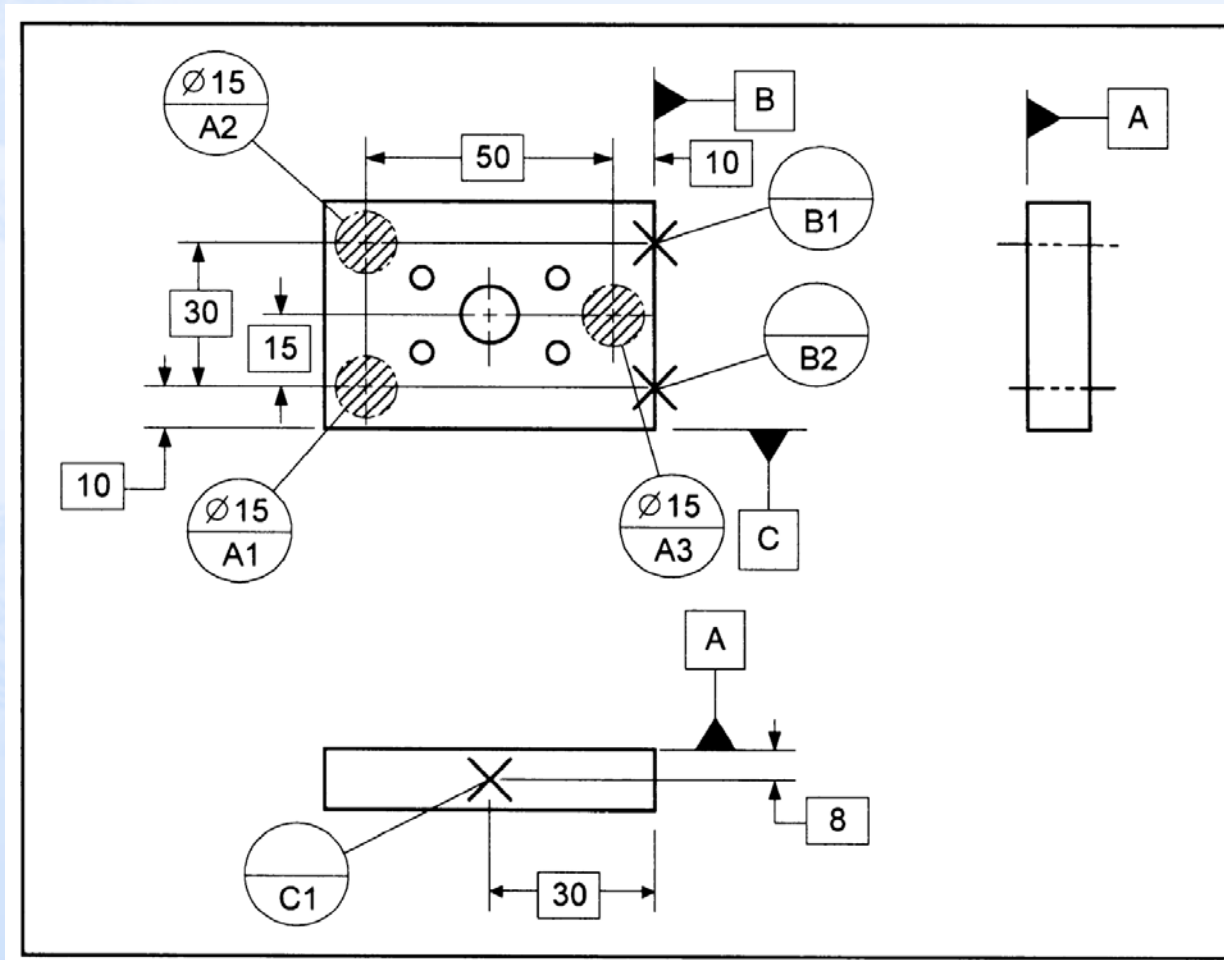


FIGURE 3-8 Basic Dimensions Used to Locate Datum Targets

# INTRODUCTION TO BASIC DIMENSIONS

## Basic dimensions

1. can be used to define the theoretically exact location, orientation, or true profile of part features or gage information.
2. that define part features must be accompanied by a geometric tolerance.
3. that define gage information do not have a tolerance shown on the print.
4. are theoretically exact (but gage-makers' tolerances do apply).

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

Depending upon its function, a FOS is controlled by a size tolerance and one or more geometric controls. Various material conditions (MMC, LMC, or RFS) may also be applied. In each case, consideration must be given to the collective effects of the size, specified material condition, and geometric tolerance of the FOS. The terms that apply to these conditions are virtual condition, inner boundary, and outer boundary.

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

## Definitions

**Virtual condition (VC)** is a worst-case boundary generated by the collective effects of a feature of size at MMC or at LMC and the geometric tolerance for that material condition. The VC of a FOS includes effects of the size, orientation, and location for the FOS. The virtual condition boundary is related to the datums that are referenced in the geometric tolerance used to determine the VC.

**Inner boundary (IB)** is a worst-case boundary generated by the smallest feature of size minus the stated geometric tolerance (and any additional tolerance, if applicable).

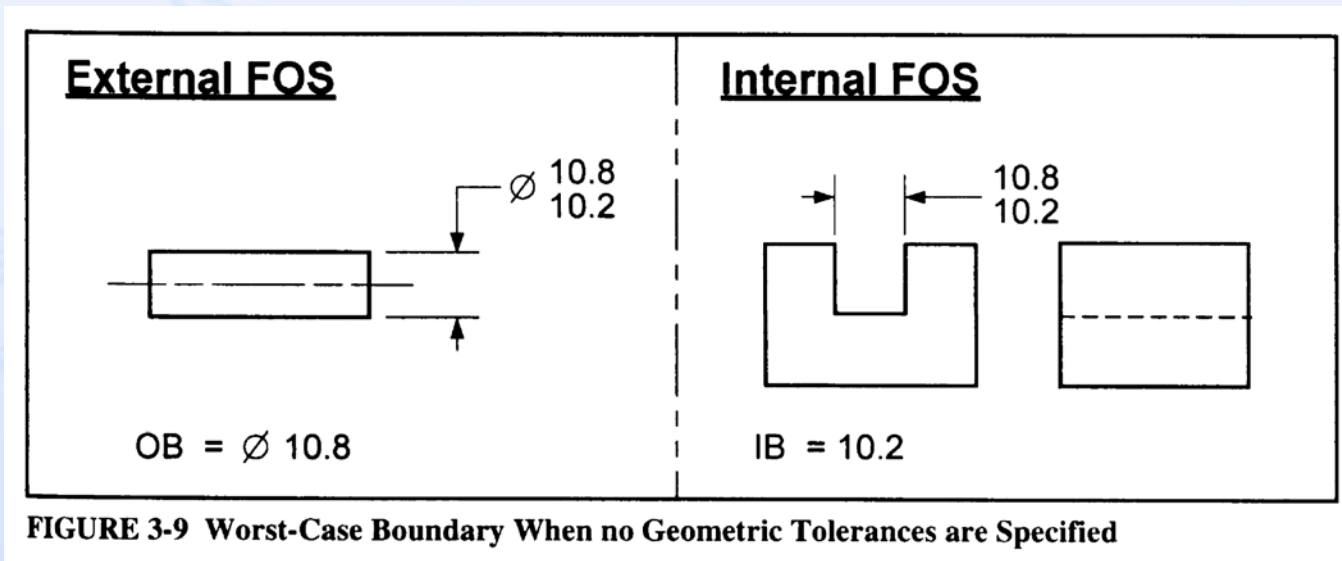
**Outer boundary (OB)** is a worst-case boundary generated by the largest feature of size plus the stated geometric tolerance (and any additional tolerance, if applicable).

**Worst-case boundary (WCB)** is a general term to refer to the extreme boundary of a FOS that is the worst-case for assembly. Depending upon the part dimensioning, a worst-case boundary can be a virtual condition, inner boundary, or outer boundary.

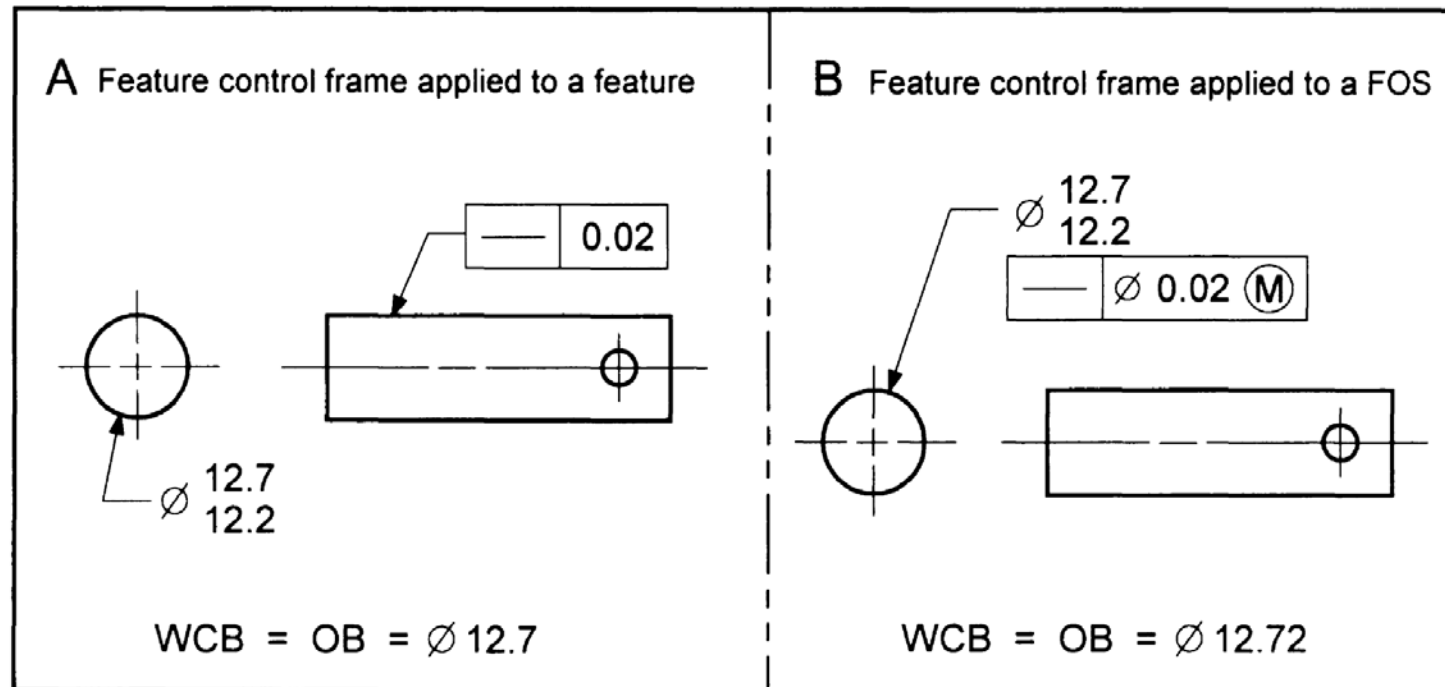
# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

## Feature of Size Boundary Conditions

If there are no geometric controls applied to a FOS, the WCB is the outer or inner boundary. The outer or inner boundary is equal to the MMC boundary as defined by Rule #1 .



# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS



**FIGURE 3-10 Feature Control Frame Placement**



# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

## MMC Virtual Condition

When a geometric tolerance that contains an MMC modifier in the tolerance portion of the feature control frame is applied to a FOS, the virtual condition (worst-case boundary) of the FOS is affected. **The virtual condition (or WCB) is the extreme boundary that represents the worst-case for functional requirements, such as clearance or assembly with a mating part.**



# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

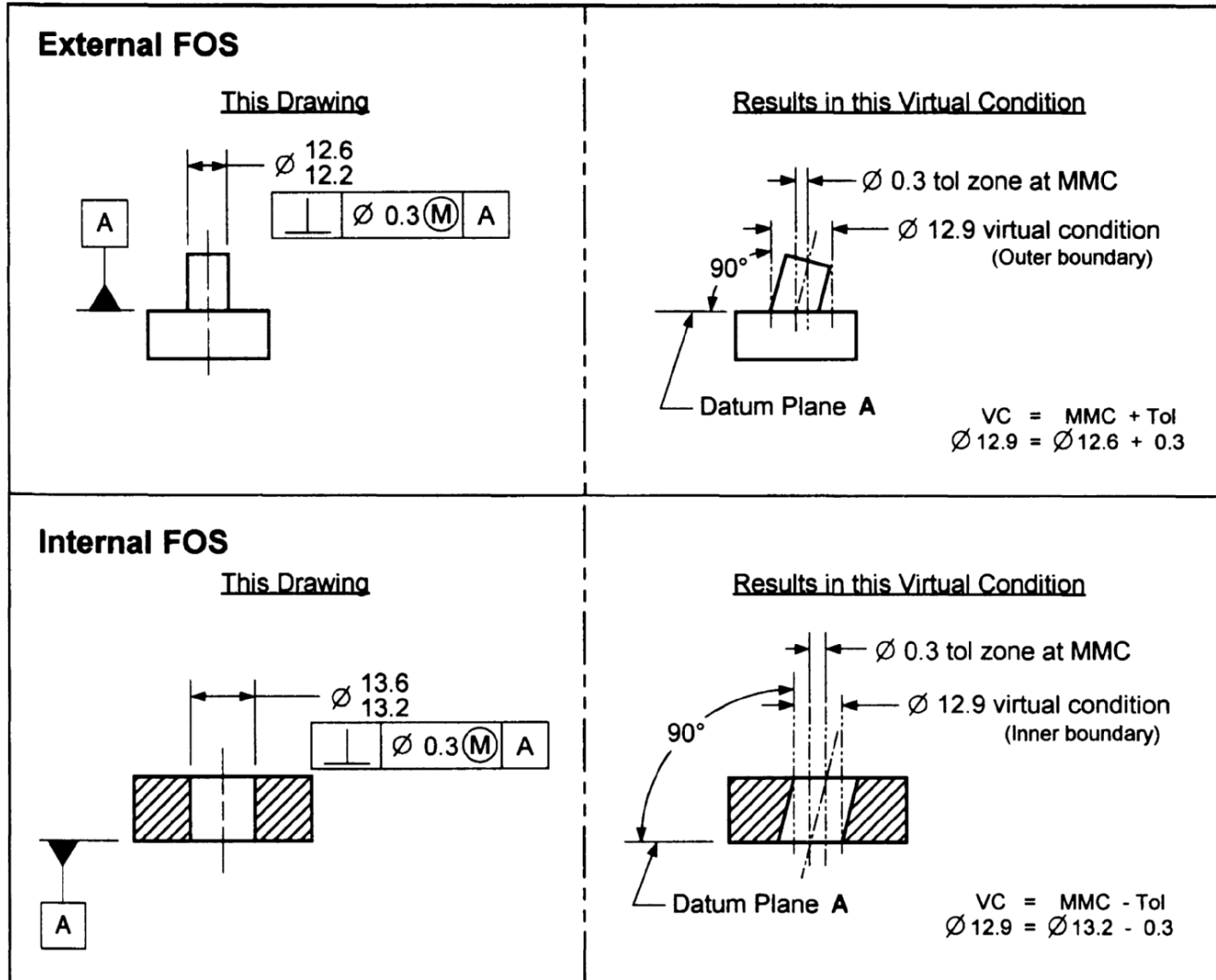
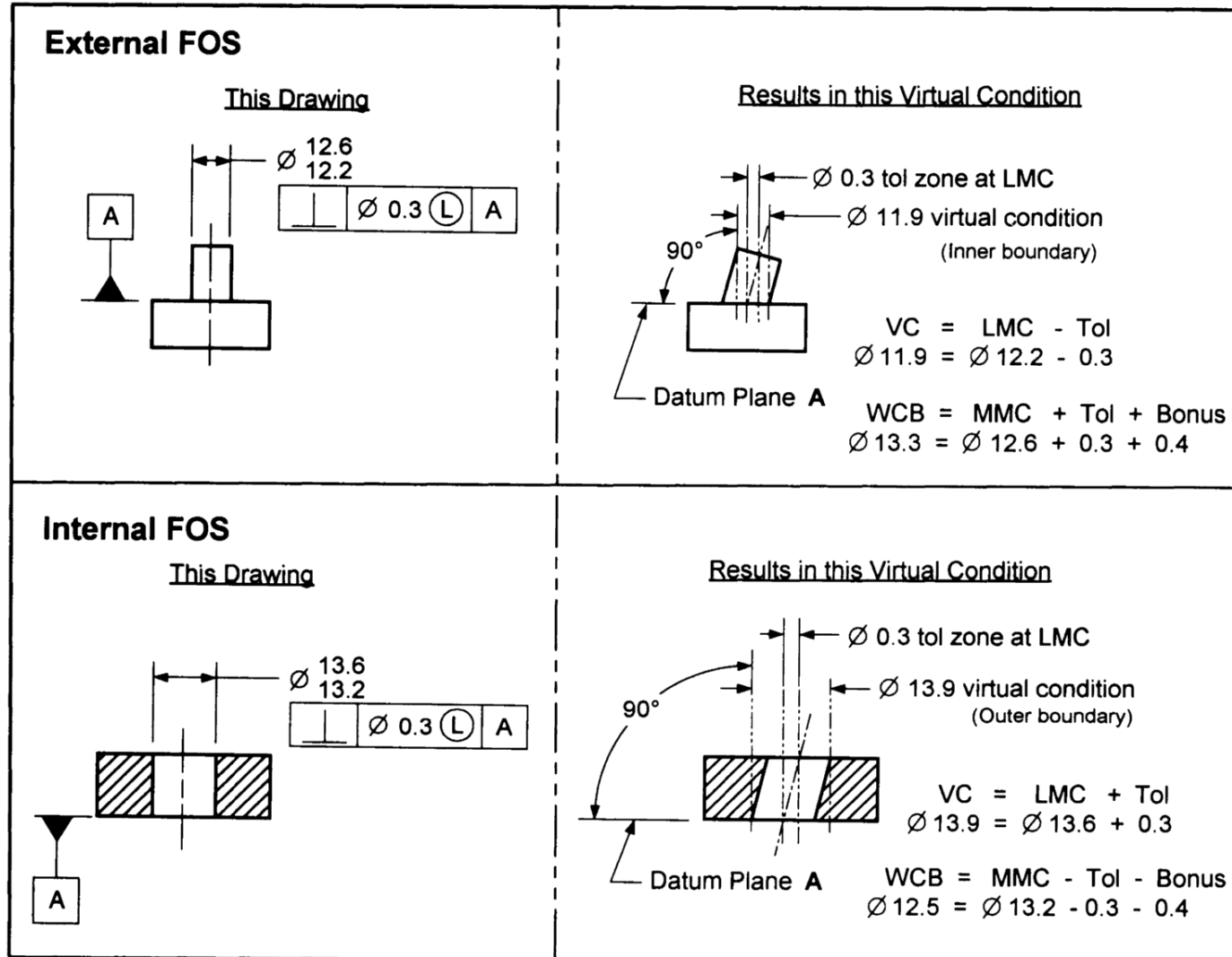


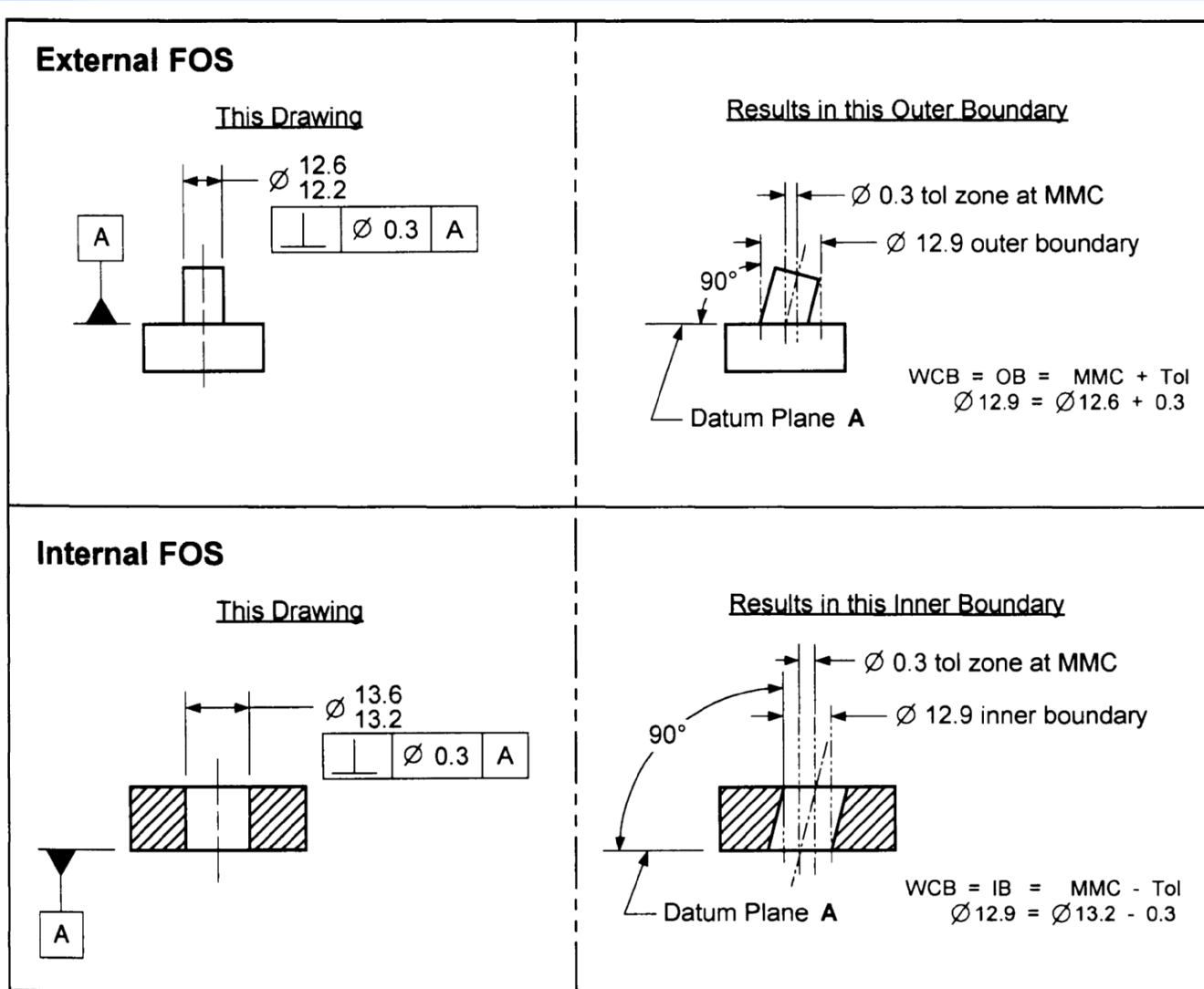
FIGURE 3-11 MMC Virtual Condition Examples

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS



**FIGURE 3-12 LMC Virtual Condition Examples**

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS



**FIGURE 3-13 RFS Inner and Outer Boundary Examples**

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

Part Specification	FOS Type	The worst case boundary (WCB) is equal to...
FOS with no GD&T specified	Internal	$IB = MMC$
	External	$OB = MMC$
FOS with GD&T specified at RFS	Internal	$IB = MMC - Tol^*$
	External	$OB = MMC + Tol^*$
FOS with GD&T specified at MMC	Internal	$VC = IB = MMC - Tol^*$
	External	$VC = OB = MMC + Tol^*$
FOS with GD&T specified at LMC	Internal	$IB = MMC - Tol^* - Bonus$
	External	$OB = MMC + Tol^* + Bonus$
* Tol represents the geometric control tolerance value		

FIGURE 3-14 WCB Formula Chart

# INTRODUCTION TO VIRTUAL CONDITION AND BOUNDARY CONDITIONS

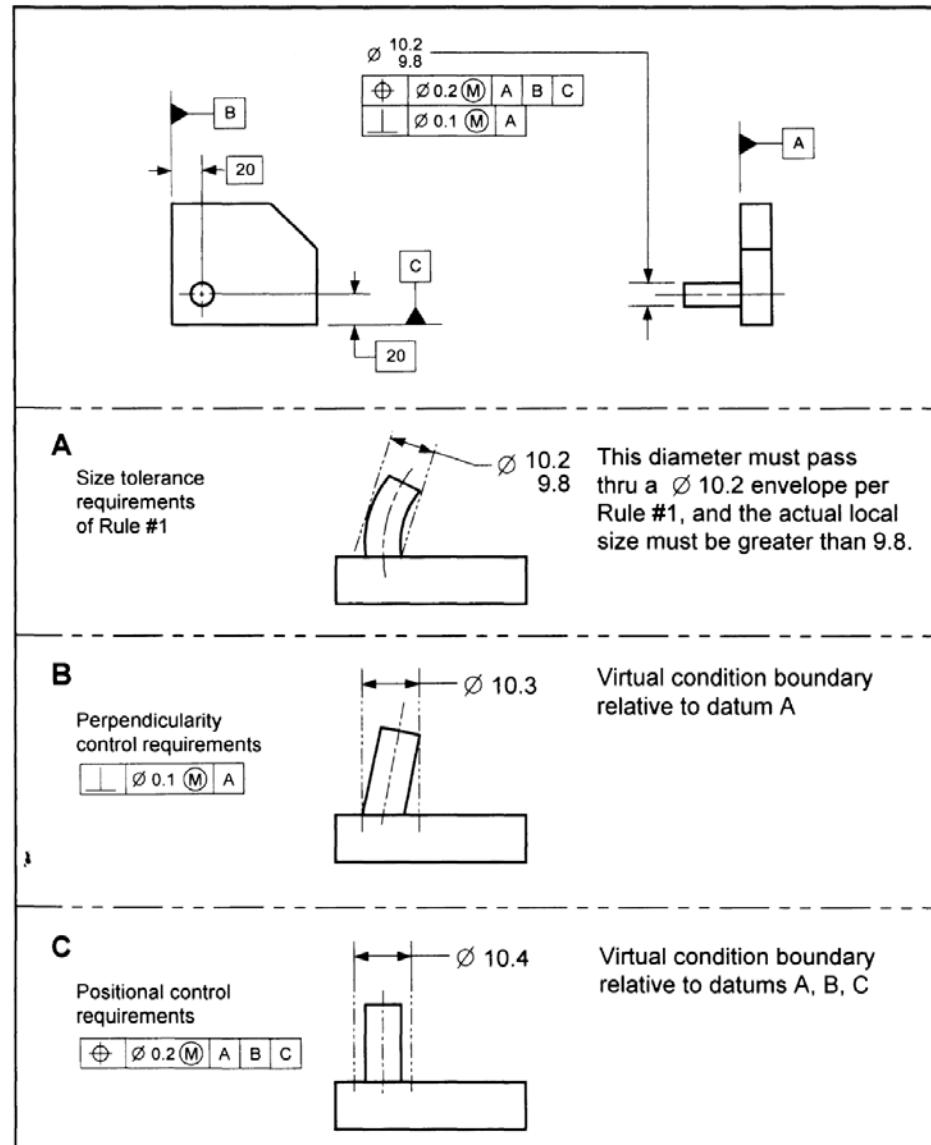
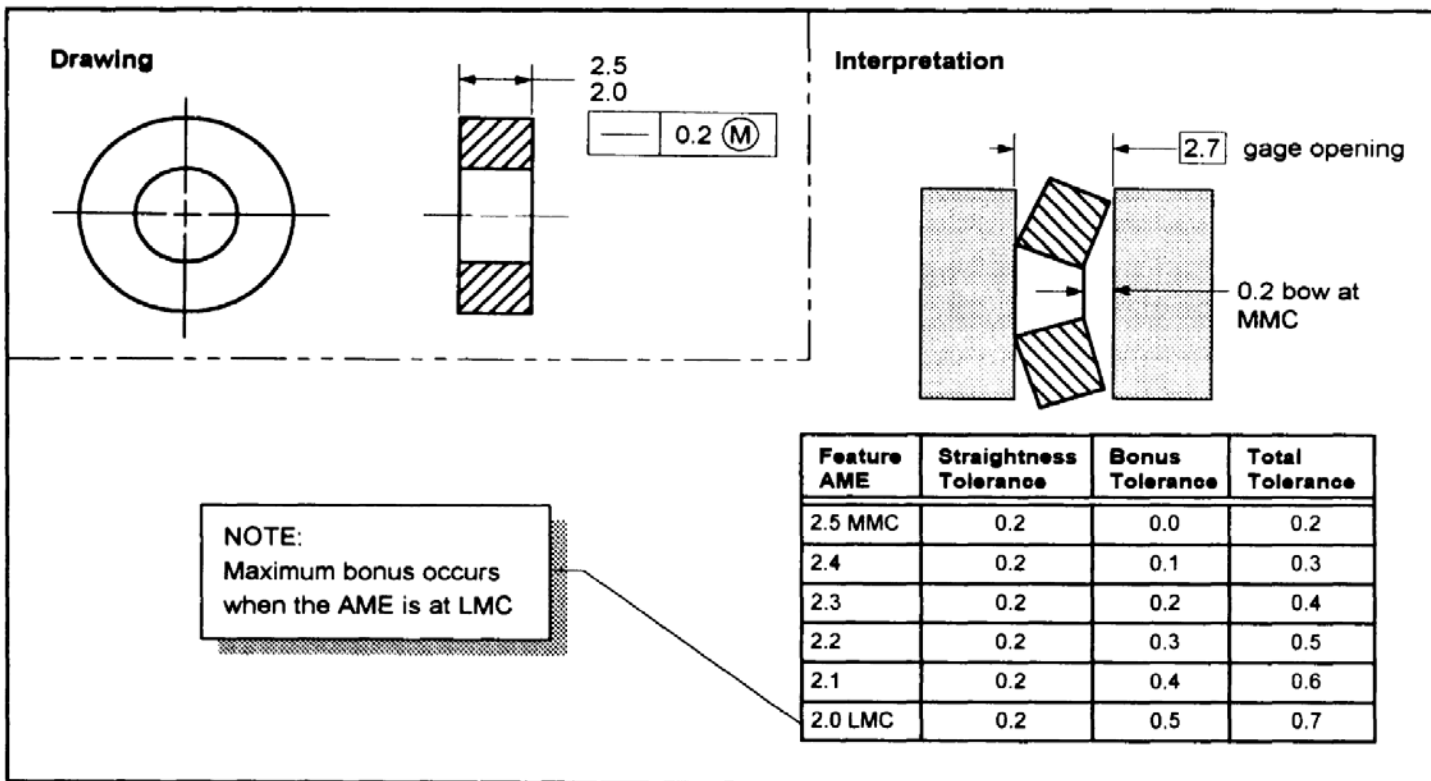


FIGURE 3-15 Multiple Virtual Conditions

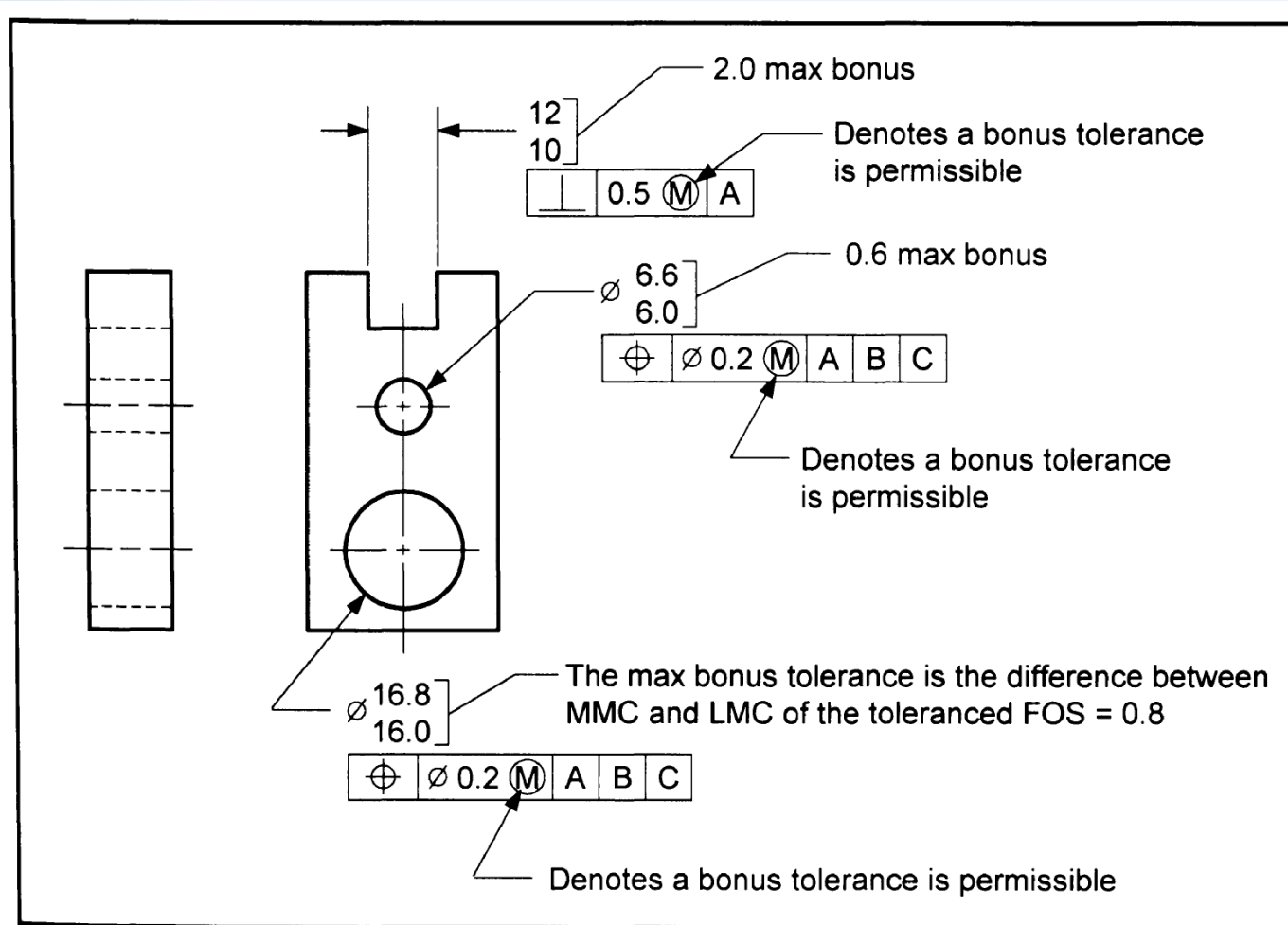
# INTRODUCTION TO BONUS TOLERANCE



**FIGURE 3-16 Bonus Tolerance Examples**



# INTRODUCTION TO BONUS TOLERANCE



**FIGURE 3-17 Bonus Tolerance**



# INTRODUCTION TO BONUS TOLERANCE

1. Bonus tolerance is an additional tolerance for a geometric control.
2. Bonus tolerance is only permissible when an MMC (or LMC) modifier is shown in the tolerance portion of a feature control frame.
3. Bonus tolerance comes from the FOS tolerance.
4. Bonus tolerance is the amount the actual mating size departs from MMC (or LMC).

# REFERENCES

<http://www.thayer.dartmouth.edu/mshop/pdf/introdr.pdf>  
[http://www.etinews.com/gdt\\_glossary.html](http://www.etinews.com/gdt_glossary.html)  
<http://www.meadinfo.org/2009/07/virtual-condition-gd.html>  
<http://www.engineersedge.com/gdt.htm>