ASME Y14.41-2019

(Revision of ASME Y14.41-2012)

Digital Product Definition Data Practices

Engineering Product Definition and Related Documentation Practices

AN INTERNATIONAL STANDARD

The American Society of Mechanical Engineers

ADOPTION NOTICE

ASME Y14.41, Digital Product Definition Data Practices, was adopted on 7 July 2003 for use by the Department of Defense (DoD). Proposed changes by DoD activities must be submitted to the DoD Adopting Activity: Commander, U.S. Army (ARDEC), ATTN: RDAR-QES-E, Picatinny Arsenal, NJ 07806-5000. Copies of this document may be purchased from The American Society of Mechanical Engineers (ASME), 150 Clove Road, 6th Floor, Little Falls, NJ 07424-2139; http://www.asme.org.

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AN INTERNATIONAL STANDARD

The American Society of Mechanical Engineers
Two Park Avenue • New York, NY • 10016 USA

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The next edition of this Standard is scheduled for publication in 2024.

Periodically certain actions of the ASME Y14 Committee may be published as Cases. Cases are published on the ASME website under the Y14 Committee Page at http://go.asme.org/Y14committee as they are issued.

Errata to codes and standards may be posted on the ASME website under the Committee Pages to provide corrections to incorrectly published items, or to correct typographical or grammatical errors in codes and standards. Such errata shall be used on the date posted.

The Y14 Committee Page can be found at http://go.asme.org/Y14committee. There is an option available to automatically receive an e-mail notification when errata are posted to a particular code or standard. This option can be found on the appropriate Committee Page after selecting "Errata" in the "Publication Information" section.

The American Society of Mechanical Engineers
Two Park Avenue, New York, NY 10016-5990

CONTENTS

Nonmandatory Appendices

Figures

Tables

FOREWORD

The development of this Standard was initiated at the request of industry and the government. A meeting was held to determine the interest in this subject in January 1997 in Wichita, Kansas, hosted by The Boeing Company in their facility. A subsequent meeting was held during the spring ASME meeting in 1997 to enlist membership of those who would be interested in working on this project.

The Chairs of the different Y14 standards continue to collaborate to improve the coordination of the Y14 standards. To this end, in this revision of ASME Y14.41 material regarding surface finish and weld symbols applied to the model has been added. The definitions for classification codes for data sets were developed within Y14.41 to describe the combinations of annotated model and drawing graphic sheets that might be required by a customer. These were given to ASME Y14.100-2013 and placed in Nonmandatory Appendix F. Seeing that most of these classification codes contain a model/annotated model, Nonmandatory Appendix F was duplicated and placed here as Nonmandatory Appendix B. At a later date, the classification codes that appear in ASME Y14.100-2017, Appendix F, will be removed and reference to Y14.41.

A clarification of the terms "model" and "annotated model" was added. An example of a nonuniform tolerance zone is shown and explained. This revision also provides guidance to limit the use of applying GD&T through notes suggesting that the use of annotation will allow for automated tools to consume those design requirements. Nonmandatory Appendix A, Table A-1 was added which contains information whether the requirements defined in this Standard can be accomplished completely by the data preparer or capabilities need to be provided by the software to meet the requirements. These additions allow the reader to find all of the requirements and information within the Standard.

It is essential that this Standard be used in close conjunction with ASME Y14.24, ASME Y14.34, ASME Y14.35, and ASME Y14.100. Although the primary purpose of ASME Y14 series standards is to establish requirements for the preparation and revision of product definition data, this Standard also includes various software-dependent requirements that may not be achievable without computer software tools that have been developed in support of facilitating these requirements. Examples of such requirements include associativity, stationary and rotating annotation planes, display management, attributes available on demand, annotation and annotation plane orientation, query, highlighting, and resolved dimension preservation and association. See Nonmandatory Appendix A for details.

This Standard is available for public review on a continuing basis. This provides an opportunity for additional public review input from industry, academia, regulatory agencies, and the public-at-large.

This edition was approved as an American National Standard on March 22, 2019.

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Engineering Product Definition and Related Documentation Practices

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General. ASME Standards are developed and maintained with the intent to represent the consensus of concerned interests. As such, users of this Standard may interact with the Committee by requesting interpretations, proposing revisions or a case, and attending Committee meetings. Correspondence should be addressed to:

Secretary, Y14 Standards Committee
The American Society of Mechanical Engineers
Two Park Avenue
New York, NY 10016-5990
http://go.asme.org/Inquiry

Proposing Revisions. Revisions are made periodically to the Standard to incorporate changes that appear necessary or desirable, as demonstrated by the experience gained from the application of the Standard. Approved revisions will be published periodically.

The Committee welcomes proposals for revisions to this Standard. Such proposals should be as specific as possible, citing the paragraph number(s), the proposed wording, and a detailed description of the reasons for the proposal, including any pertinent documentation.

Proposing a Case. Cases may be issued to provide alternative rules when justified, to permit early implementation of an approved revision when the need is urgent, or to provide rules not covered by existing provisions. Cases are effective immediately upon ASME approval and shall be posted on the ASME Committee web page.

Requests for Cases shall provide a Statement of Need and Background Information. The request should identify the Standard and the paragraph, figure, or table number(s), and be written as a Question and Reply in the same format as existing Cases. Requests for Cases should also indicate the applicable edition(s) of the Standard to which the proposed Case applies.

Attending Committee Meetings. The Y14 Standards Committee regularly holds meetings and/or telephone conferences that are open to the public. Persons wishing to attend any meeting and/or telephone conference should contact the Secretary of the Y14 Standards Committee. Future Committee meeting dates and locations can be found on the Committee Page at http://go.asme.org/Y14committee.

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Section 1
General

1.1 SCOPE

This Standard establishes requirements and references documents applicable to the preparation and revision of digital product definition data, hereafter referred to as data sets. This Standard defines exceptions and additional requirements to existing ASME standards for using digital product definition data set(s) or drawing graphic sheet(s) in digital format, hereafter referred to as drawing graphic sheet(s). When no exception or additional requirements are stated, existing ASME standards shall apply. It is essential that this Standard be used in close conjunction with ASME Y14.24, ASME Y14.34, ASME Y14.35, and ASME Y14.100.

1.2 STRUCTURE OF STANDARD

This Standard supports two methods of preparing a data set: annotated model, and an annotated model with a drawing graphic sheet. See paras. 5.2.1 and 5.2.2. The structure starts with the requirements common to both methods, and then branches to the other sections that have differing requirements for each method. In addition, it provides a guide for the many Computer-Aided Design (CAD) software packages to develop better modeling and annotation practices for CAD and engineering disciplines.

1.3 ASME Y14 SERIES CONVENTIONS

The conventions in paras. 1.3.1 through 1.3.9 are used in this and other ASME Y14 standards.

1.3.1 Mandatory, Recommended, Guidance, and Optional Words

(a) The word "shall" establishes a requirement.

(b) The word "will" establishes a declaration of purpose on the part of the design activity.

(c) The word "should" establishes a recommended practice.

(d) The word "may" establishes an allowed practice.

(e) The words "typical," "example," "for reference," or the Latin abbreviation "e.g." indicate suggestions given for guidance only.

(f) The word "or" used in conjunction with a requirement or a recommended practice indicates that there are two or more options for complying with the stated requirement or practice.

(g) The phrase "unless otherwise specified" or UOS shall be used to indicate a default requirement. The phrase is used when the default is a generally applied requirement and an exception may be provided by another document or requirement.

1.3.2 Cross-Reference of Standards

Cross-reference of standards in text with or without a date following the standard designator shall be interpreted as follows:

(a) Reference to other ASME Y14 standards in the text without a date following the standard designator indicates that the issue of the standard identified in the References section (Section 2) shall be used to meet the requirement.

(b) Reference to other ASME Y14 standards in the text with a date following the standard designator indicates that only that issue of the standard shall be used to meet the requirement.

1.3.3 Invocation of Referenced Standards

The following examples define the invocation of a standard when specified in the References section (Section 2) and referenced in the text of this Standard:

(a) When a referenced standard is cited in the text with no limitations to a specific subject or paragraph(s) of the standard, the entire standard is invoked. For example, "Dimensioning and tolerancing shall be in accordance with ASME Y14.5" is invoking the complete standard because the subject of the standard is dimensioning and tolerancing and no specific subject or paragraph(s) within the standard are invoked.

(b) When a referenced standard is cited in the text with limitations to a specific subject or paragraph(s) of the standard, only the paragraph(s) on that subject is invoked. For example, "Assign part or identifying numbers in accordance with ASME Y14.100" is invoking only the paragraph(s) on part or identifying numbers because the subject of the standard is engineering drawing practices and part or identifying numbers is a specific subject within the standard.

(c) When a referenced standard is cited in the text without an invoking statement such as "in accordance with," the standard is invoked for guidance only. For example, "For gaging principles, see ASME Y14.43" is only for guidance and no portion of the standard is invoked.

1.3.4 Parentheses Following a Definition

When a definition is followed by a standard referenced in parentheses, the standard referenced in parentheses is the source for the definition.

1.3.5 Notes

Notes depicted in this Standard in **ALL UPPERCASE** letters are intended to reflect actual drawing entries. Notes depicted in initial uppercase or lowercase letters are to be considered supporting data to the contents of this Standard and are not intended for literal entry on drawings. A statement requiring the addition of a note with the qualifier "such as" is a requirement to add a note, and the content of the note is allowed to vary to suit the application.

1.3.6 Acronyms and Abbreviations

Acronyms and abbreviations are spelled out the first time used in this Standard, followed by the acronym or abbreviation in parentheses. The acronym is used thereafter throughout the text.

1.3.7 Units

The International System of Units (SI) is featured in this Standard. It should be understood that U.S. Customary units could equally have been used without prejudice to the principles established.

1.3.8 Figures

The figures in this Standard are intended only as illustrations to aid the user in understanding the practices described in the text. In some cases, figures show a level of detail as needed for emphasis. In other cases, figures are incomplete by intent so as to illustrate a concept or facet thereof. The absence of figure(s) has no bearing on the applicability of the stated requirements or practice. To comply with the requirements of this Standard, actual data sets shall meet the content requirements set forth in the text. To assist the user of this Standard, a listing of the paragraph(s) that refer to an illustration appears in the lower right-hand corner of each figure. This listing may not be all inclusive. The absence of a listing is not a reason to assume inapplicability. Some figures are illustrations of models in a three-dimensional environment. The absence of dimensioning and tolerancing annotations in a view may indicate that the product definition is defined in 3D. Dimensions that locate or orient and are not shown are considered basic and shall be queried to determine the intended requirement. When the letter "h" is used in figures for letter heights or for symbol proportions, select the applicable letter height in accordance with ASME Y14.2. Multiview drawings contained within figures are third angle projection.

1.3.9 Precedence of Standards

The following are ASME Y14 Standards that are basic engineering drawing standards:

ASME Y14.1, Decimal Inch Drawing Sheet Size and Format
ASME Y14.1M, Metric Drawing Sheet Size and Format
ASME Y14.2, Line Conventions and Lettering
ASME Y14.3, Orthographic and Pictorial Views
ASME Y14.5, Dimensioning and Tolerancing
ASME Y14.24, Types and Applications of Engineering Drawings
ASME Y14.34, Associated Lists
ASME Y14.35, Revision of Engineering Drawings and Associated Documents
ASME Y14.36, Surface Texture Symbols
ASME Y14.38, Abbreviations and Acronyms for Use on Drawings and Related Documents
ASME Y14.41, Digital Product Definition Data Practices
ASME Y14.100, Engineering Drawing Practices

All other ASME Y14 standards are considered specialty types of standards and contain additional requirements or make exceptions to the basic standards as required to support a process or type of drawing.

1.4 REFERENCE TO THIS STANDARD

When data sets are based on this Standard, this fact shall be noted in the data set or in a document referenced by the data set. References to this Standard shall state ASME Y14.41-2019.

1.5 SYMBOLS

The use of symbols to indicate dimensional requirements does not preclude the use of equivalent terms or abbreviations in accordance with ASME Y14.38 when symbology is considered inappropriate.

Section 2
References

2.1 INTRODUCTION

The following revisions of American National Standards form a part of this Standard to the extent specified herein. A more recent revision may be used provided there is no conflict with the text of this Standard. In the event of a conflict between the text of this Standard and the references cited herein, the text of this Standard shall take precedence.

2.2 CITED STANDARDS

ASME Y14.1-2012, Decimal Inch Drawing Sheet Size and Format

ASME Y14.1M-2012, Metric Drawing Sheet Size and Format

ASME Y14.2-2014, Line Conventions and Lettering

ASME Y14.3-2012, Orthographic and Pictorial Views

ASME Y14.5-2018, Dimensioning and Tolerancing

ASME Y14.24-2012, Types and Applications of Engineering Drawings

ASME Y14.34-2013, Associated Lists

ASME Y14.35-2014, Revision of Engineering Drawings and Associated Documents

ASME Y14.38-2007, Abbreviations and Acronyms for Use on Drawings and Related Documents

ASME Y14.100-2017, Engineering Drawing Practices

Publisher: The American Society of Mechanical Engineers (ASME), Two Park Avenue, New York, NY 10016-5990 (www.asme.org)

IEEE/ASTM SI 10-2016, American National Standard for Use of the International System of Units (SI): The Modern Metric System[1]

Publisher: Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Lane, Piscataway, NJ 08854 (www.ieee.org)

AWS A2.4, Standard Symbols for Welding, Brazing, and Nondestructive Examination

Publisher: American Welding Society (AWS), 8669 NW 36 Street, #130, Miami, FL 33166 (www.aws.org)

[1] IEEE/ASTM standards are also available from the American Society for Testing and Materials (ASTM International), 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959 (www.astm.org).

Section 3
Terms and Definitions

The following terms are defined as their use applies in this Standard.

3.1 ANNOTATED MODEL

annotated model: a combination of model, annotation, and attributes that describe a product.

3.2 ANNOTATION

annotation: visible dimensions, tolerances, notes, text, or symbols.

3.3 ANNOTATION PLANE

annotation plane: a conceptual plane containing annotation.

3.4 ASSEMBLY MODEL

assembly model: an annotated model in which the product described is an assembly of two or more items.

3.5 ASSOCIATED ENTITY

associated entity: the portion of the product definition data to which annotation or attribute(s) pertain.

3.6 ASSOCIATED GROUP

associated group: a user-defined set of related digital elements.

3.7 ASSOCIATIVITY

associativity: the established relationship between digital elements.

3.8 ATTRIBUTE

attribute: a dimension, tolerance, note, text, or symbol required to complete the product definition or feature of the product that is not visible, but available upon interrogation of the annotated model.

3.9 COORDINATE SYSTEM

coordinate system: a representation of a system to determine the position of geometric elements in space, e.g., Cartesian coordinate system.

3.10 DATA

data: information represented in a formal manner suitable for communication, interpretation, or processing by human beings or computers.

3.11 DATUM SYSTEM

datum system: a partial or complete datum reference frame.

3.12 DERIVATIVE

derivative: data duplicated or extracted from the original. A copy of a derivative is also a derivative (ASME Y14.100).

3.13 DESIGN ACTIVITY

design activity: an organization that has, or has had, responsibility for the design of an item (ASME Y14.100).

3.14 DESIGN ACTIVITY IDENTIFICATION (DAI)

Design Activity Identification (DAI): the application of a unique identifier that distinguishes an activity or organization from another activity or organization. Examples of activity identification include activity name, activity name and address, or CAGE Code (ASME Y14.100).

3.15 DIGITAL ELEMENT

digital element: geometric element, feature, group of features, annotation, associated group, or attribute that exists in a data set.

3.16 DIGITAL ELEMENT IDENTIFIER

digital element identifier: a label or name used to specify a unique digital element.

3.17 DIRECTION-DEPENDENT TOLERANCE

direction-dependent tolerance: a tolerance that invokes a zone of parallel lines or curves.

3.18 DRAWING GRAPHIC SHEET

drawing graphic sheet: the two-dimensional (2D) geometric elements and annotations that define an item and the product definition elements of the sheet

format in accordance with ASME Y14.1 or ASME Y14.1M (ASME Y14.100).

3.19 FEATURE

feature: a physical portion of a part (such as a surface, pin outside diameter, hole, or slot) or its representation on drawings, models, or digital data files (ASME Y14.5).

3.20 GEOMETRIC ELEMENT

geometric element: a discrete entity (e.g., point, line, curve, plane, surface, solid, volume, vector, coordinate system) used in a digital data set to represent or present physical features of the product definition.

3.21 HARD COPY

hard copy: a printed or plotted copy of a displayed image on a medium such as paper or polyester film.

3.22 INSTALLATION MODEL

installation model: an annotated model in which the product described is an installation, showing parts or assemblies and a partial or complete representation of the installation site.

3.23 ITEM

item: a nonspecific term used to denote any unit or product including materials, parts, assemblies, equipment, accessories, and computer software (ASME Y14.100).

3.24 MANAGEMENT DATA

management data: the data required for the release, control, and storage of product definition data as well as other relevant engineering data.

3.25 MODEL

model: the portion of the data set that contains model geometry and supplemental geometry.

3.26 MODEL GEOMETRY

model geometry: geometric elements used to represent the definition of an item.

3.27 MODEL VALUE

model value: the numerical value derived by interrogating the model that quantifies the form and spatial relationships of the geometry composing a model, or assembly of models, to the precision of the computer system.

3.28 ORIGINAL

original: the current design activity's reproducible drawing or data set on which the revision record is kept and recognized as official (ASME Y14.100).

3.29 PRECISION

precision: indicates the number of significant digits of the product definition required in the production of the part to fulfill the design intent.

3.30 PRODUCT DEFINITION DATA

product definition data: denotes the totality of product definition elements required to completely define a product. Product definition data includes geometry, topology, relationships, tolerances, attributes, and features necessary to completely define a component part or an assembly of parts for the purpose of design, analysis, manufacture, test, and inspection (ASME Y14.100).

3.31 PRODUCT DEFINITION DATA SET

product definition data set: a collection of one or more data file(s) that discloses, directly or by reference, by means of presentation (e.g., graphic or textual), representation (e.g., semantics or machine readable), or combinations of both, the physical or functional requirements of an item.

3.32 PRODUCT DEFINITION ELEMENTS

product definition elements: a unit of data for which the definition, identification, representation, and permissible values are specified (ASME Y14.100).

3.33 QUERY

query: a means of interrogating a digital element or the relationship between digital elements.

3.34 REPRESENTED LINE ELEMENT

represented line element: a supplemental geometry line or curve segment indicating the orientation of a direction dependent tolerance.

3.35 RESOLVED DIMENSION

resolved dimension: a model value that is rounded off to the number of decimal places required for the design.

3.36 SAVED VIEW

saved view: a stored and retrievable specific orientation and a magnification factor of an annotated model (ASME Y14.3).

3.37 SPECIAL CHARACTER

special character: entries such as dash (-), slash (/), and asterisk (*) that are not included in the set of capital letters A-Z, lowercase letters a-z, numerals 0-9, and punctuation symbols (ASME Y14.100).

3.38 SUPPLEMENTAL GEOMETRY

supplemental geometry: geometric elements included in product definition data to communicate design requirements but not intended to represent an item.

3.39 ACRONYMS

The following is a list of acronyms used in this Standard:

3.39.1 ASME

ASME stands for The American Society of Mechanical Engineers.

3.39.2 CAD

CAD stands for Computer-Aided Design.

3.39.3 CAGE

CAGE stands for Commercial and Government Entity.

3.39.4 GD&T

GD&T stands for geometric dimensioning and tolerancing.

3.39.5 IEEE

IEEE stands for the Institute of Electrical and Electronics Engineers.

3.39.6 PIN

PIN stands for Part or Identifying Number.

3.39.7 SI

SI stands for the International System of Units.

3.40 ABBREVIATIONS

The following is a list of abbreviations used in this Standard:

3.40.1 2D

2D stands for two-dimensional.

3.40.2 3D

3D stands for three-dimensional.

3.40.3 deg

deg stands for degree.

Section 4
Data Set Identification and Control

This Section establishes requirements for a data set identification system.

4.1 GENERAL

The current revision of the data and the computer application(s) and version(s) used to develop the data set shall be specified with other management data. See subsection 5.3.

4.1.1 Data Set Identifier

The identification of the data set, the annotated model, the drawing graphic sheet, the associated lists when used, and the Part or Identifying Number (PIN) for the item being defined may be identical. See Figure 4-1. The data set identifier shall be unique and consist of numeric, alpha, or special characters in any combination. Spaces are not permitted between any of the characters of the data set identifier.

(a) Data Set Identifier Length. The length of the data set identifier may be a direct function of the computer system and the operating system. When the PIN is used as the data set identifier, the length shall be compatible with recognized limitations on PIN number length in accordance with ASME Y14.100.

(b) Special Characters. Special characters shall be selected in a manner that does not hinder data set identification or have an adverse effect on the computer system operation such as dash (-), slash (/), or asterisk (*).

(c) Identifier Prefixes and Suffixes. A recognizable prefix or suffix may be included as part of the identifier to associate files and sets of related data.

4.1.2 Drawing Graphic Sheet Identification

Drawing graphic sheet identification shall be assigned in accordance with ASME Y14.100.

4.1.3 Associated List Identification

Associated list identification shall be assigned in accordance with ASME Y14.34.

4.1.4 Part or Identifying Number

The PIN shall be assigned in accordance with ASME Y14.100.

4.2 RELATED DATA

Related data shall be integral to or referenced in the data set. Related data consists of, but is not limited to the following: analytical data, associated lists, test requirements, material specifications, and process and finish requirements in accordance with Figure 4-1.

4.3 DATA MANAGEMENT

Paragraphs 4.3.1 through 4.3.4 describe the structure and control requirements for data management.

4.3.1 Management System

A data management system shall provide control and tracking information of the data sets. This system may include work in process, data-review status, annotated-model-checked status, release status, design tool and version, libraries.

4.3.2 Approval

The data set shall be approved in accordance with ASME Y14.100.

4.3.3 Storage and Retention

Data sets shall be controlled and available throughout the life cycle of a product.

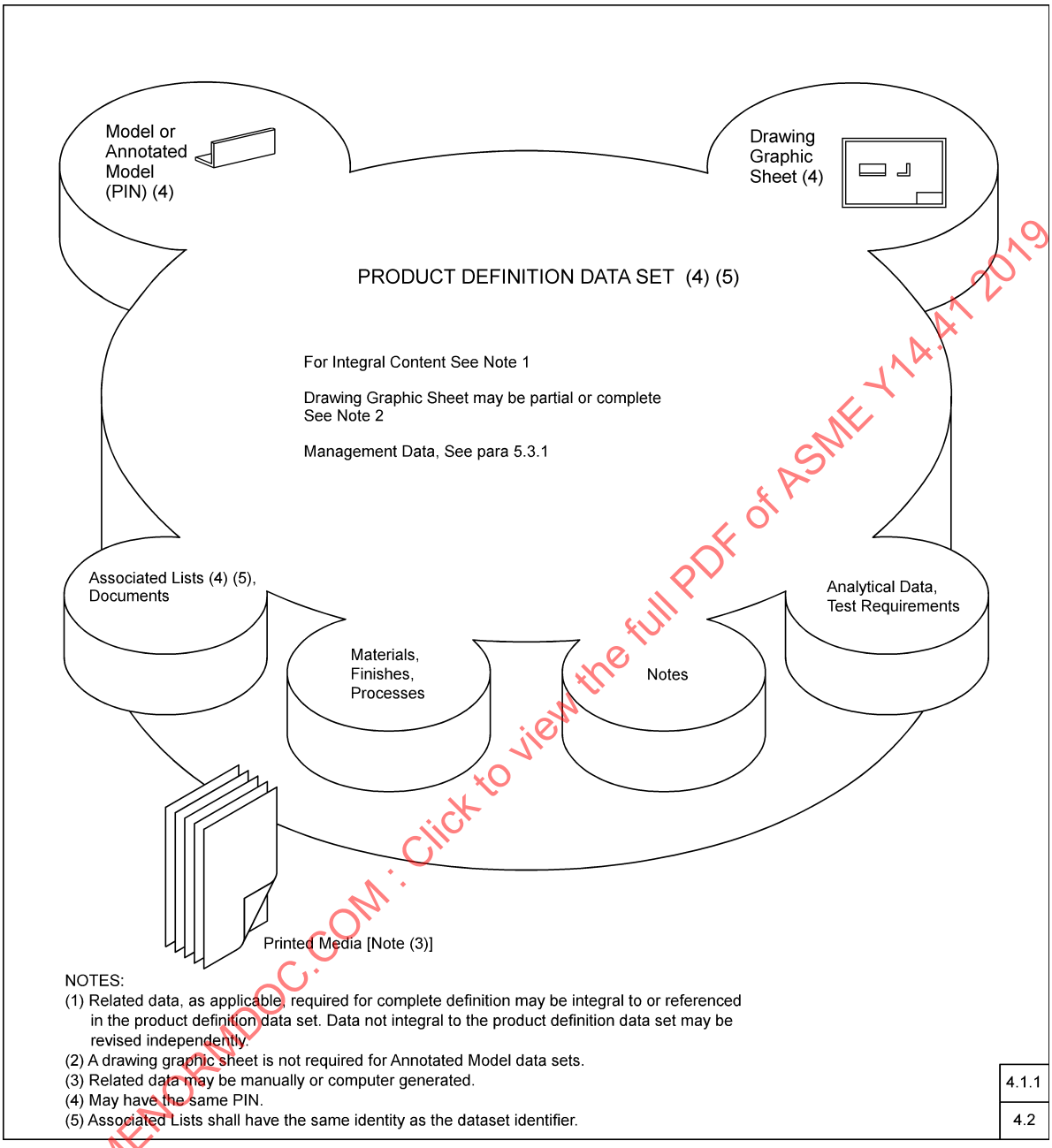
4.3.4 Revision History

The following requirements apply to revision history:

(a) Revision history shall be prepared in accordance with ASME Y14.35.

(b) Revision history shall be recorded in the data set.

Figure 4-1 Contents of a Product Definition Data Set



NOTES:
(1) Related data, as applicable, required for complete definition may be integral to or referenced in the product definition data set. Data not integral to the product definition data set may be revised independently.
(2) A drawing graphic sheet is not required for Annotated Model data sets.
(3) Related data may be manually or computer generated.
(4) May have the same PIN.
(5) Associated Lists shall have the same identity as the dataset identifier.

4.1.1
4.2

Section 5
Data Set Requirements

This Section establishes the requirements for a data set. The data set shall provide complete product definition; for example, a model, its annotation, attributes, and supporting documentation.

5.1 GENERAL ANNOTATED MODEL REQUIREMENTS

Paragraphs 5.1.1 through 5.1.7 describe general requirements for an annotated model.

5.1.1 Model Requirement

A model is required and shall be in accordance with Section 6.

5.1.2 Associativity

Associativity shall be available, maintainable, and electronically accessible.

5.1.3 Coordinate Systems

An annotated model shall contain one or more coordinate systems. A coordinate system shall be depicted by three mutually perpendicular line segments with its origin located at the intersection of the three axes. Each axis shall be labeled with an uppercase letter indicating the positive direction. Coordinate systems shall be right-handed unless otherwise specified. See Figure 5-1.

5.1.4 Applications of Supplemental Geometry

When supplemental geometry is used, there shall be a clear distinction between the supplemental geometry and the model geometry. The following is a list of requirements for the use of supplemental geometry.

(a) Represented Line Element. The following geometric tolerances may use a represented line element to clarify the directionality of a two-dimensional tolerance zone of parallel lines. When a represented line element is used to indicate the direction of a geometric tolerance application, the leader from the feature control frame shall terminate on the represented line element in an arrowhead. See Figure 12-4.

(1) Straightness applied to the line elements of a planar surface. See Table 12-1 and Figure 12-4.

(2) Orientation tolerance applied on an Each Element basis. See para. 12.2.2(a) and Figure 12-9.

(3) Line profile. See para. 12.2.3(e) and Figure 12-18.

(b) Associativity. The represented line element, the feature control frame, and the controlled feature shall be associated. See Figures 12-4, 12-9, and 12-18.

(c) Centerlines and Centerplanes. Display of centerlines or centerplanes for features of size are optional.

(d) Direction of Movement for Movable Datum Targets. Represented line elements are used to indicate the direction of movement for movable datum targets. See para. 11.2.3(b) and Figure 11-4, illustration (b) or para. 11.3(d) and Figure 11-11, illustration (b).

(e) Datum Target Areas or Locations. The areas for datum targets may be indicated using supplemental geometry. The "X" for point targets may also be indicated using supplemental geometry. See Figure 11-4, illustration (b).

(f) Nonuniform Tolerance Zones. Nonuniform tolerance zone boundaries for profile, as defined in ASME Y14.5, shall be modeled using supplemental geometry. See para. 12.2.3.1 and Figure 12-20.

5.1.5 Part Features Not Fully Modeled

A simplified representation of part features such as threads, holes, fillets, rounds, and drafts may be shown using partial geometry definition, annotations, attributes, or a combination thereof. See Figure 7-4 and para. 6.1.2.

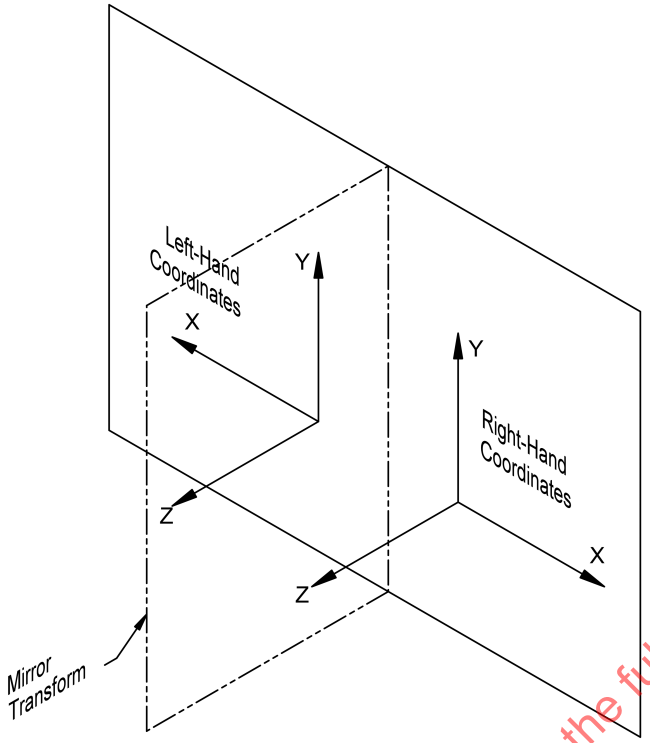
5.1.6 Assembly Model Completeness

Assembly model completeness shall be in accordance with para. 6.1.2, except part and subassembly models shown in the assembly model need only show sufficient detail to ensure correct identification, orientation, and placement. The assembly model may be shown in an exploded, partially assembled, or completely assembled state. Location and orientation of parts and subassemblies may be shown by geometric definition, annotation, attributes, or a combination thereof.

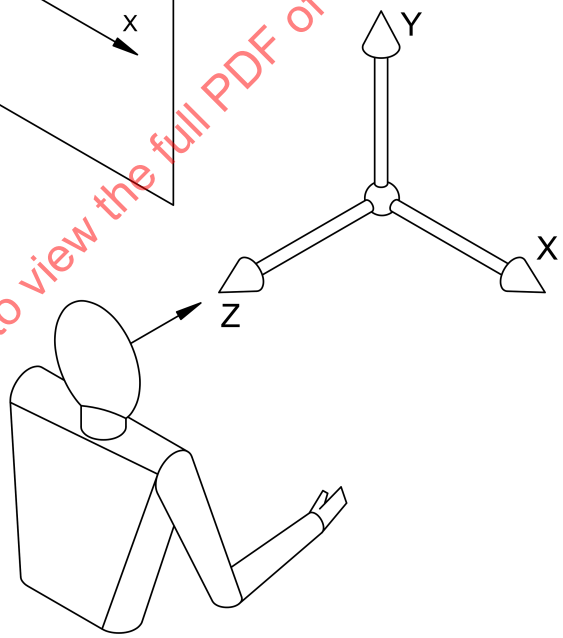
5.1.7 Installation Model Completeness

Installation completeness shall be in accordance with paras. 6.1.2 and 5.1.6 except part, assembly, and installation models shown in the installation model need only show sufficient detail to provide installation and space requirements. The maximum envelope for part, assembly, and installation may be shown using supplemental

Figure 5-1 Left-Hand and Right-Hand Coordinate Systems



(a) Mirror Image Relationship.



Right-hand Coordinate System:
When observed in the negative Z direction with positive Y ascending, positive X is directed to the right-hand side of the observer.

(b) Recognizing the right-hand system.

5.1.3

geometry, annotation, or a combination of both. Location and orientation of part, assembly, and installation may be shown by geometric definition, annotation, attributes, or a combination thereof.

5.2 GENERAL METHOD REQUIREMENTS

Paragraphs 5.2.1 and 5.2.2 cover the product-definition methods. Each different method for specifying product definition is used in support of different industry processes and requirements. The data set is the original for all of the methods, and any hard-copy output is a derivative.

5.2.1 Annotated Model Without a Drawing Graphic Sheet Method

The annotated model without a drawing graphic sheet method provides the same product design requirements as a drawing graphic sheet that contains complete product definition. All Y14 standards apply to an annotated model, unless exceptions or additions are identified. The following subparagraphs describe requirements when an annotated model is used without a drawing graphic sheet.

(a) Product definition data, including but not limited to notes, associated lists, marking requirements, dimensions, and tolerances shall be contained or referenced in the data set.

(b) The following product definition elements of a drawing graphic sheet format as defined in ASME Y14.1 or ASME Y14.1M are required and shall be contained in the data set:

(1) Design Activity Identification, e.g., Commercial and Government Entity (CAGE) Code
(2) data set title
(3) data set identifier
(4) approval indicators and approval dates
(5) contract number when required
(6) originator's name and date

(c) When working with an annotated model, the first or third angle projection symbol in accordance with ASME Y14.3 is not required.

5.2.2 Annotated Model With a Drawing Graphic Sheet Method

Subparagraphs (a) through (k) describe requirements when complete product definition is contained in the annotated model and drawing graphic sheet.

(a) A complete definition of a product shall contain an annotated model and a drawing graphic sheet that may contain orthographic views, axonometric views, or a combination thereof. Annotation may be applied to the annotated model, on the drawing graphic sheet, or a combination of both.

NOTE: The development of a drawing graphic sheet that provides a complete product definition is allowed.

(b) Product definition data created or shown in the annotated model and subsequently shown on the drawing graphic sheet shall be in agreement.

(c) Product definition data created and shown on the drawing graphic sheet shall not conflict with product definition data in the annotated model.

(d) The drawing graphic sheet shall contain a border and title block information in accordance with ASME Y14.1 or ASME Y14.1M.

(e) The drawing graphic sheet or associated list shall reference all applicable annotated models or models and data for the product specified.

(f) Minimum drawing graphic sheet hard copy output capability shall be in accordance with ASME Y14.1 or ASME Y14.1M, ASME Y14.2, and ASME Y14.3.

(g) Annotation displayed on the drawing graphic sheet shall be interpretable without the use of query.

(h) When complete product definition is not contained on the drawing graphic sheet, it shall be noted.

(i) When complete product definition is not contained in the annotated model, it shall be noted.

(j) Dimensions, tolerances, datum specifications, and notes on drawing graphic sheets may be shown in true profile views and refer to visible outlines, or appear in axonometric views.

(k) The use of color is acceptable on drawing graphic sheets prepared by digital data files.

5.3 MANAGEMENT DATA

Management data that is not placed on a drawing graphic sheet shall be placed in the annotated model or in the data set.

5.3.1 Management Data in the Data Set

The following management data shall be contained in the data set or in the annotated model as applicable:

(a) application data
(b) approval
(c) data set identification
(d) design activity transfer
(e) revision history for the data set
(f) ASME Y14.41 Note
(g) CAD Maintained Notation
(h) Design Activity Identification
(i) Duplicate Original Notation
(j) item identification
(k) SI/U.S. Customary Notation
(l) navigation data
(m) scale

5.3.2 Management Data in an Annotated Model

Management data in an annotated model shall be included as annotation, attributes, or both. The management data shall not rotate when presented as annotation.

5.4 SECURITY MARKINGS

Security markings shall be placed in the file(s) or in the referenced document(s) to which it applies. The following requirements pertain to annotated models.

5.4.1 Location of Security Marking on Annotated Models

Security marking in an annotated model shall be included as annotation, attributes, or both. The security marking shall not rotate when presented as annotation. Reproductions and derivatives of technical data, or any portions thereof, subject to asserted restrictions, shall also reproduce the asserted restrictions.

5.4.2 Government, Department of Defense, and Other Federal Agencies Security Marking

Annotated models containing classified information, e.g., secret, confidential, etc., shall

(a) contain the applicable security markings

(b) be controlled in accordance with the applicable security level

(c) have the applicable security markings constantly displayed for all mediums of viewing

5.4.3 Company Security Marking

Annotated models containing company intellectual property may include notes to this effect. These include, but are not limited to, the following:

(a) company proprietary notes

(b) competition sensitive information

(c) copyright notices

The display and control shall be in accordance with company policy.

5.4.4 Government Notices, Statements, and Legends

Annotated models may require government notices, statements, and legends. Contractual requirements determine which are applicable. These include, but are not limited to

(a) distribution statements

(b) export control notices

(c) rights in data legends

(d) copyright and trademark markings

5.5 VIEWS ON ANNOTATED MODELS

See ASME Y14.3 for sections and views.

Section 6
Model Requirements

This Section establishes the requirements for a model.

6.1 GENERAL

Models represent ideal geometric constructs; that is, perfect dimensionality and shape aspect of the part geometry are assumed. Parts shall be modeled at a specified dimensional condition(s); for example, minimum, maximum, or mean. The dimensional condition(s) shall be specified in one or more notes or in a referenced document.

6.1.1 Geometric Scale, Units, and Precision

The following are the requirements concerning the scale, units, and precision of a model:

(a) Scale. Unless otherwise specified, models shall be created at a scale of 1:1. When the model is not created at 1:1 scale, the scale shall be indicated in the Management Data. See para. 5.3.1.

(b) Units. The units of measure (SI or U.S. Customary) at which the model is created shall be specified within the data set.

(c) Precision. The precision for interpreting data from a model shall be at least one significant digit higher than the maximum number of significant digits used in the annotations and attributes in the data set. The number of significant digits required for the product definition shall not exceed the precision capabilities of the CAD application.

6.1.2 Model Completeness

The model shall contain the complete geometric definition of the part.

(a) Models not fully modeled shall be identified as such (e.g., partially modeled symmetrical part).

(b) Features that are not fully modeled shall be identified as such (e.g., threaded holes that are only shown as holes).

Section 7
Annotated Model and Drawing Graphic Sheet Requirements

This Section establishes the requirements for the application, display management, and query of product definition data in annotated models and drawing graphic sheets. Specific requirements for particular types of product definition data are described in Sections 8 through 14.

7.1 COMMON REQUIREMENTS

Paragraphs 7.1.1 through 7.1.4 describe requirements common to annotated models and drawing graphic sheets.

7.1.1 Display Management

Display management shall include the ability to enable or disable the display of all annotation, annotation by type, or selected annotation, except as noted in subsection 5.4. See Figure 7-1.

7.1.2 Hard Copy

A hard copy of any given visual display shall be available on demand. When a hard copy is intended to be used as a drawing graphic sheet, it shall meet applicable drawing graphic sheet standards.

7.1.3 Leader Lines

The following subparagraphs describe common requirements for leader lines.

(a) Leader lines directed to represented line elements shall terminate with an arrowhead. See Figure 12-18.

(b) When an indicated element is a surface, the leader shall terminate with a dot within the bounds of the surface. Leader lines may terminate on the rim or edge of a feature of size when doing so provides a clearer understanding of the intention of the annotation. Leader lines on a rim or edge shall terminate with an arrowhead. See Figure 7-2.

7.1.4 Attributes

Attributes are used to capture additional information that is not shown using geometry or shown as annotation on the annotated model. Attributes shall be available on demand. Attributes may be presented using text description, forms, or other techniques. See Figure 7-4 for an example of how the attributes of a hole could be represented. Applications of attributes include, but are not limited to, coatings, knurling, threaded holes, and pins.

7.2 ANNOTATED MODEL REQUIREMENTS

Paragraphs 7.2.1 through 7.2.6 describe requirements for annotation applied to a model. These are general requirements that apply to all types of annotation. Specific requirements for particular types of annotation are addressed in Sections 8 through 14. See Figure 7-2 for a diagram showing the relationship between annotation and model geometry.

7.2.1 Associativity

The following are general requirements for defining an associative relationship between digital elements.

(a) Selection of Associated Entities. Annotation may be associated to a feature, a group of features, or a portion of an applicable feature. For an example of the associated features for a dimension, see Figure 7-3.

(b) Associated Groups. Annotation, model geometry, and supplemental geometry may be placed into associated groups to indicate their relationships. For example:

(1) supplemental geometry used to define location, orientation, or further clarify the application of annotation in an annotated model

(2) a coordinate system for datum symbols and datum targets

(3) other annotation. This could include qualifying notes and size limit callouts

(c) Associativity Agreement. The associated entities, annotation, and attributes shall be in agreement with each other.

(d) Continuous Feature. When features are designated as CONTINUOUS FEATURE or the continuous feature symbol is used, the appropriate features should be designated as the associated objects for the accompanying Geometric Dimensioning and Tolerancing (GD&T). Extension lines between the features shall not be used on annotated models.

7.2.2 Annotation Planes

The following describe the requirements for annotation planes and their use.

(a) Annotation in Annotation Planes. All annotation shall be specified in one or more annotation planes.

(b) Annotation Plane Orientation. The orientation and normal vector of the annotation plane shall be maintained relative to the geometry as the annotated model is

manipulated in three-dimensional (3D) space. See Figure 7-5 and (c). When CAD software does not support maintenance of annotation plane orientation relative to the geometry, the annotated model method shall not be used.

(c) Annotation Reading Direction. To ensure the annotation is being interpreted as intended (for example, the text could be upside down or backwards following rotation of the annotated model), one of the following techniques shall be used:

(1) ensure the reading direction is updated after rotation of an annotated model.

(2) include a means of determining the correct reading direction in each annotation plane applied to an annotated model.

(3) when using saved views, ensure the annotated model is orientated in the intended view direction. For example, this may be accomplished by including a means of determining the correct reading direction in the view.

(d) Use of True Profiles. When tolerancing features, alignment of the annotation plane to the true profile is not required.

(e) Annotation Legibility. Legibility requirements of ASME Y14.2 shall apply when the annotation is viewed perpendicular to the annotation plane.

(f) Overlapping Annotation in an Annotation Plane. Annotation in any given annotation plane shall not overlap other annotation in the same annotation plane when the annotated model is viewed in the intended view direction.

(g) Annotation Over the Model. Annotation within any given annotation plane may be placed over the model when the annotated model is viewed perpendicular to the annotation plane as long as the annotation is readable.

(h) Annotation Inside the Geometry of the Model. Annotation within any given annotation plane may be placed inside the geometry of the model as long as the annotation is readable.

7.2.3 Leader and Extension Lines

Requirements for leader and extension lines in annotated models are described as follows:

(a) Extension Lines. Visible gaps between extension (projection) lines and geometry are not required on annotated models.

(b) Leader Lines

(1) A solid leader line shall be used to indicate all datum targets in an annotated model.

(2) Leader lines shall be directed to an associated entity. See para. 7.2.1(c).

7.2.4 Direction-Dependent Tolerances

When a direction-dependent tolerance (e.g., straightness) is applied to an annotated model, the direction shall be explicitly defined as described in either (a) or (b) as follows:

(a) Supplemental geometry is added to the model geometry to define the direction of application. The model geometry to which the tolerance applies shall be defined as the associated geometry for the annotation. See Figures 12-4, 12-9, and 12-18, and para. 5.1.4(a).

(b) A coordinate system vector is used to define the direction of application. The coordinate system vector, associated feature, and tolerance shall be organized as an associated group. See Figures 12-5, 12-10, and 12-19.

7.2.5 Indicating Limited Application of a Tolerance

Limited length, area, and location indicators may consist of, but are not limited to, supplemental geometry and associative annotation. When supplemental geometry is used, it shall be located on the model geometry. See Figures 11-3 and 12-16.

7.2.6 Query

The ability to query the annotated model shall be available. A notation stating the requirement for query of the annotated model or associated data shall be added to the drawing graphic sheet or in the general notes. The annotated model shall contain information needed to enable the following types of queries. The software shall be able to support all of these requirements individually and in any combination. See Nonmandatory Appendix A for more information.

(a) Obtaining Model Values. Model values shall be obtainable from the annotated model.

(b) Annotation To/From Model Geometry. The ability to traverse the relationship between model geometry and annotation, in either order, shall be available within the annotated model. This includes

(1) Graphic Display of Associated Entities. The associated entities for a piece of annotation shall be highlighted, or otherwise distinguished from other entities on the display, on demand. See Figure 7-3 and Figure 11-10, illustrations (b) through (f).

(2) Graphic Display of Associated Annotation. All annotations associated with selected geometry or features shall be highlighted, or otherwise distinguished from other entities, on demand. See Figure 7-6 and Figure 12-3, illustration (c).

(c) Digital Element Identifiers. Digital element identifiers shall be obtainable from the annotated model. See Figure 7-7.

(d) Model Geometry and Features

(1) Features shall be identifiable by selecting a geometric element of the feature.

(2) All geometric elements in an associated group shall be identifiable by selecting any geometric element within the group.

(3) All features in an associated group shall be identifiable by selecting one of the features.

(e) Feature Control Frames, Datum Feature Symbols, and Datum Targets

(1) Upon selection of a feature control frame, the datum feature symbols and datum target symbols that correspond to the datum references shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-8.

(2) Upon selection of a feature control frame, the portion of the corresponding coordinate system representing the partial or complete datum reference frame referenced in the feature control frame shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-10, illustration (a).

(3) Upon selection of a nonuniform profile feature control frame, the associated nonuniform tolerance zone and the associated toleranced feature(s) shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-13, illustration (a).

(4) Upon selection of a datum target symbol or a datum feature symbol, other datum target symbols and datum feature symbols that have the same datum letter shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-9.

(f) Annotation and Supplemental Geometry. Upon selection of annotation, the supplemental geometry used in the definition of the annotation shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-10, illustration (b).

(g) Nonuniform Tolerance Zone

(1) Upon selection of a nonuniform tolerance zone, the associated toleranced feature(s) and the nonuniform profile feature control frame shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-13, illustration (b).

(2) Upon selection of a feature controlled by a nonuniform profile tolerance, the nonuniform tolerance zone and the nonuniform profile feature control frame shall be highlighted or otherwise distinguished from other entities on the display. See Figure 7-13, illustration (c).

(h) Associated Groups. Upon selection of one of the digital elements in an associated group, the members of the associated group shall be highlighted or otherwise distinguished from other entities on the display.

(i) Attribute. Upon interrogation of any specific feature or aspect of the annotated model, the attribute data shall be provided. See para 7.1.4.

7.3 DRAWING GRAPHIC SHEET REQUIREMENTS

See ASME Y14.3 for sections and views. Specific requirements for particular types of annotation are addressed in Sections 8 through 14. The relationship between an annotated model and a drawing graphic sheet is illustrated in Figures 7-11 and 7-12. Figure 7-11 shows an annotated model where all of the annotation is displayed on the model at the same time, or in one Saved View. Figure 7-12 shows the same model geometry with no annotation displayed and all of the annotation has been placed in orthographic views on a drawing graphic sheet. Either method may be used.

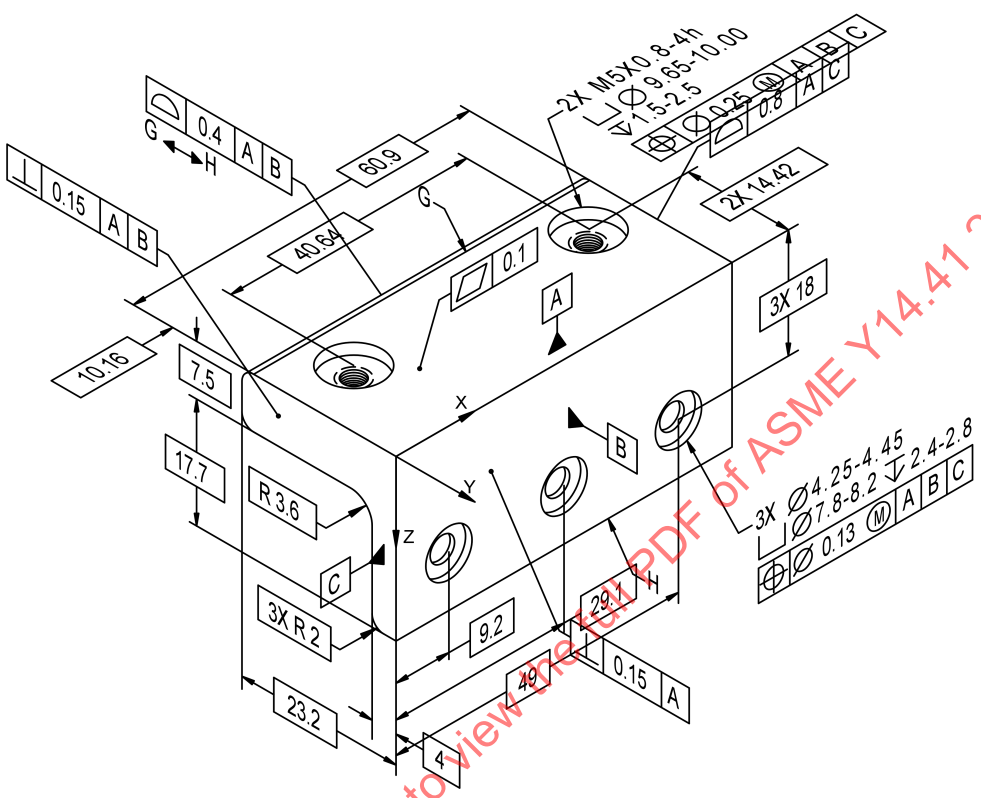
7.3.1 Annotation in Axonometric Views

(a) The orientation of the annotation shall be parallel to, normal to, or coincident with the surface to which it applies.

(b) Annotation shall not overlap other annotation.

(c) Annotation shall not overlap the part.

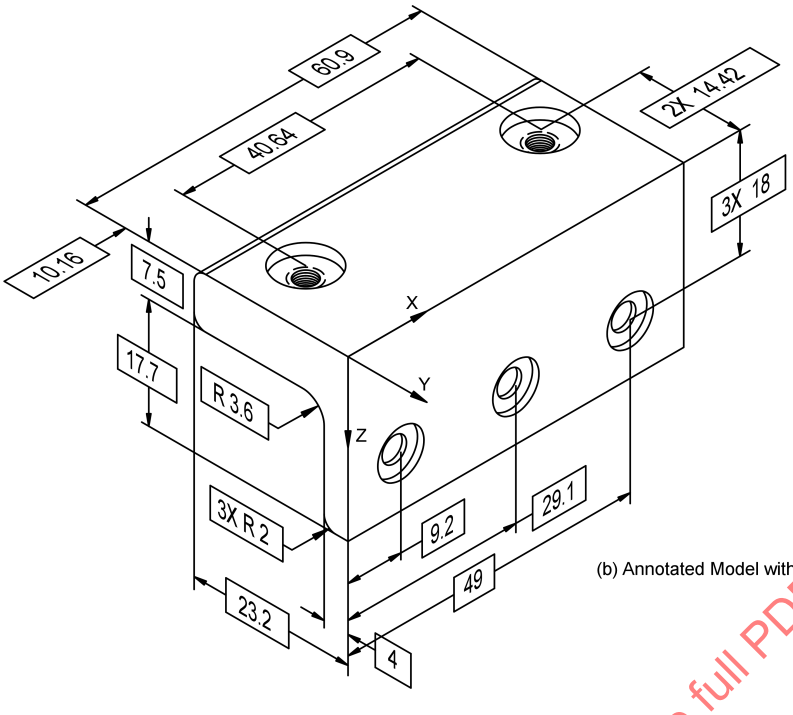
Figure 7-1 Display Management



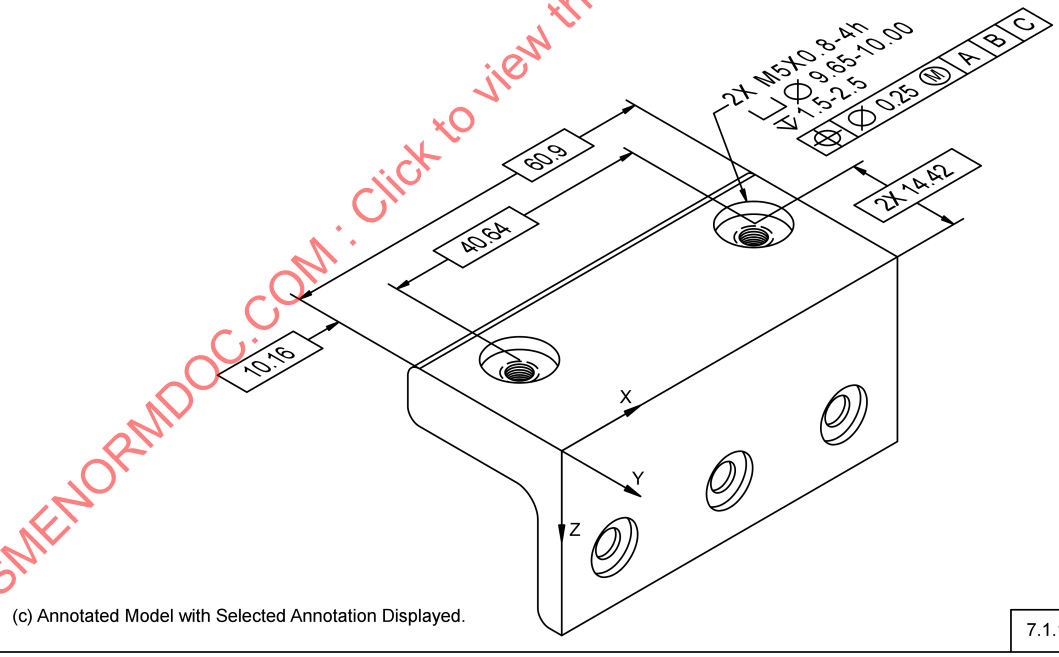
(a) Annotated Model With All Annotation Displayed.

7.1.1

Figure 7-1 Display Management (Cont'd)



(b) Annotated Model with One Type of Annotation Displayed.



(c) Annotated Model with Selected Annotation Displayed.

7.1.1

Figure 7-2 Annotation and Model Geometry Relationship

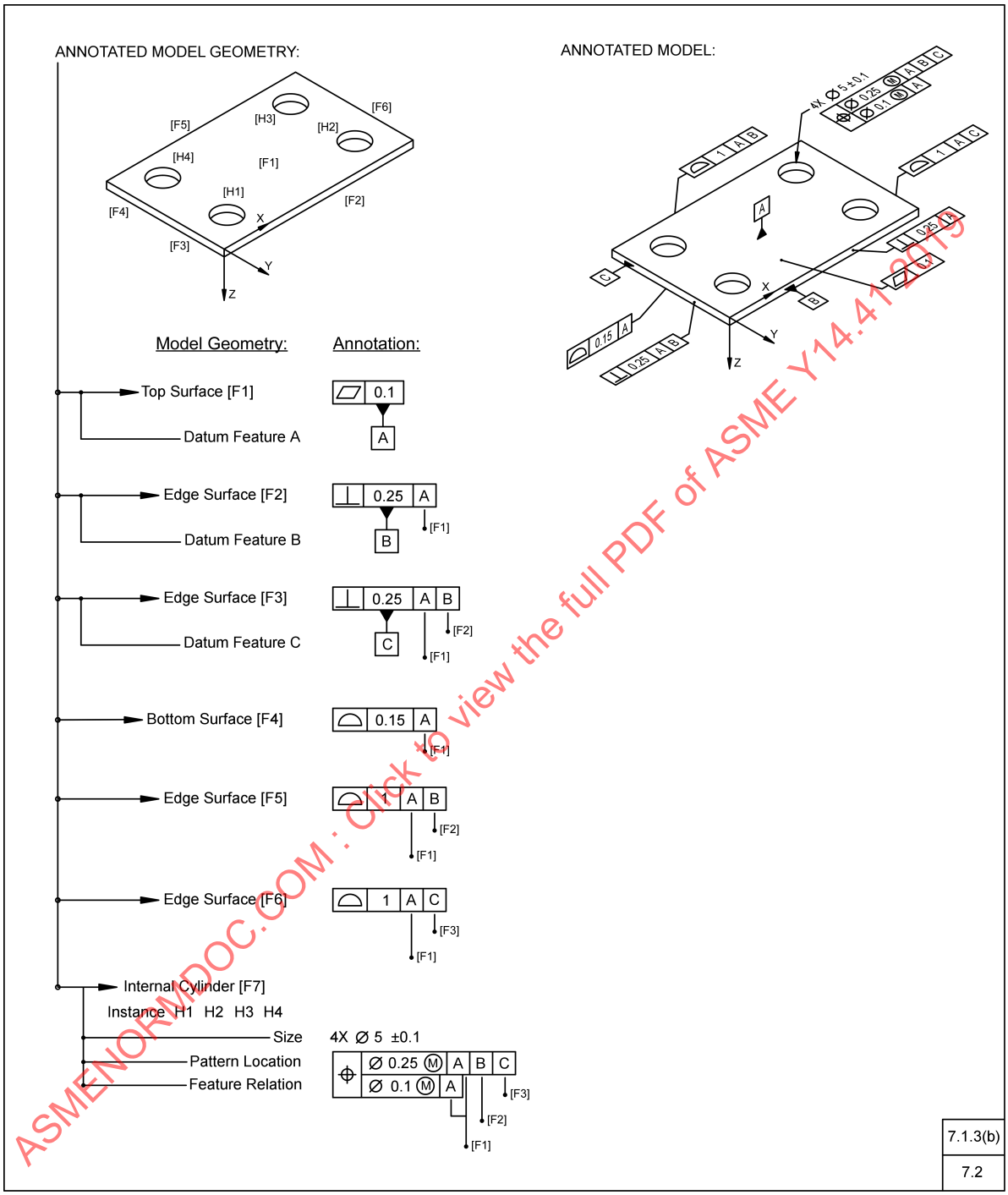


Figure 7-3 Tolerance Query Associativity

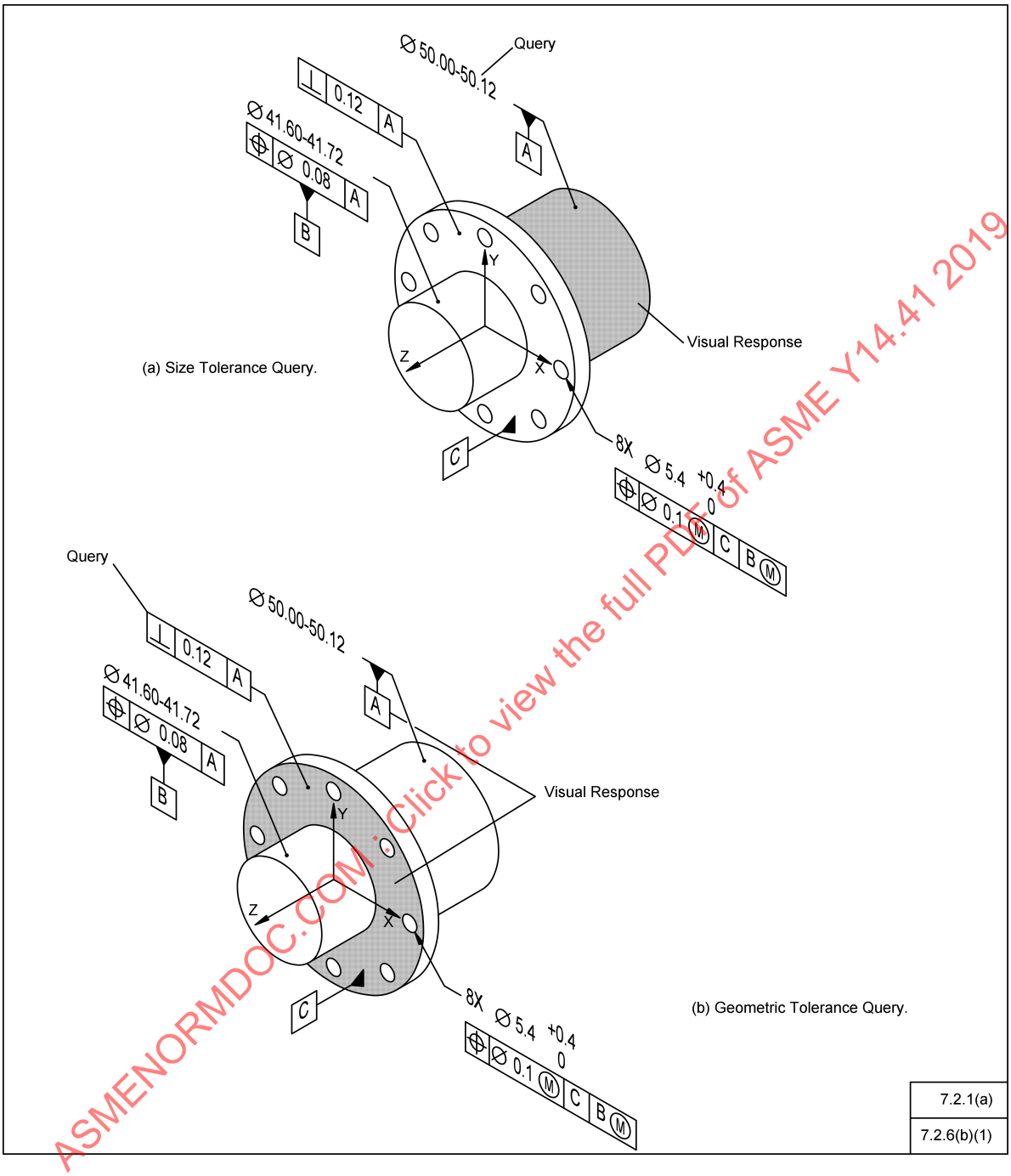
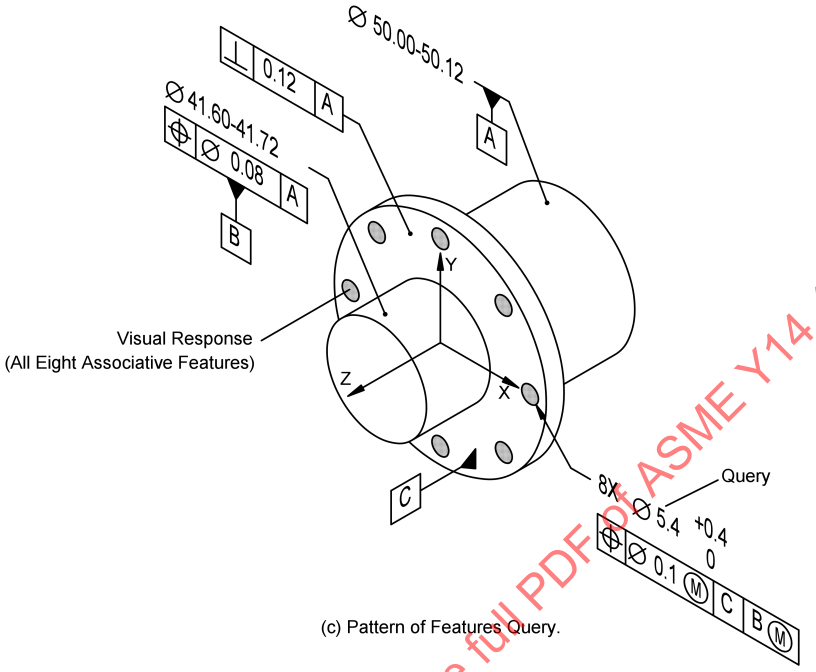


Figure 7-3 Tolerance Query Associativity (Cont'd)



(c) Pattern of Features Query.

7.2.1(a)
7.2.6(b)(1)

Figure 7-4 Simplified Feature Representation and Attributes

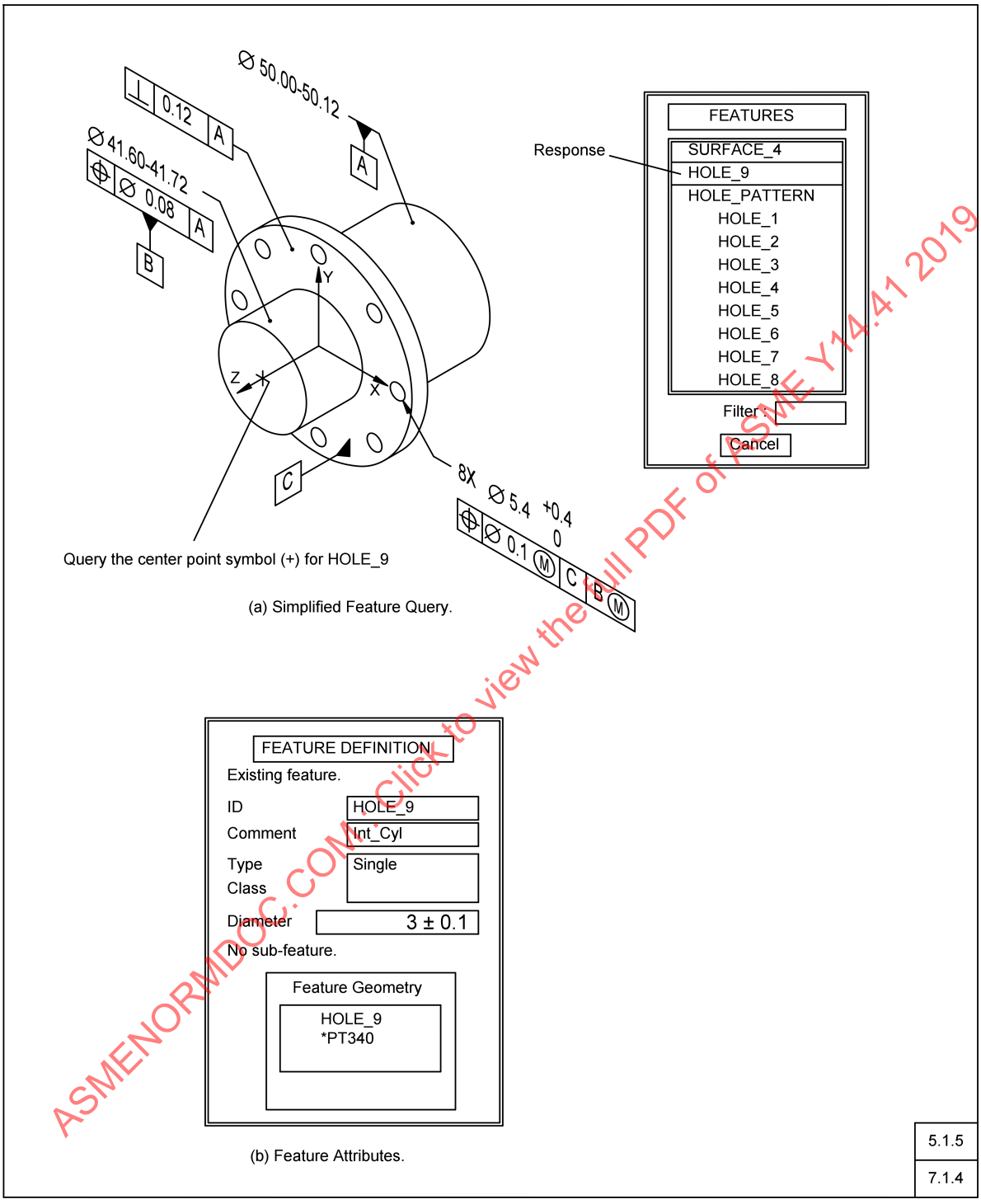


Figure 7-5 Annotation Planes Relative to Annotated Model Geometry

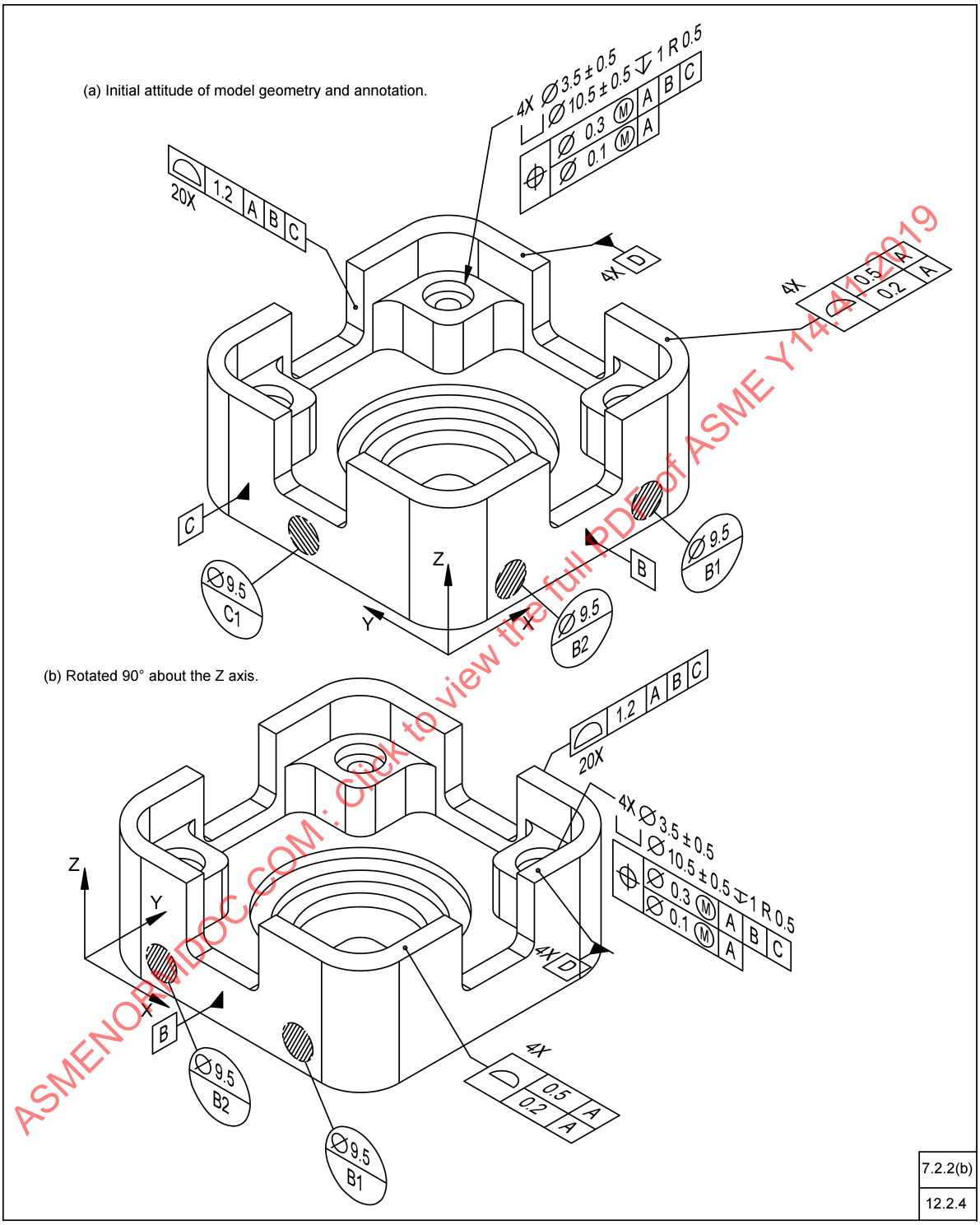


Figure 7-6 Graphic Display of Associated Annotation

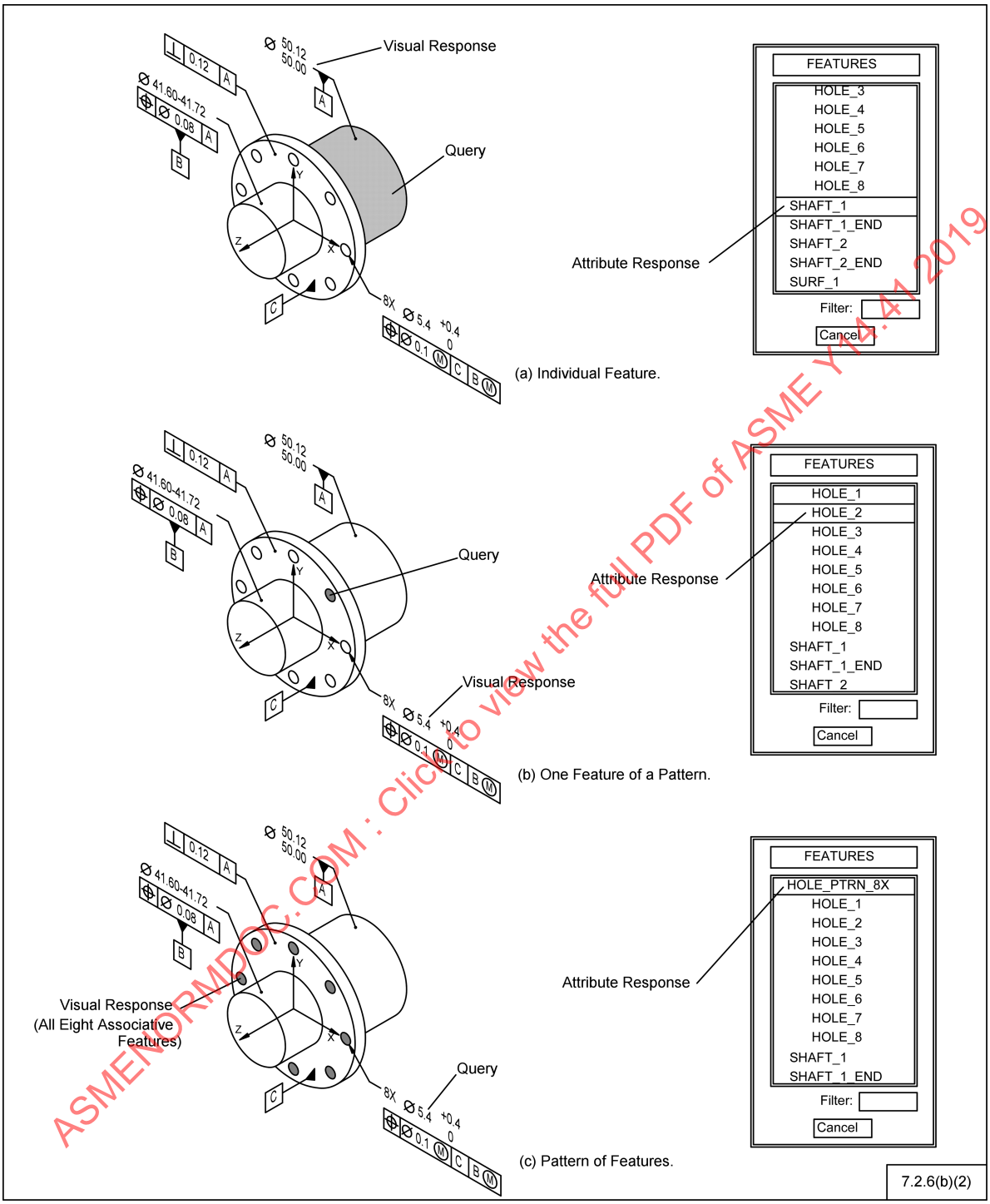


Figure 7-7 Listing of Digital Element Identifiers

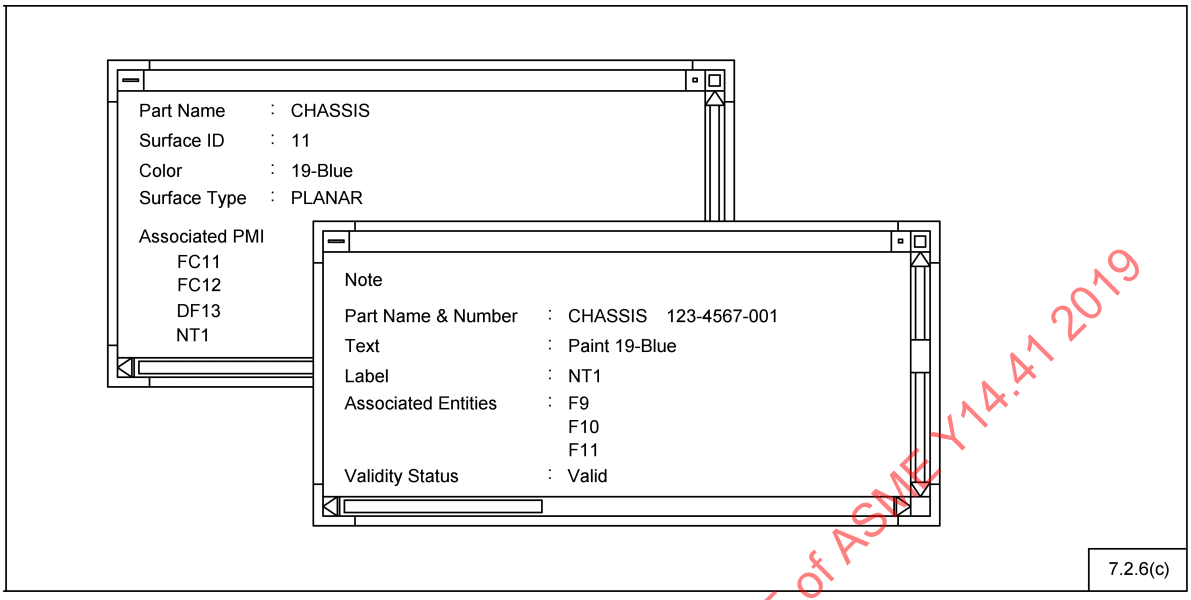


Figure 7-8 Queries for Datum Feature Symbols and Datum Target Symbols

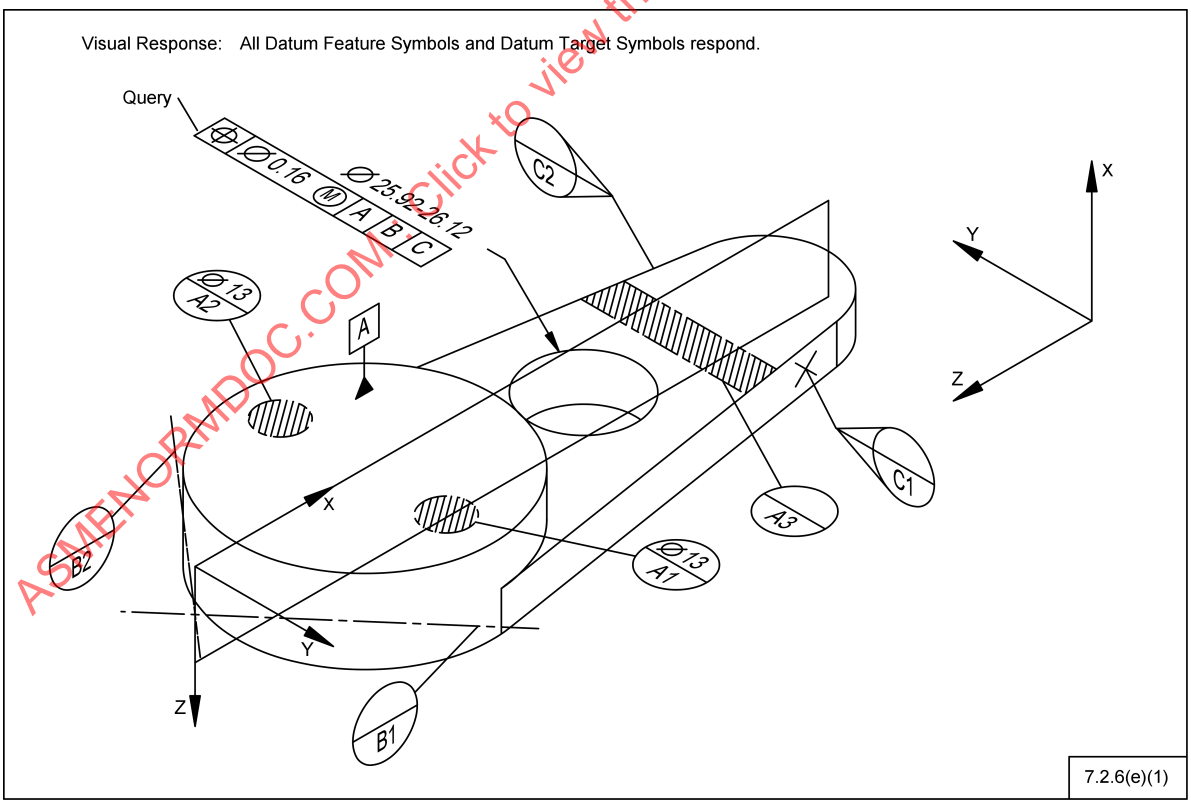


Figure 7-9 Queries for Datum Targets

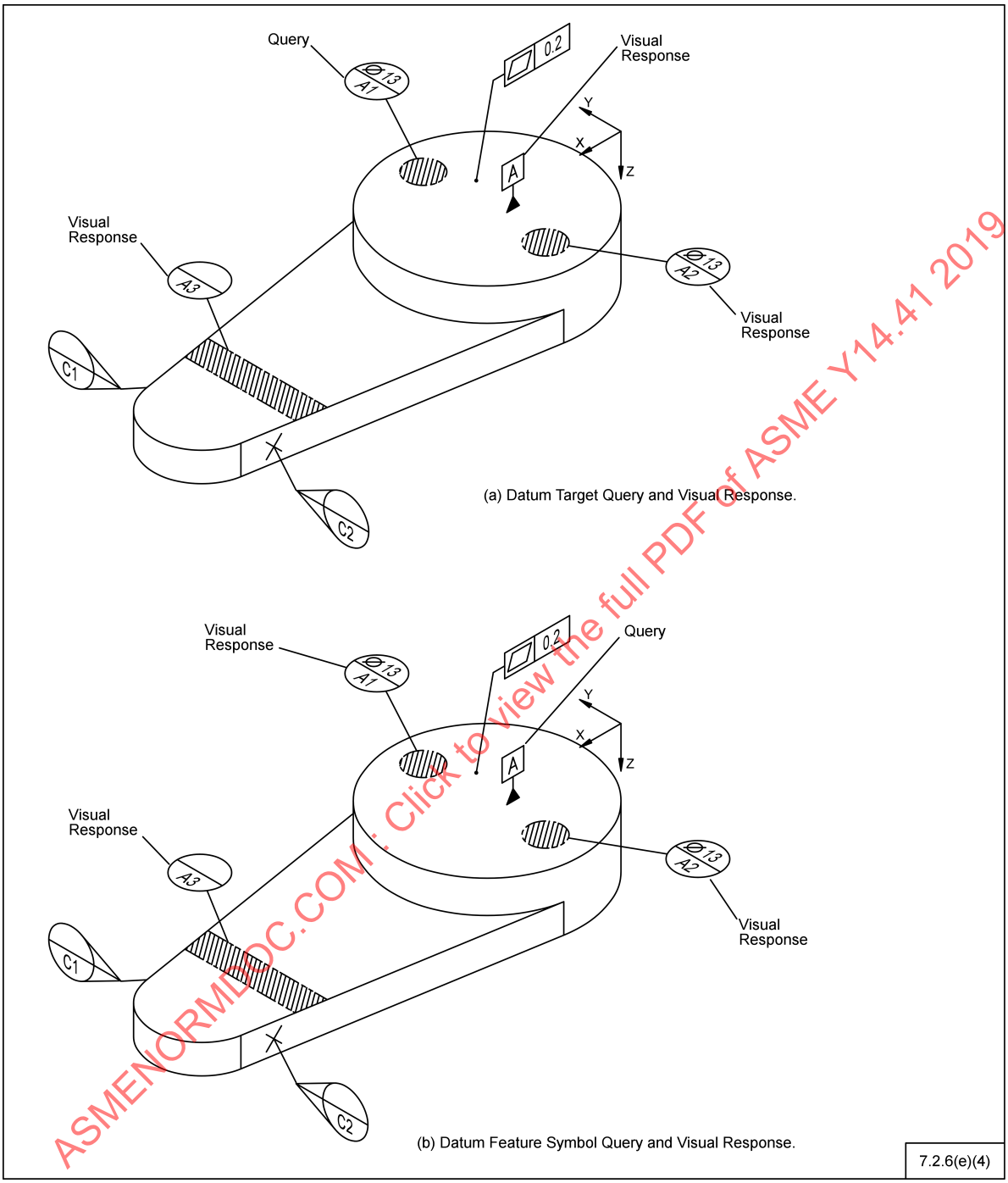
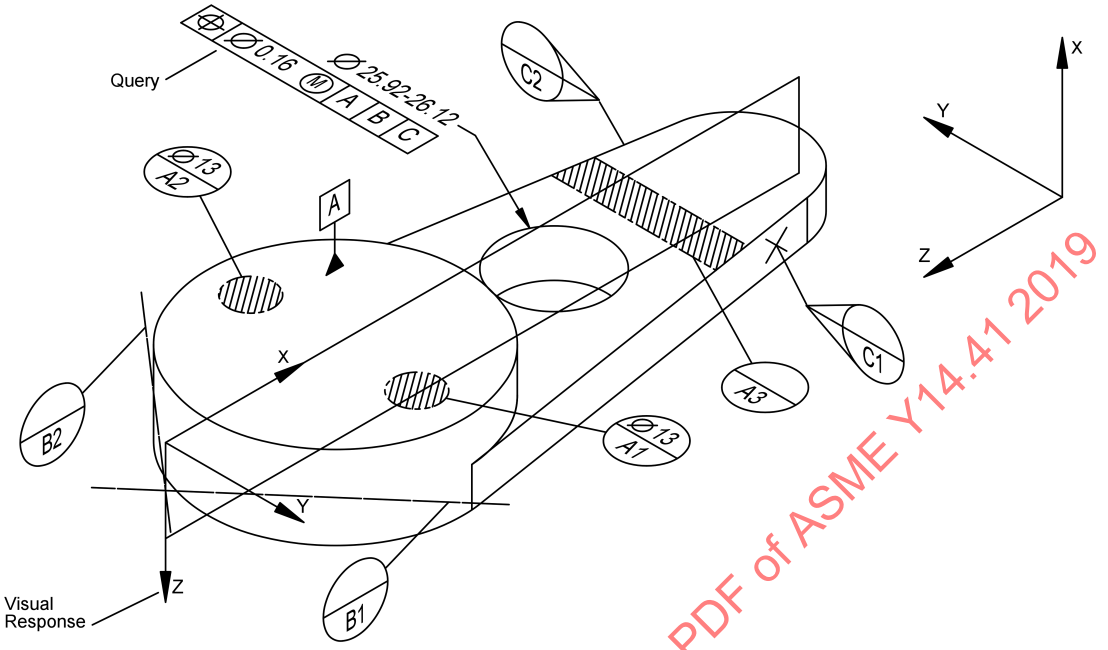
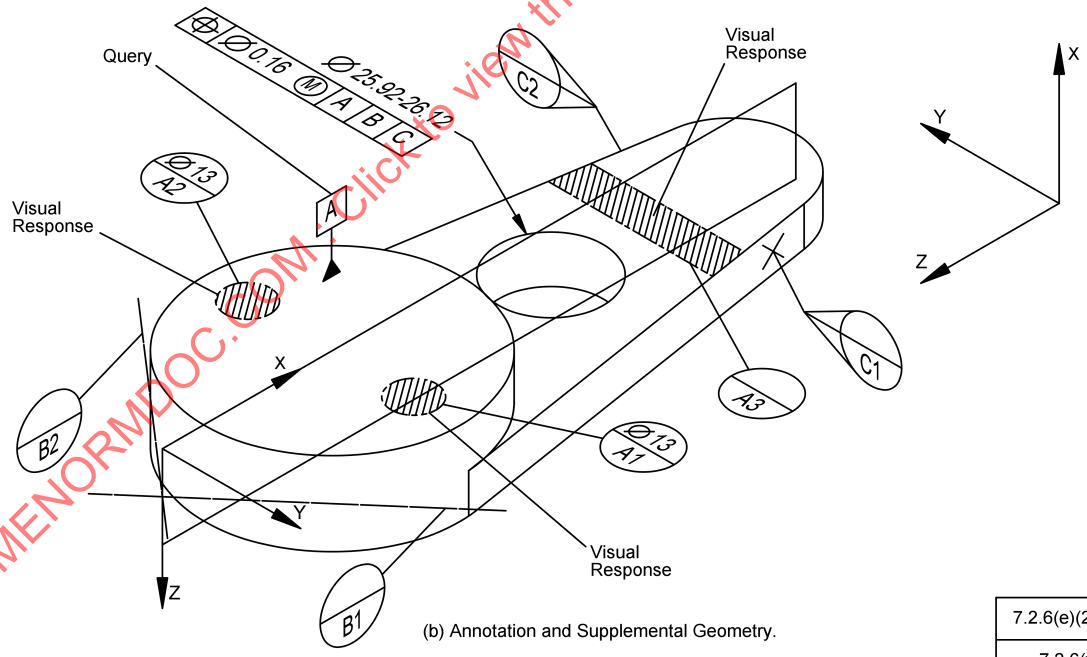


Figure 7-10 Queries for Coordinates and Supplemental Geometry



(a) Feature Control Frame and Corresponding Coordinate System



(b) Annotation and Supplemental Geometry.

7.2.6(e)(2)
7.2.6(f)

Figure 7-11 Annotated Model

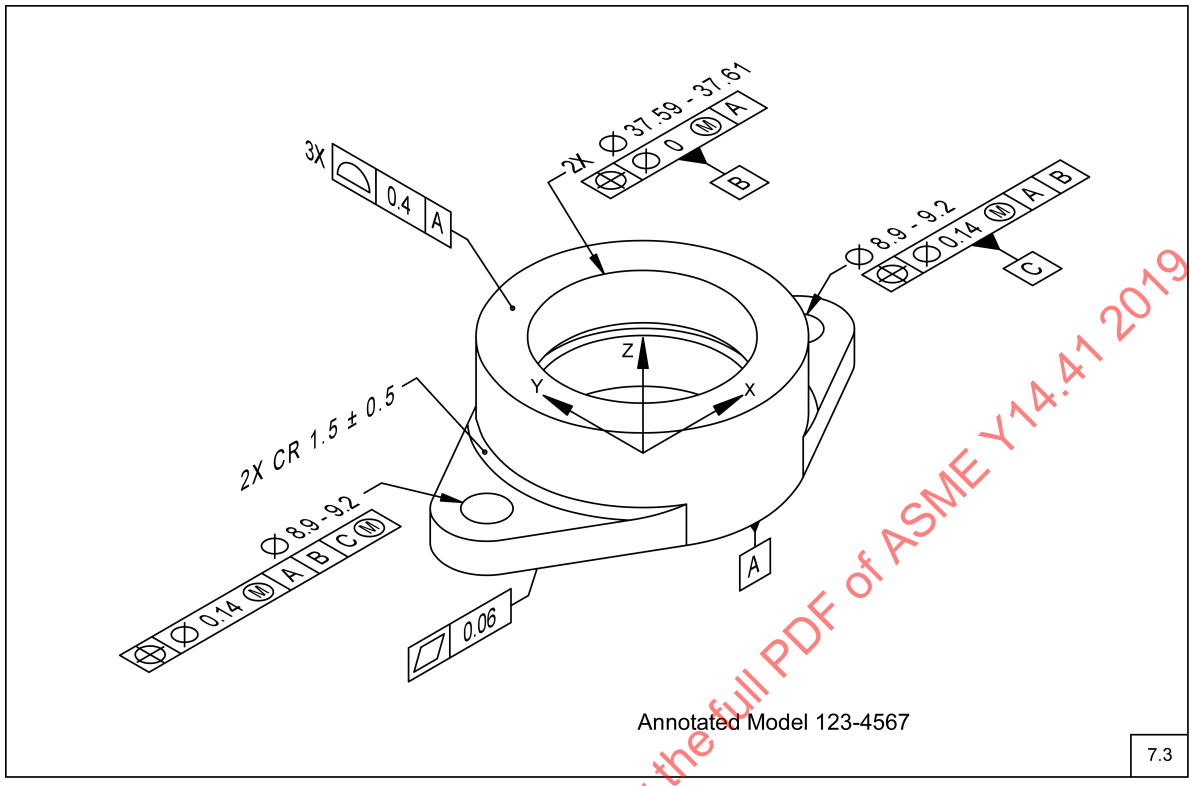


Figure 7-12 Model and Drawing Graphic Sheet

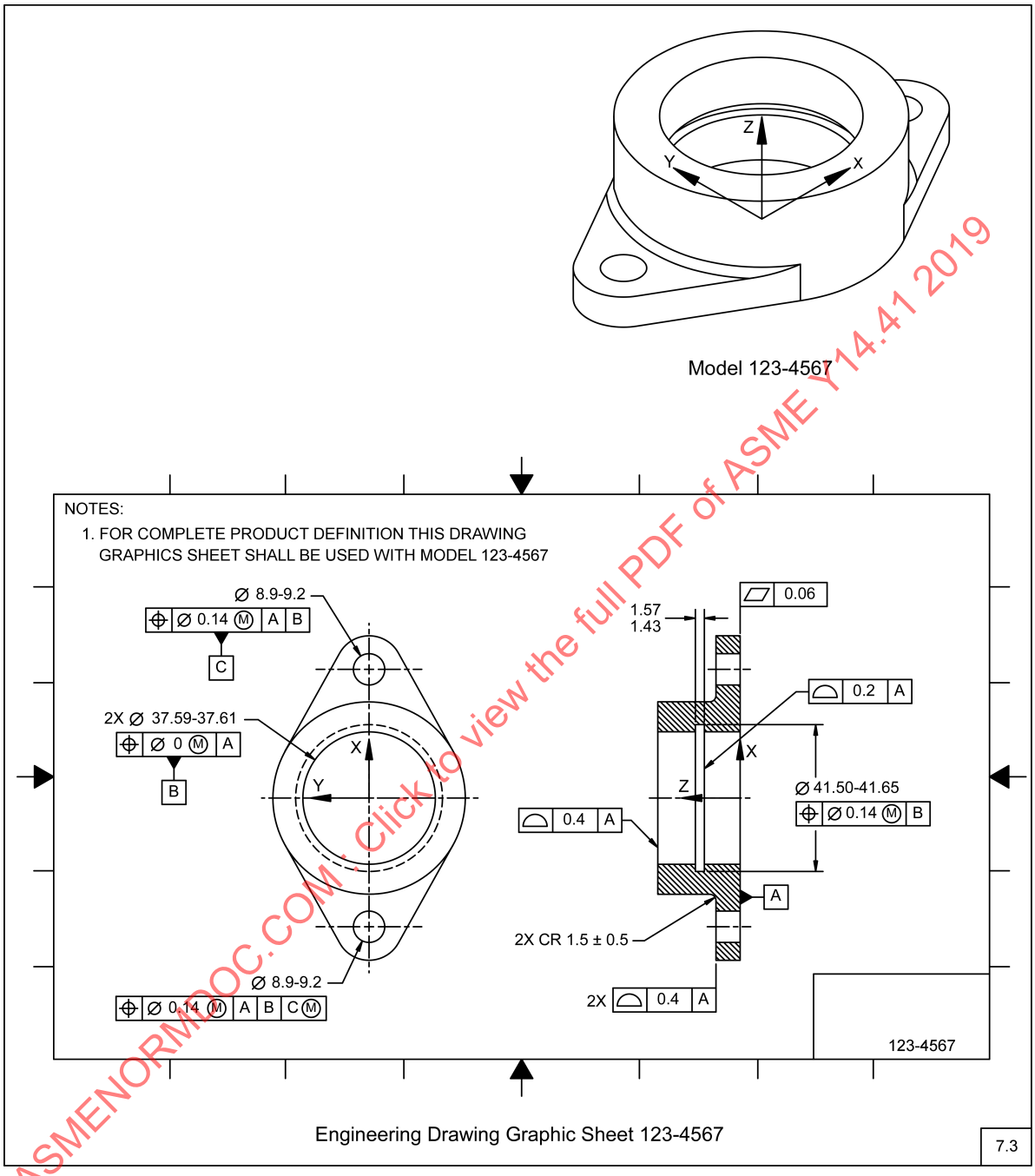
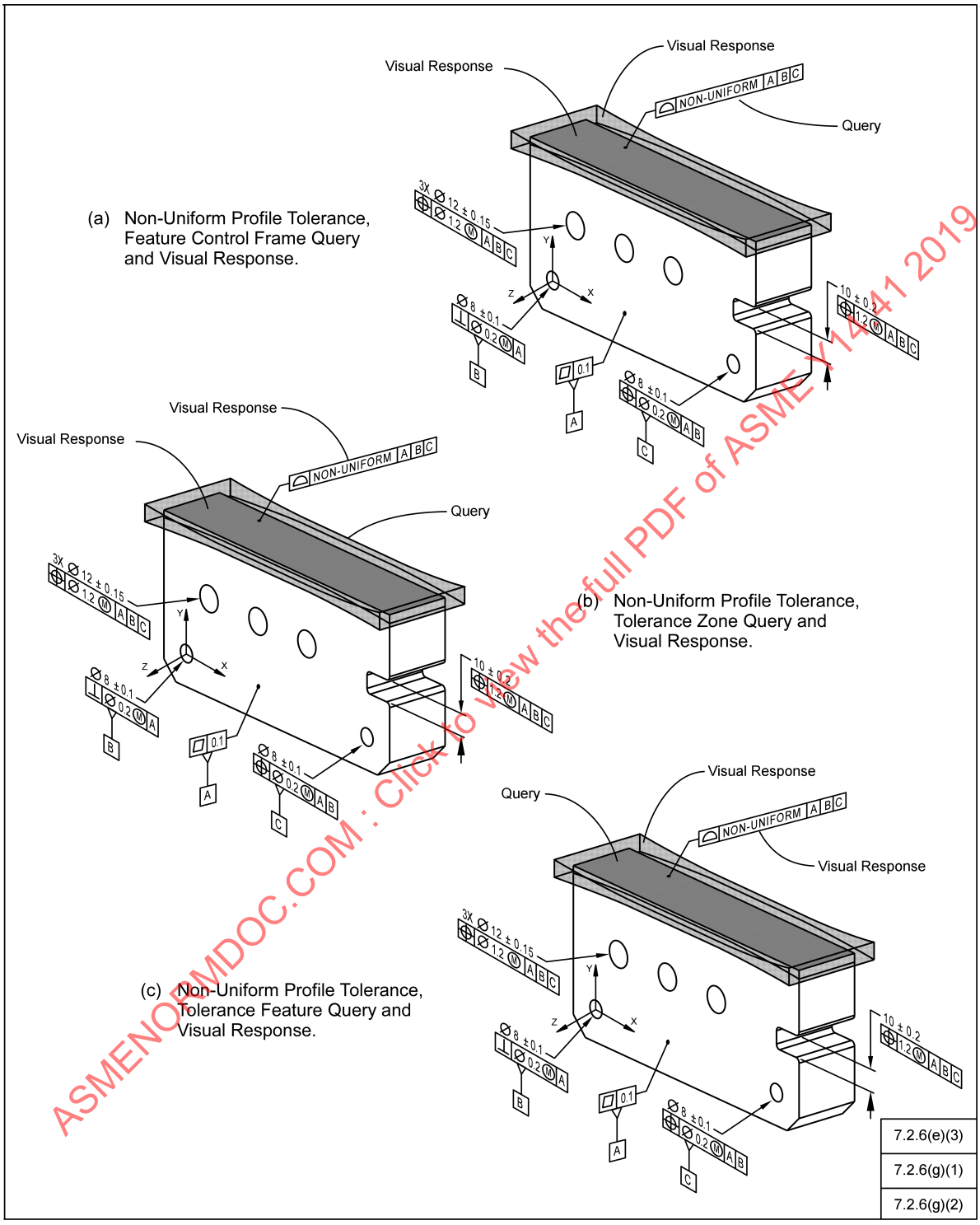


Figure 7-13 Query for Nonuniform Tolerance Zones



Section 8
Notes and Special Notations

This Section establishes requirements for the application of notes and special notations used with an annotated model, a drawing graphic sheet, or a combination of both.

8.1 COMMON REQUIREMENTS

There are no common requirements for notes and special notations.

8.2 ANNOTATED MODEL REQUIREMENTS

Paragraphs 8.2.1 through 8.2.5 describe requirements for annotated models.

8.2.1 Notes Area Annotation Plane

When general notes, flag notes, and special notations are placed in an annotated model, the notes shall be placed as annotation in a single annotation plane or a similar method. These notes shall not rotate.

8.2.2 General Notes

General notes do not require associativity. General notes may include default tolerance(s) for the entire annotated model. See subsection 12.1 for using general notes for geometric tolerances.

8.2.3 Local Notes

Local notes shall be associated to the applicable digital elements in the annotated model.

8.2.4 Flag Notes

When a flag note is used in an annotated model, the following shall apply:

(a) The flag note, in accordance with ASME Y14.100, shall be placed as one or a combination of the following:

(1) annotation in the notes area annotation plane

(2) an attribute

(3) an associated list

(b) The flag note symbol shall be shown adjacent, associated, and rotate with the applicable digital elements in the annotated model.

(c) When a flag note is placed in accordance with (a)(1) or (a)(2), the flag note shall be associated with the applicable digital elements.

(d) When a flag note is placed in accordance with (a)(3), associativity may be used.

8.2.5 Special Notations

When special notations, as defined in ASME Y14.100, are placed in an annotated model, the following shall apply:

(a) When the special notations are applicable to the entire annotated model, the special-notations symbol and the associated text shall be placed on the notes area annotation plane in accordance with para. 8.2.1.

(b) When the special notations are applicable only to a portion of an annotated model, the special-notations symbol and its associated text shall be placed on the notes area annotation plane in accordance with para. 8.2.1. The special-notations symbol shall be shown adjacent to the applicable digital elements in the annotated model. The special-notations symbol shall be associated to the digital elements to which it applies.

8.3 DRAWING GRAPHIC SHEET REQUIREMENTS

Paragraph 8.3.1 describes requirements for drawing graphic sheets.

8.3.1 Local Notes in Axonometric Views

Local notes shall have a leader line(s) that clearly indicates the feature(s) that is related to the note. For leader line terminators, see para. 7.1.3.

Section 9
Model Values and Dimensions

This Section establishes the requirements for model value query, and resolved, basic, size, and limit dimensions in a data set. Direct tolerancing methods applicable to dimensions, as defined in ASME Y14.5, should only be used to define the size of a feature. See para. 9.2.2 and Section 10. Geometric tolerancing is the preferred method. This Section also contains the common requirements for associativity and dimensions in an annotated model or drawing graphic sheet. Linear, radial, and angular dimensions are addressed in Section 10.

9.1 COMMON REQUIREMENTS

All model values and resolved dimensions shall be obtained from the model. The following subparagraphs address requirements for model values and resolved dimensions. Model values are obtained for one of the following purposes:

(a) to determine the location and orientation of surfaces

(b) to determine the distance or angle between two surfaces

(c) to determine the position (basic location and orientation) of features of size

(d) to determine the feature relation (the basic hole-to-hole spacing and orientation) dimensions within a pattern of features of size

(e) to determine the contour of surface geometry

(f) to determine the size value for a feature of size or features of size within a pattern

Model value queries (a) through (d) shall always be conducted in relation to the absolute or a user-defined coordinate system of the design model. For queries (e) and (f), direct interrogation of the model surface or feature of size may be conducted without regard to coordinate system.

9.1.1 Resolved Dimensions

Dimensions displayed in an annotated model or a drawing graphic sheet are resolved dimensions. Resolved dimensions derived from model values are considered the same as dimensions specified per ASME Y14.5. For examples of resolving model values to displayed dimensions, see Table 9-1. The requirements for resolved dimensions follow.

(a) To obtain a resolved dimension, a model value shall be rounded to the number of decimal places required for the design.

(b) All resolved dimensions shall be absolute values in accordance with ASME Y14.5.

(c) Rounding shall be in accordance with IEEE/ASTM SI 10.

(d) Resolved Dimension Preservation and Association. A direct and permanent association to the originating model value shall be established and maintained for every resolved dimension.

(e) Utilization of Model Values or Resolved Dimensions. The use of model values or resolved dimensions for analyses and other processes shall be defined in appropriate documentation.

9.2 ANNOTATED MODEL REQUIREMENTS

Requirements for attaching and displaying basic and size dimensions in an annotated model are defined in the following paragraphs. Linear, radial, and angular dimensions are addressed in Section 10. Dimensions and tolerances may be shown to internal features without the use of a section. See Figure 10-4, illustration (c).

9.2.1 Queried Model Values

Queried model values of feature(s) shall be interpreted as basic unless otherwise dimensionally specified in the data set. A model value shall be rounded to the number of decimal places required for the design. Queried model values of feature(s) that are controlled elsewhere shall be considered reference.

9.2.2 Basic Dimensions

The following requirements apply to basic dimensions in an annotated model.

(a) Basic Dimensions. Querying of the model for the profile, location, and orientation of a feature shall occur within the appropriate coordinate system. See subsection 9.1 and para. 11.2.1(a).

(b) Displaying Basic Dimensions. The display of basic dimensions may be necessary in defining some annotated model relationships. Displayed basic dimensions shall be enclosed in a box in accordance with ASME Y14.5.

(c) Placement. Basic dimensions should be placed in annotation planes that are parallel with one of the planes of the absolute or a user-defined coordinate system. An example of an exception is the 3X 6.35 basic dimension shown in Figure 9-1.

(d) Attachment to Surface Features. Basic dimensions defining surface curvature or extent, such as fillets, rounds, or chamfers, shall be directed to the feature surface by a leader. See Figure 9-1.

(e) Attachment With Dimension and Extension Lines. Basic dimensions defining linear distance or angular relation shall be shown using dimension and extension lines. See Figure 9-1.

(f) Implied Angle. There are no 90 deg implied angles in a model. All angular values shall be queried from the model unless a dimension is displayed. The coordinate system(s) and planes associated with a datum reference frame(s) and orthographic views are 90 deg.

9.2.3 Size Dimensions

A displayed feature of size dimension shall always include a tolerance.

(a) Size Dimension and Annotated Model Agreement. A size dimension shall agree with the queried model value for the same feature when the model value is rounded to the same number of decimal places. This agreement shall meet one of the following requirements, depending on the tolerance expression used.

(1) Bilateral or Unilateral Tolerance. The displayed size dimension shall equal the resolved model value.

(2) Limit Dimensions. The resolved model value shall equal one of the limit dimensions, or a value within the displayed range of limits.

(3) Dimensions With Plus/Plus or Minus/Minus Tolerances. The resolved model value shall not be within the displayed range of limits.

(b) Placement and Attachment. The placement and attachment methods for size dimensions are as follows:

(1) Spherical Surface. The size dimension and leader shall be placed on an annotation plane containing the feature centerpoint.

(2) Cylindrical Surface. The size dimension and leader shall be placed on an annotation plane perpendicular to the feature axis or containing the feature axis.

(3) Set of Two Opposed, Parallel Surfaces (a Width). The size dimension, dimension line, and extension lines shall be placed on an annotation plane perpendicular to or containing the feature centerplane. The extension lines shall clearly indicate the surfaces comprising the width. See Figure 9-2 for examples.

(c) Use of the Term TRUE. The term TRUE, when used with a dimension, shall not be used on annotated models.

9.3 DRAWING GRAPHIC SHEET REQUIREMENTS

Basic dimensions not displayed on a drawing graphic sheet shall be obtained by querying of the model.

9.3.1 Presentation of Dimensions in Axonometric Views

Requirements for dimensions on axonometric views of a drawing graphic sheet are defined in the following subparagraphs.

(a) Displayed Dimensions. Dimensions shown in an axonometric view shall be true, and the use of the term TRUE is not required.

(b) Displayed Basic Dimensions. Basic dimensions shall be enclosed in a box in accordance with ASME Y14.5.

(c) Dimension Leader Lines. Leader lines shall be used to relate a dimension to a cylindrical feature. The leader line shall be directed to the intersection of the cylindrical feature and a surface. Leader lines shall terminate with an arrowhead.

Figure 9-1 Placement and Attachment of Basic Dimensions

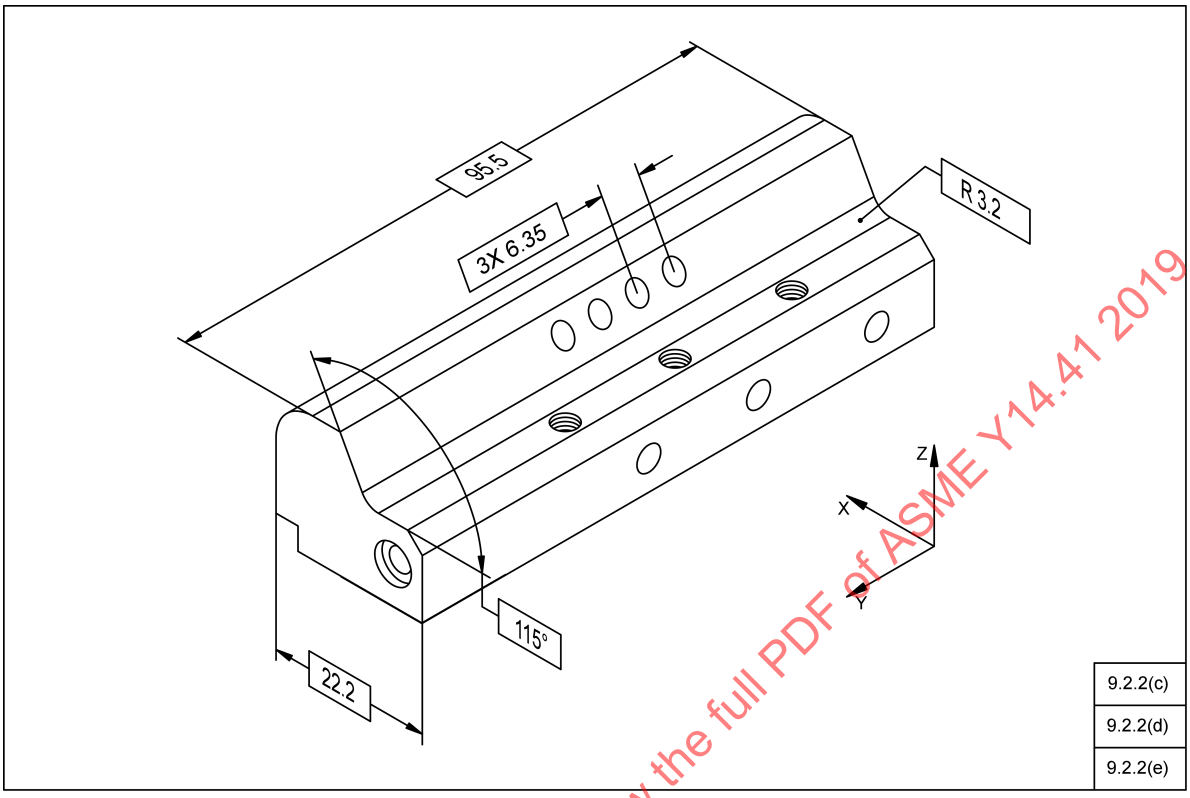


Figure 9-2 Placement and Attachment of Size Dimensions

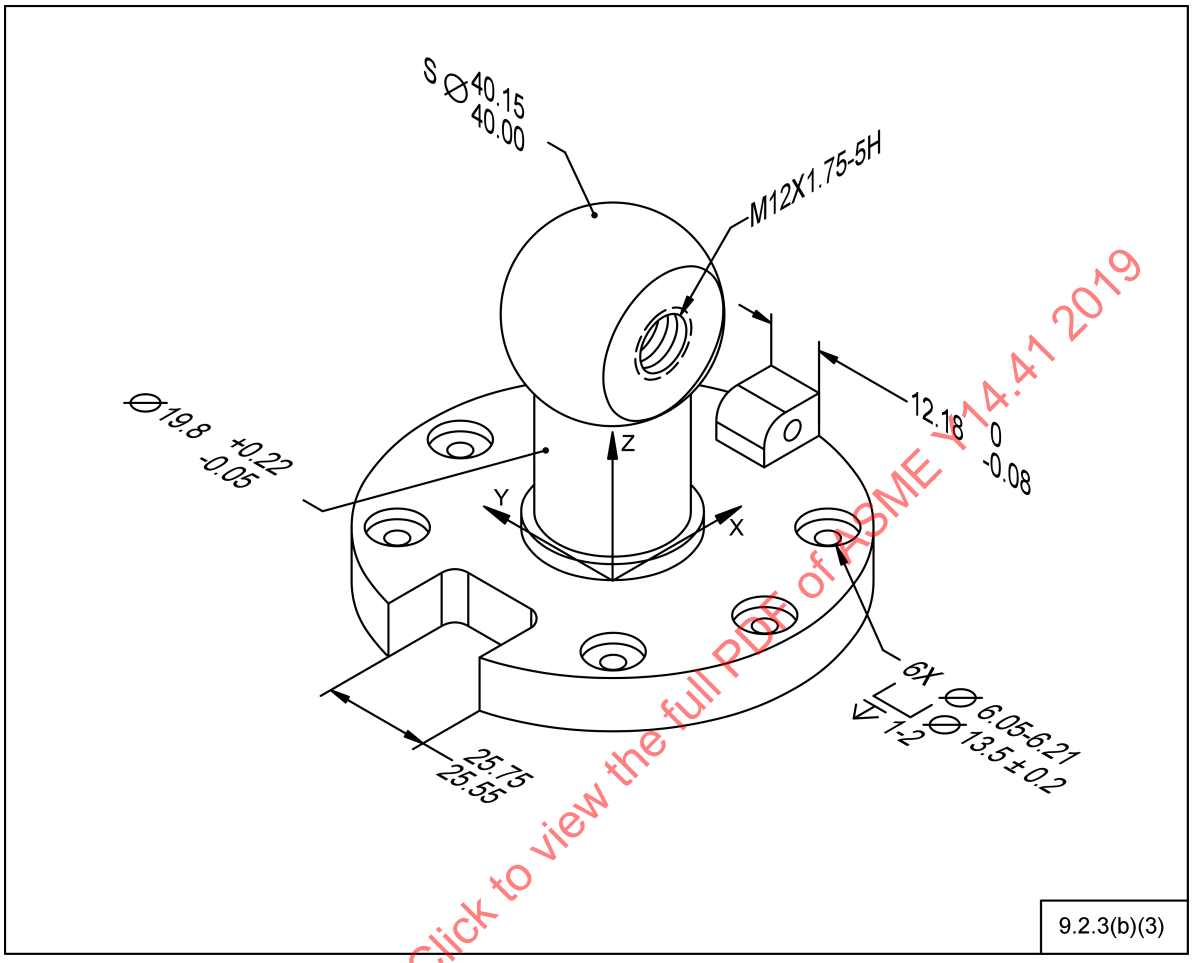
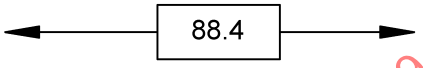
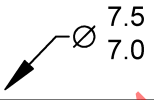
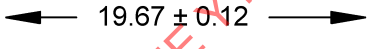
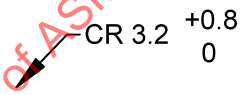
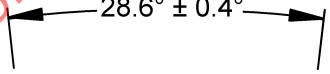
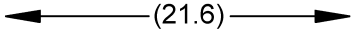


Table 9-1 Resolved Dimension Examples

ASME Y14.5	ASME Y14.41		Application Example:
	Model Value (3)	Resolved Dimension	
Basic (1)	88.4100000...	88.4	
Size (2)	7.0000000...	7.0	
Linear	19.6666666...	19.67	
Radial	3.1500000...	3.2	
Angular	28.5918273...	28.6	
Single Limit (1)	12.0000000...	12	
Reference (1)	21.6018043...	21.6	

NOTES:
(1) Linear, radial, angular, diametral or spherical diameter.
(2) Linear, diametral or spherical diameter.
(3) The values shown are examples. Actual values will reflect the defined precision of the model and the rounding requirements of each particular application.

9.1.1

Section 10
Plus and Minus Tolerances

This Section establishes the placement, attachment, and display requirements for plus and minus tolerances in a data set.

10.1 COMMON REQUIREMENTS

One or more general notes defining plus and minus tolerances may be specified.

10.2 ANNOTATED MODEL REQUIREMENTS

Table 10-1 lists general applications for plus and minus tolerance of linear, radial, and angular dimensions. The attachment method generally used is shown.

NOTE: The features listed in Table 10-1 do not comprise an exhaustive list, and define requirements that are applicable to similar and other valid applications. The omission of a particular application is not cause to consider the application invalid.

10.2.1 Chamfers

Attachment for 90 deg surface intersections with an equally disposed chamfer is indicated in Table 10-1. Oblique surface intersections, unequally disposed extents, or chamfers defined using a linear and angular dimension require the use of dimension and extension lines. See Figure 10-1, illustrations (c) and (d). The value shall be located and oriented in a manner that is clear.

10.2.2 Depth Specification

When a feature depth is governed by a remaining thickness tolerance, the feature tolerance and the remaining thickness requirement should be an associated group. See Table 10-1 and Figure 10-4, illustration (c).

10.3 DRAWING GRAPHIC SHEET REQUIREMENTS

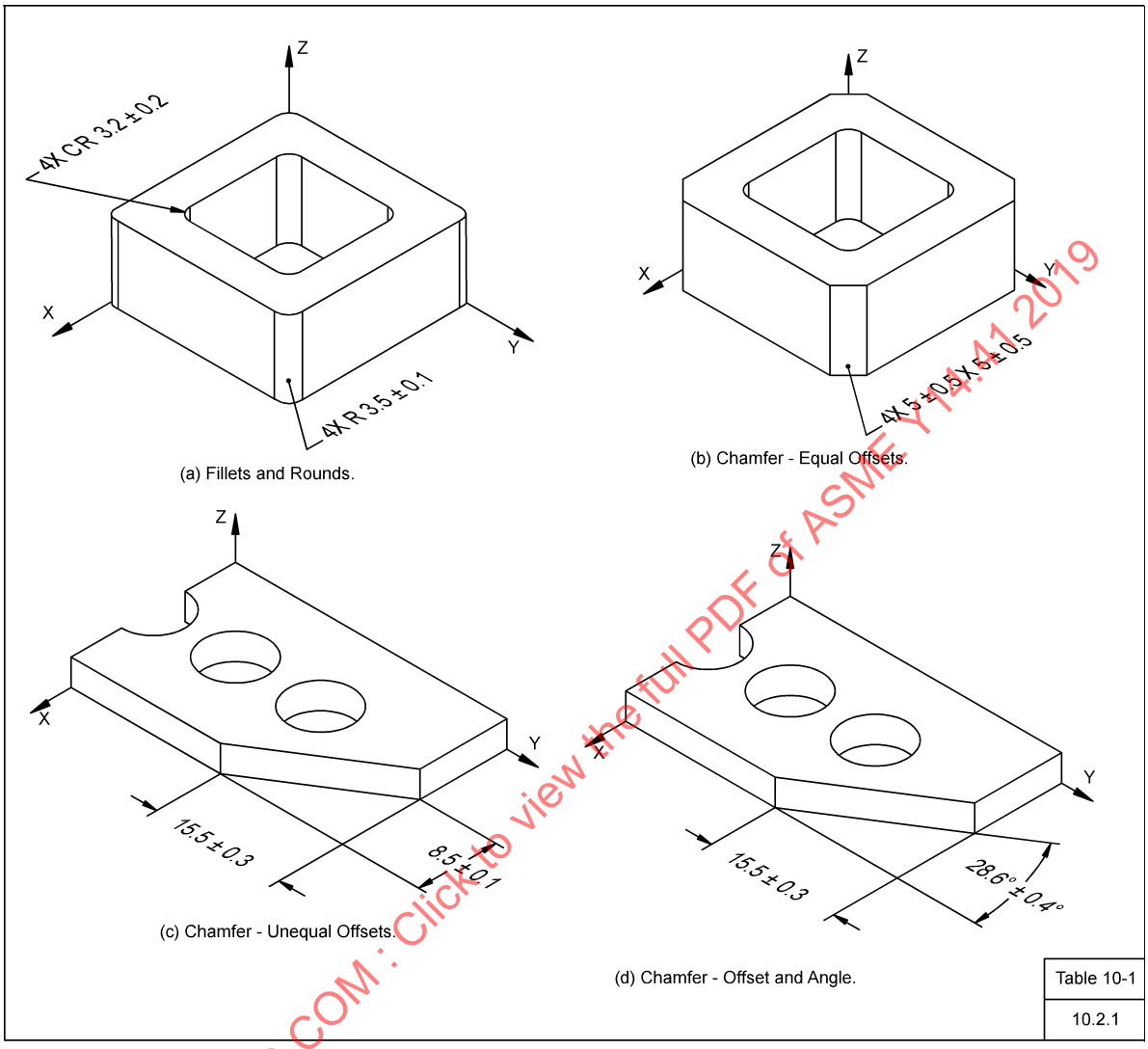
Use existing drawing standards for plus and minus tolerances. See subsection 1.1.

Table 10-1 Plus and Minus Tolerance Applications

General Applications	Attachment Technique			Paragraph	Figure
	Size Callout	Directed Leader	Extension Lines		
Fillets, Rounds, Chamfers	…	●	…	10.2.1	10-1
Reliefs, Step Surfaces	…	…	●	…	10-2
Countersinks	●	…	…	…	10-3(a)
Oblique Surfaces	…	…	●	…	10-3(b)
Entry Depth and Spotface	●	…	…	10.2.2	10-4(a)(b)
Remaining Thickness	…	…	●	10.2.2	10-4(c)
Notches, Flats, and Pin Height	…	…	●	…	10-5

10.2
10.2.1

Figure 10-1 Attachment Techniques: Fillets, Rounds, and Chamfers



(a) Fillets and Rounds.

(b) Chamfer - Equal Offsets.

(c) Chamfer - Unequal Offsets.

(d) Chamfer - Offset and Angle.

Table 10-1
10.2.1

Figure 10-2 Attachment Techniques: Reliefs and Step Surfaces

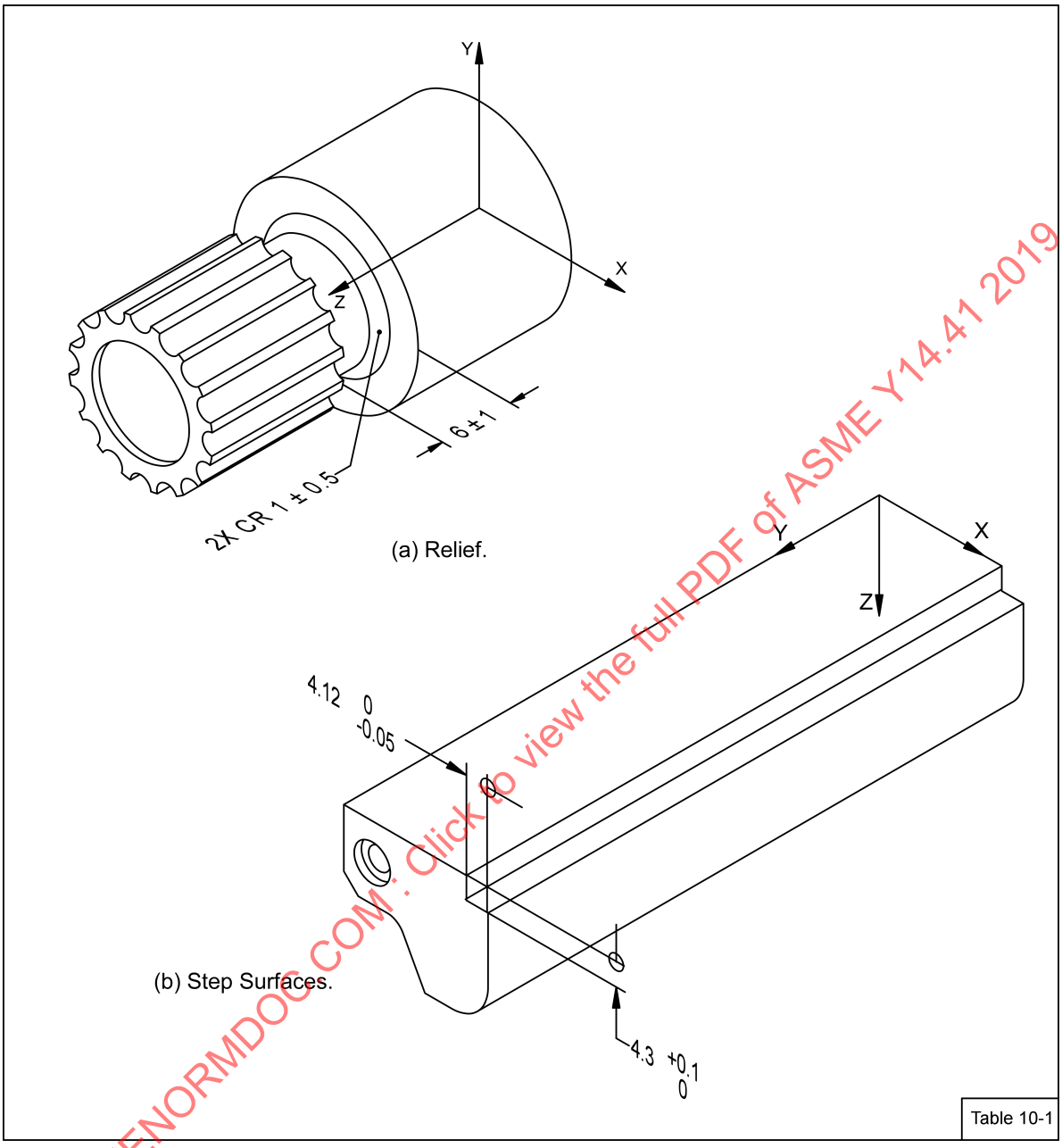


Figure 10-3 Attachment Techniques: Countersinks and Oblique Surfaces

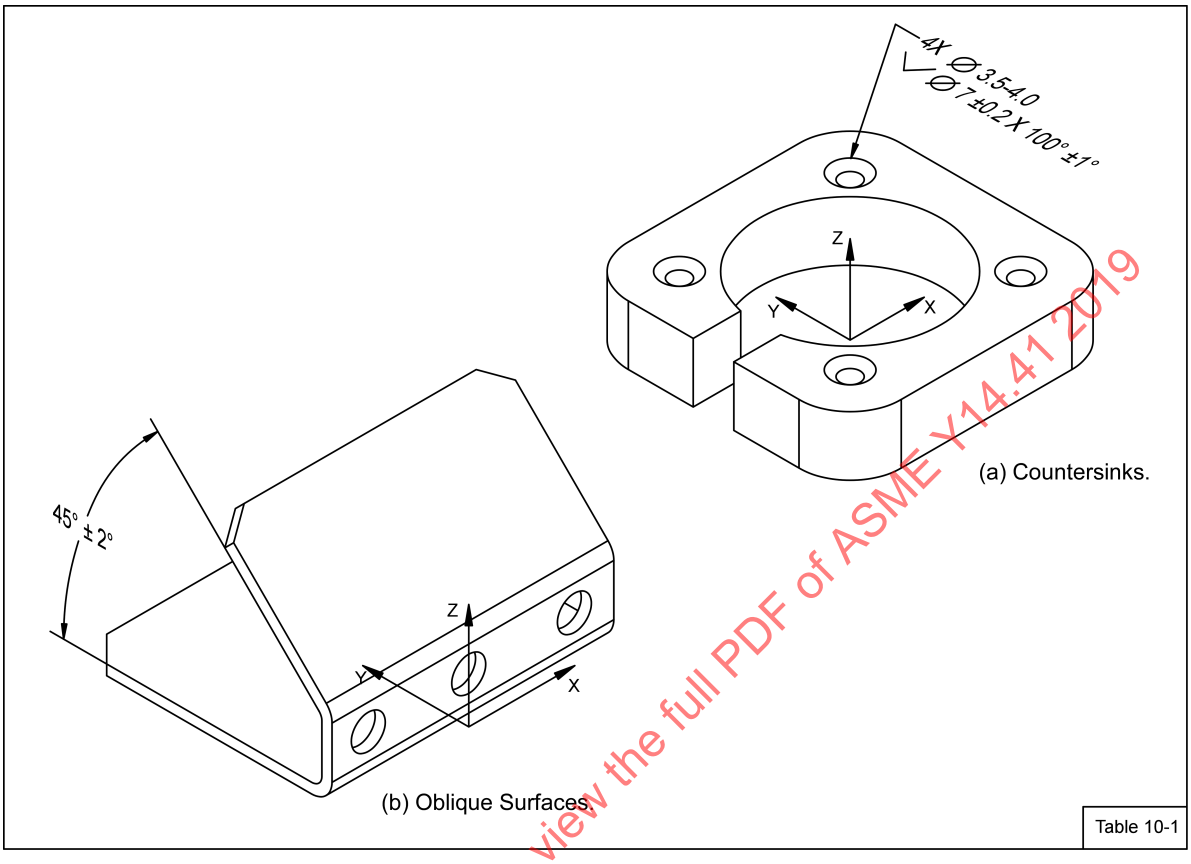


Figure 10-4 Attachment Techniques: Depth, Spotface, Remaining Thickness

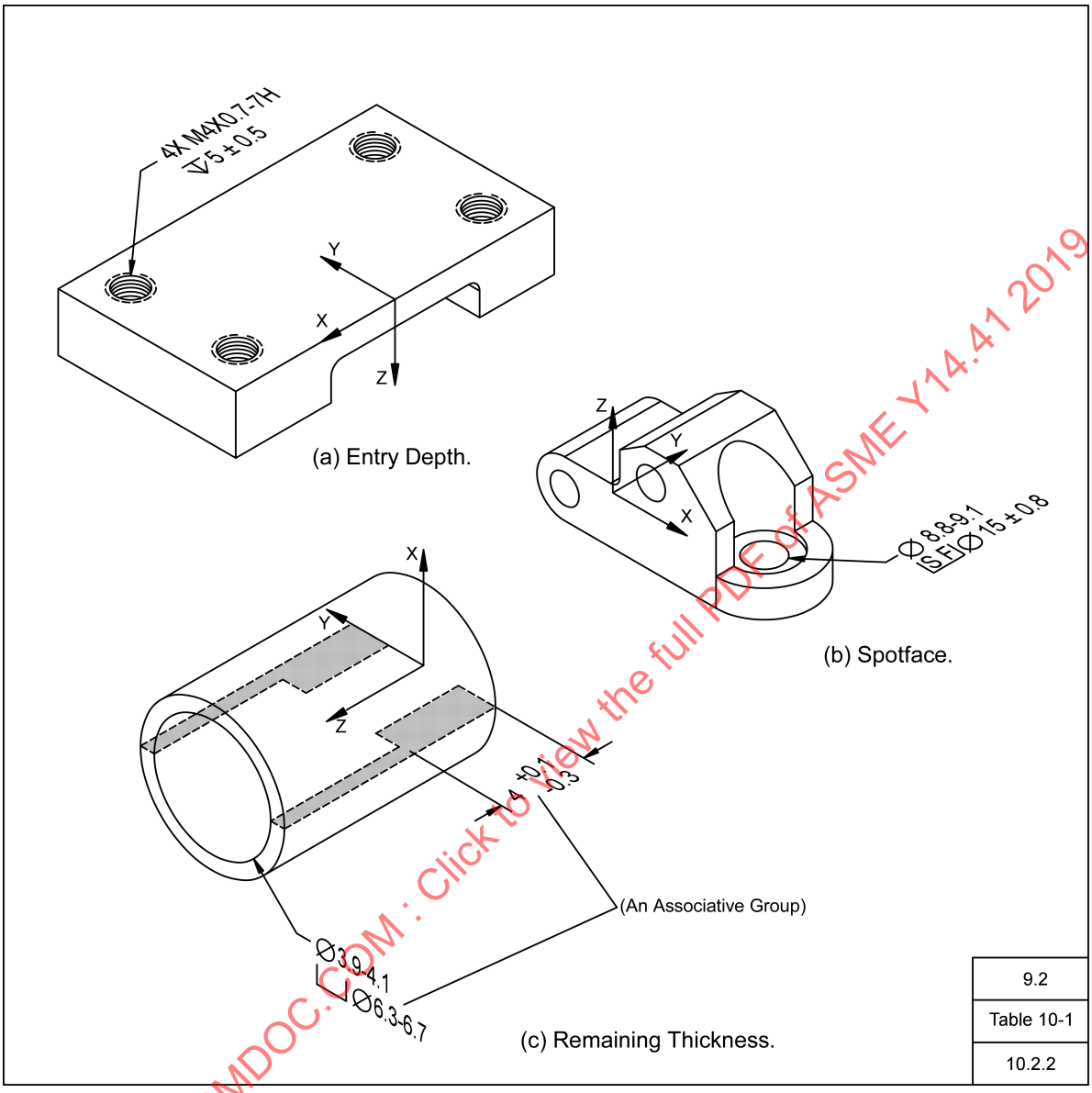
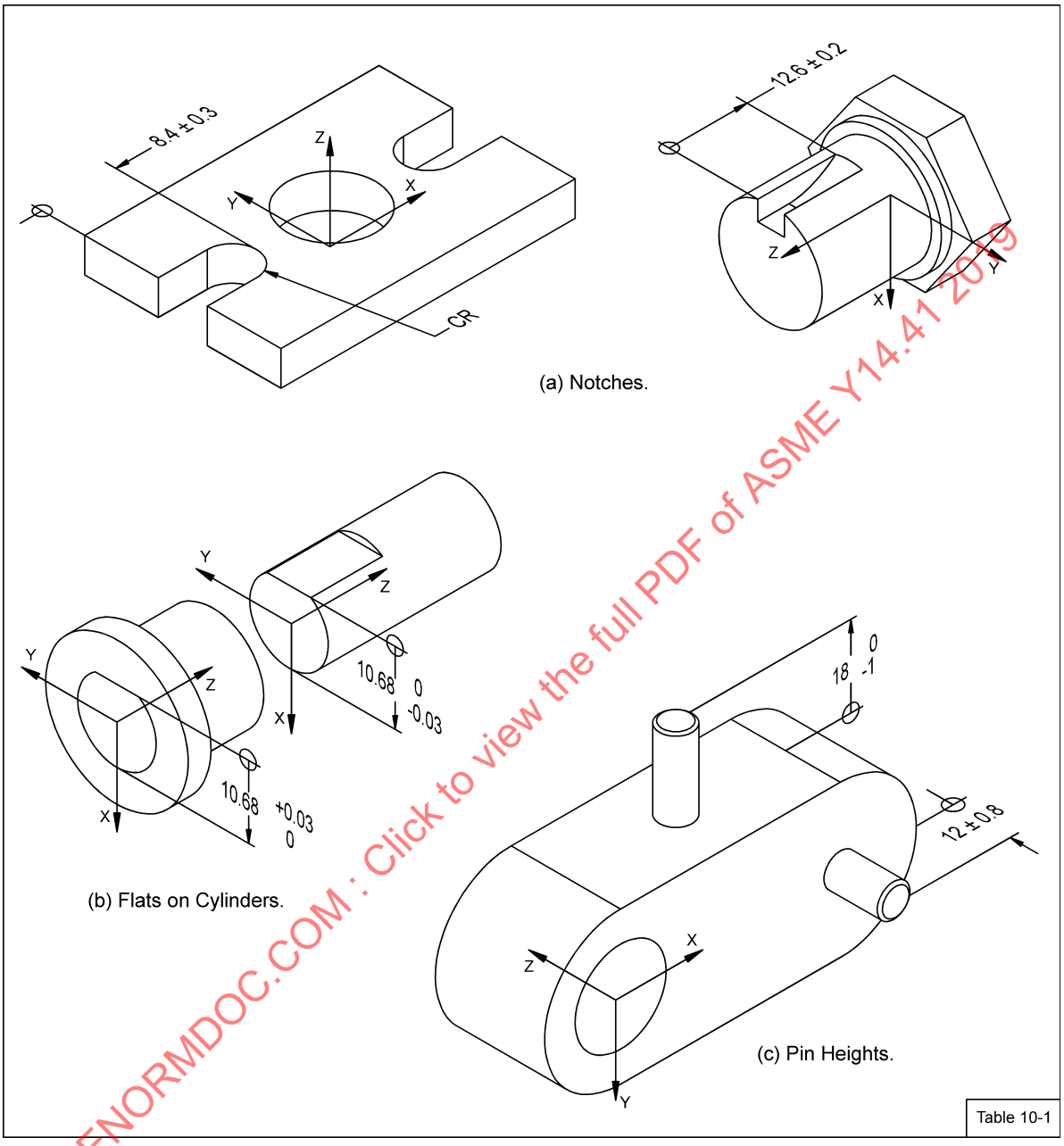


Figure 10-5 Attachment Techniques: Notches, Flats, and Pin Heights



Section 11
Datum Applications

This Section establishes practices for organizing, attaching, and displaying datum feature symbols, datum targets, and related information associated with annotated models. Requirements and recommendations for correlating datum features to the coordinate axes of the annotated model space are given.

11.1 COMMON REQUIREMENTS

There are no exceptions or additions to existing standards that are common for datum applications. See subsection 1.1.

11.2 ANNOTATED MODEL REQUIREMENTS

Paragraphs 11.2.1 through 11.2.4 describe requirements applicable to annotated models.

11.2.1 Datum Reference Frames and Coordinate Systems

The following requirements apply to the relationship between the datum reference frames on the annotated model and the coordinate systems.

(a) Datum Reference Frame and Coordinate System Correspondence. Each datum reference frame shall be associated to a corresponding coordinate system.

(b) Datum Reference Frame and Coordinate System Associativity. A definite visual association between any datum reference frame and the corresponding coordinate system shall be preserved throughout navigation and interrogation of the presented design data.

(c) Multiple Datum Reference Frame and Coordinate Systems Relationship. When more than one datum reference frame is imposed upon an annotated model, each distinguished datum reference frame-to-coordinate system relationship shall be clearly presented and maintained. See Figure 11-1, illustrations (a), (b), and (c) for an example of multiple datum reference frames and coordinate systems organized in a single design presentation.

(d) Datums Established From Complex or Irregular Surfaces. A coordinate system shall be used to indicate the orientation of a datum reference frame that has been defined from complex or irregular surfaces.

(e) Labeling of Datum Reference Frames. When a datum reference frame is labeled, the label shall take the form of "DRF_XXX" where the datum letters of the datum reference frame are used in place of "XXX".

(1) When used, a customized datum reference frame in accordance with ASME Y14.5 shall be labeled.

(2) When a datum reference frame is not a customized datum referenced frame, labeling is optional. See Figure 11-1, illustrations (a), (b), and (c).

11.2.2 Identification of Datum Features

The following subparagraphs describe requirements for identification of datum features and attachment or placement of datum feature symbols on annotated models.

(a) Identification of Datum Features. Figure 11-2 demonstrates symbol attachment methods for identifying the datum features. The datum feature symbol should be attached to the surface representing the datum feature. Single extension lines of feature outlines should not be used for attachment of datum feature symbols. Particular requirements and the preferred methods governing each of the four fundamental datum feature types are given in the following subparagraphs.

(1) Identification of a Planar Surface Datum Feature. The datum feature symbol is placed on an annotation plane perpendicular to the surface. See datum A in Figure 11-2, illustration (a).

(2) Identification of a Spherical Surface Datum Feature. The datum feature symbol is attached as shown to the size limits imposed upon the feature. See datum F in Figure 11-2, illustration (a).

(3) Identification of a Cylindrical Surface Datum Feature. The datum feature symbol is attached as shown to the size limits imposed upon the feature. See datum B in Figure 11-2, illustration (a).

(4) Identification of a Set of Two Opposed, Parallel Planes (a Width). The datum feature symbol and the dimension and extension lines are placed on an annotation plane perpendicular to the width centerplane. The size limits shall be organized and displayed similarly as shown. See datum C and datum E in Figure 11-2, illustration (a).

(5) Identification of Limited Area Application. When the surface containing a datum feature also contains an area of limited application of a geometric tolerance, the limited area of application is represented on the model geometry using supplemental geometry. See Figure 11-3.

(6) The datum feature symbol may also be placed on the horizontal portion of a leader line that is directed to the appropriate surface. See Figures 11-5 and 12-25.

(7) The datum feature symbol may be attached above or below a feature control frame. See datum B, datum E, and datum G in Figure 11-2, illustration (b).

(b) Query of Datum Features and Design Data. A query of any datum feature shall permit access to all relevant information for the datum feature. This includes the datum feature symbol, the size limits (if applicable), any applied geometric tolerance, and the relevant coordinate system.

11.2.3 Datum Target Identification and Attachment

The following subparagraphs describe the requirements for attaching, associating, and displaying datum targets on annotated models.

(a) V-Type Equalizers. V-type equalizers shall use the display presentation method of Figure 11-4, illustration (a). The V-type equalizers shall be represented by supplemental geometry tangent to the cylindrical datum feature with the leader of a datum target symbol attached.

(b) Movable Datum Targets. When a datum target does not have a fixed location, the datum target may be represented as supplemental geometry. The movable datum target symbol of ASME Y14.5 shall be attached. See Figure 11-4, illustration (b). The direction of movement shall be indicated by the addition of a represented line element to the model geometry to indicate the direction of movement. The represented line element shall be placed on the outside of the material. The line element shall be placed at the point of contact for a datum target point, along the line for a datum target line or within the area for a datum target area. The movement is along the represented line element. See Figure 11-4, illustration (b).

(c) Establishing Datum Target Points on a Cylindrical Surface. A datum target point on a cylindrical surface shall use the display presentation method shown in Figure 11-5 and Figure 11-6.

(d) Establishing Datum Axis Targets on Two Exterior Cylindrical Surfaces. A datum target area on a cylindrical surface shall use the display presentation method shown in Figure 11-6.

(e) Establishing a Circular Datum Target Line on a Cylindrical Surface. When the designated target for a cylindrical datum feature is a circular line, the display and attachment method shown in Figure 11-6, illustration (b), shall be employed, using supplemental geometry to represent the circular datum target line.

(f) Distinguishing Datum Target Areas. Datum target areas shall be shown using shading or section lining. See Figures 11-4 and 11-6.

11.2.4 Multiple Features Establishing a Datum

When two or more features are combined to establish a datum, associativity shall be established in the design presentation. For several common instances, the following display and associativity requirements apply. A phantom line connecting the features, as depicted in ASME Y14.5, shall not be used.

(a) A Pattern of Features Establishing a Datum Axis. When a pattern of features of size is used to establish a datum axis, the involved features and any applied tolerance for these features shall be organized as an associated group. See Figure 11-7.

(b) Two Coaxial Cylinders Establishing a Single Datum Axis. When two coaxial and cylindrical datum features are used to establish a single, common datum axis, the involved features and any applied tolerance for these features shall be organized as an associated group. See Figure 11-8.

(c) Coplanar Surfaces Establishing a Datum Plane. When two or more coplanar surface features are used to establish a datum plane, the involved model surfaces and any applied tolerance for these surfaces shall be organized as an associated group. See Figure 11-9. When an intervening feature separates the surfaces being toleranced, the profile tolerance shall be attached to one of the surfaces but not both. See Figure 11-10.

11.3 DRAWING GRAPHIC SHEET REQUIREMENTS

Datum features in axonometric views shall be indicated as follows:

(a) Datum Reference Frame and Coordinate System Correspondence. The corresponding coordinate system shall be displayed in each axonometric view in which a datum reference frame is cited.

(b) Identification of Datum Features in Axonometric Views. The following subparagraphs describe requirements for identification of datum features in axonometric views:

(1) The datum feature symbol should be attached to the model geometry surface representing the datum feature. A single extension line of a feature outline should not be used for attachment of datum feature symbols in an axonometric view.

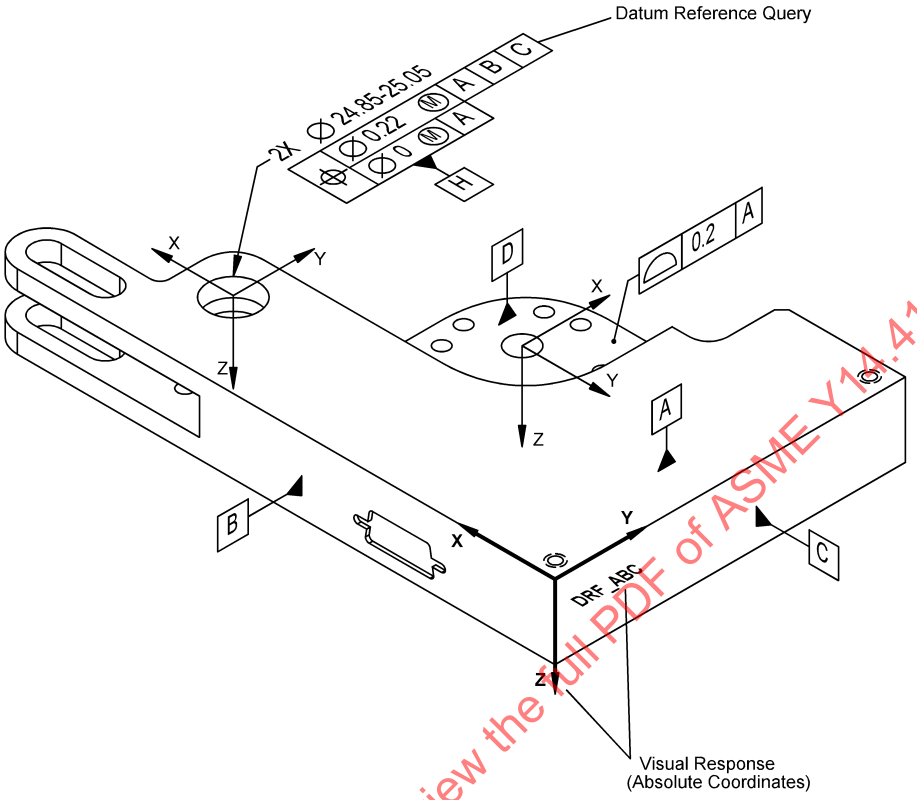
(2) Datum feature symbols may be attached to the dimension for features of size when the feature is used to define a datum. See Figure 11-2.

(c) V-Type Equalizers Using Axonometric Views. V-type equalizers shall use the display presentation method of Figure 11-11, illustration (a). The V-type equalizers shall be represented by supplemental geometry tangent to the cylindrical datum feature with the leader of a datum target symbol attached.

(d) Movable Datum Targets Using Axonometric Views. When a datum target does not have a fixed location, the datum target may be represented as supplemental

geometry. The movable datum target symbol of ASME Y14.5 shall be attached. See Figure 11-11, illustration (b). The direction of movement shall be indicated by the addition of a represented line element to the model geometry to indicate the direction of movement. The represented line element shall be placed on the outside of the material. The line element shall be placed at the point of contact for a datum target point, along the line for a datum target line, or within the area for a datum target area. The movement is along the represented line element. See Figure 11-11, illustration (b).

Figure 11-1 Datum System and Coordinates Relationship



(a) Absolute Coordinates Corresponding to a Datum System.

11.2.1(c)
11.2.1(e)(2)

Figure 11-1 Datum System and Coordinates Relationship (Cont'd)

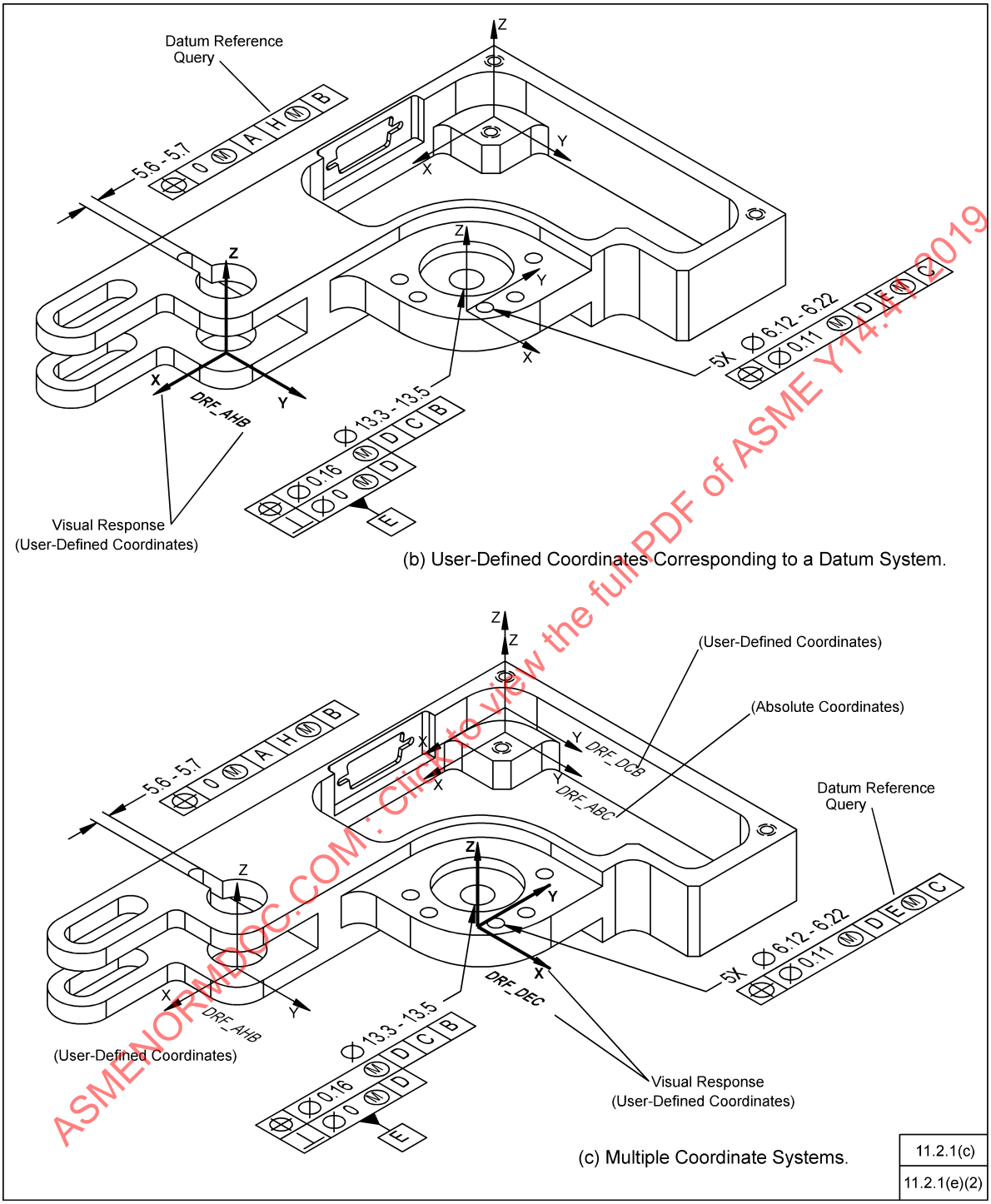


Figure 11-2 Datum Feature Symbol Attachments

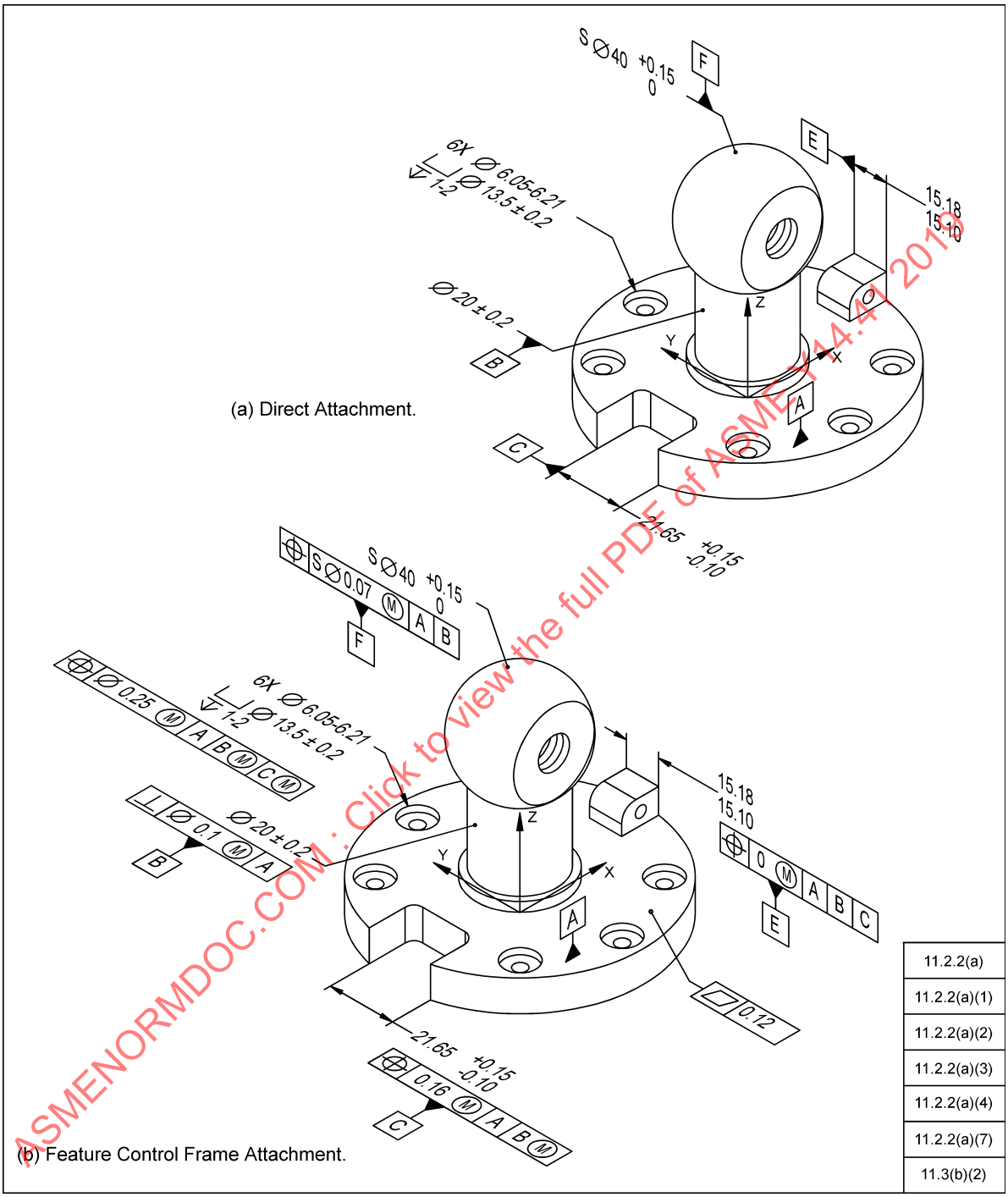
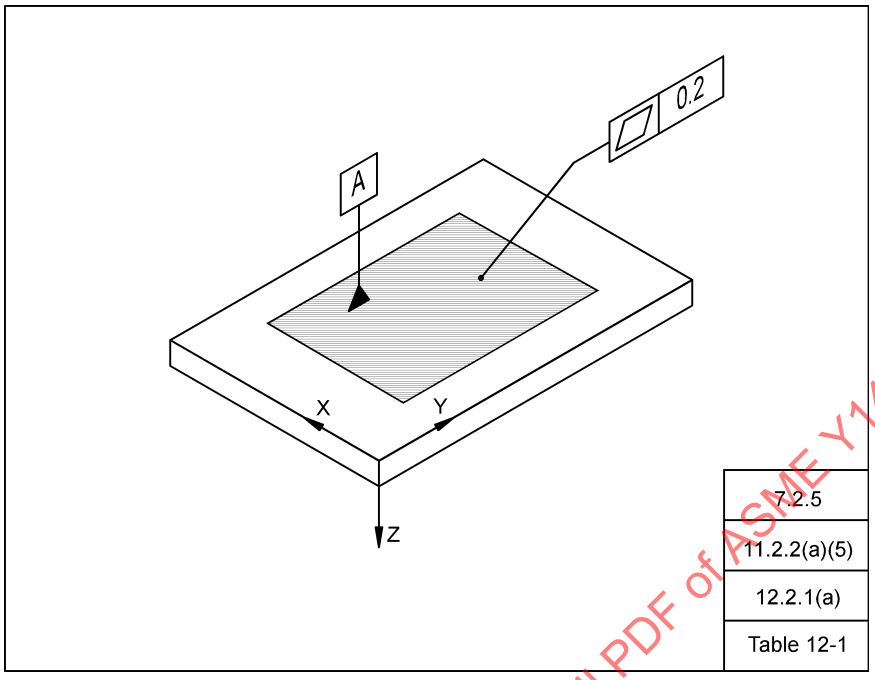
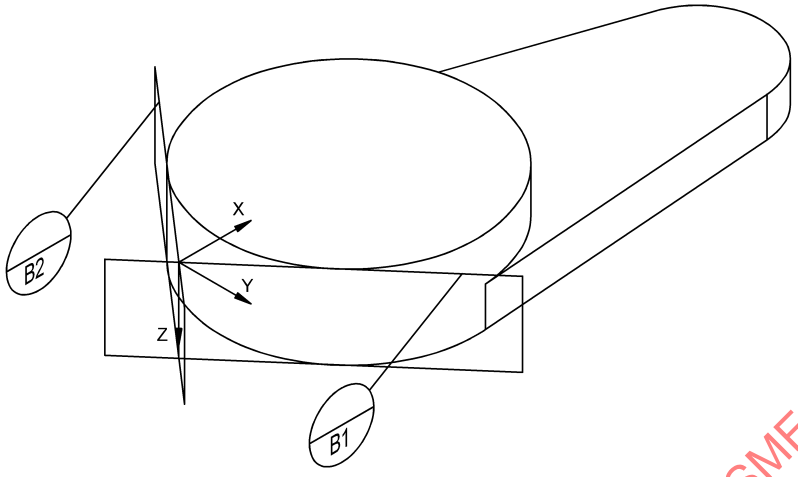


Figure 11-3 Partial Surface as a Datum Feature

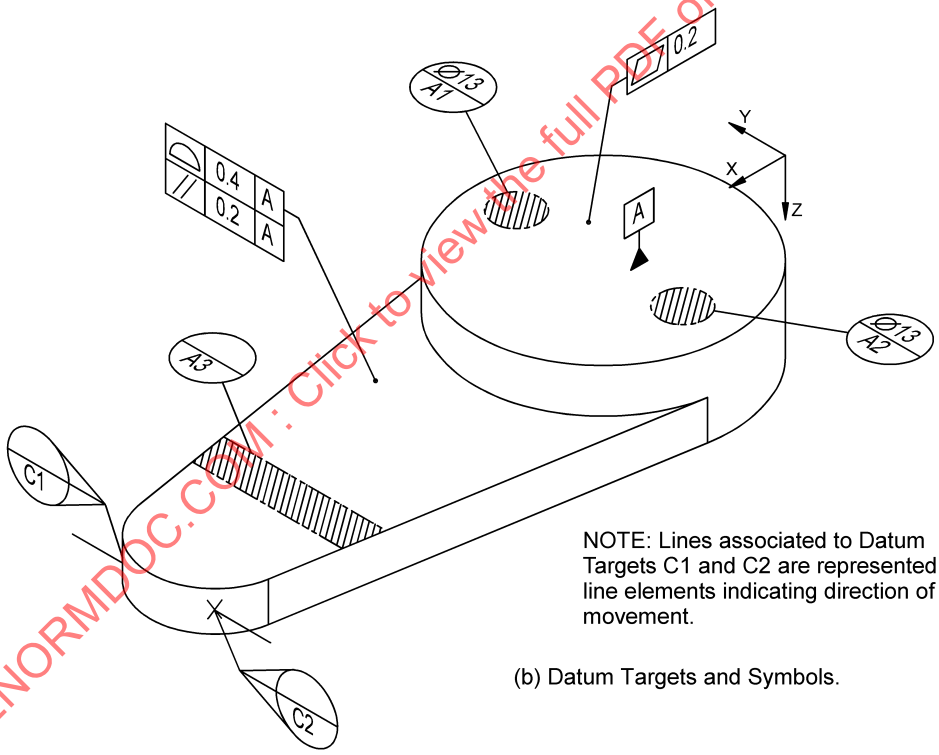


7.2.5
11.2.2(a)(5)
12.2.1(a)
Table 12-1

Figure 11-4 Datum Targets and Symbols Attachment



(a) V-type Equalizer - Datum Target Planes.



NOTE: Lines associated to Datum Targets C1 and C2 are represented line elements indicating direction of movement.

(b) Datum Targets and Symbols.

5.1.4(d)
5.1.4(e)
11.2.3(a)
11.2.3(b)
11.2.3(f)

Figure 11-5 Equalizing Target Points Establish a Datum Axis on an Internal Cylindrical Surface

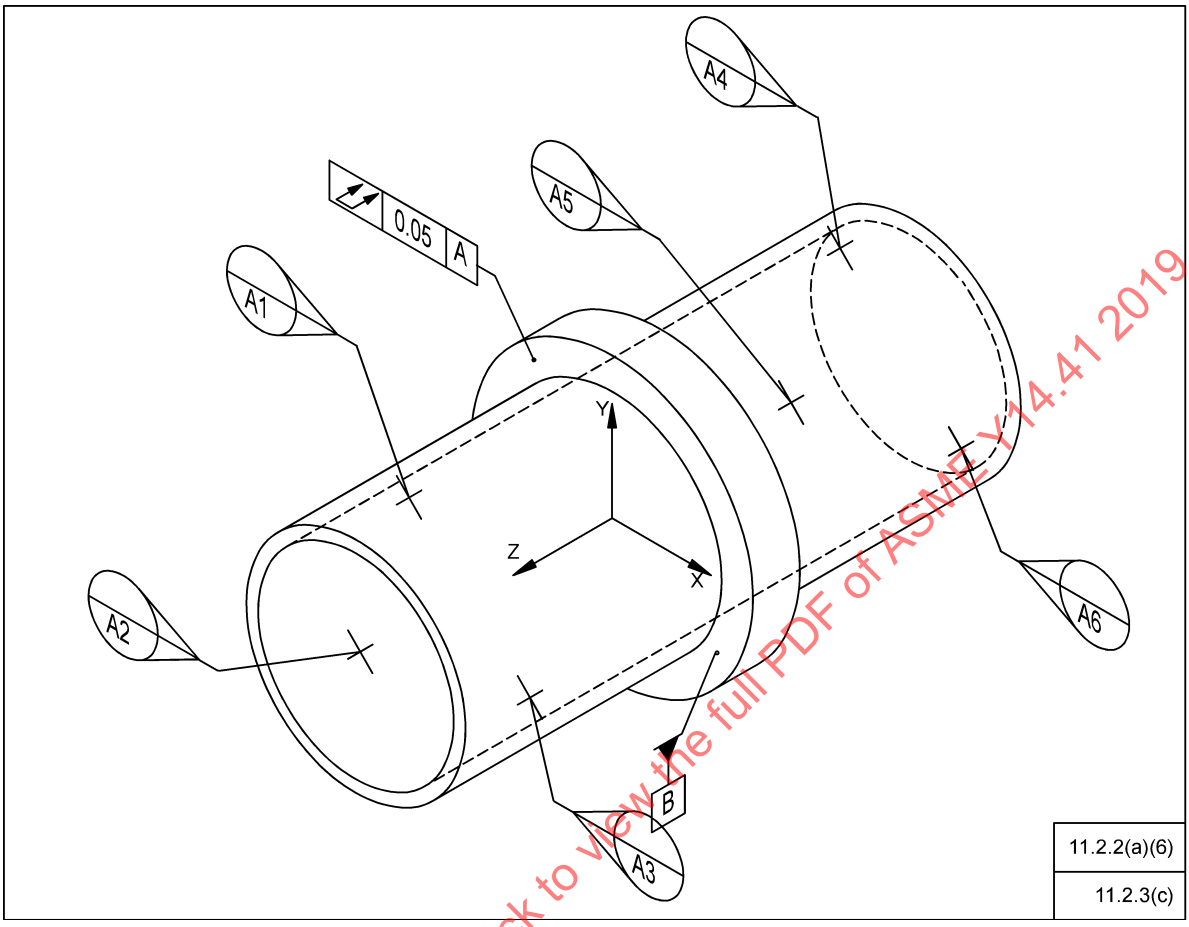
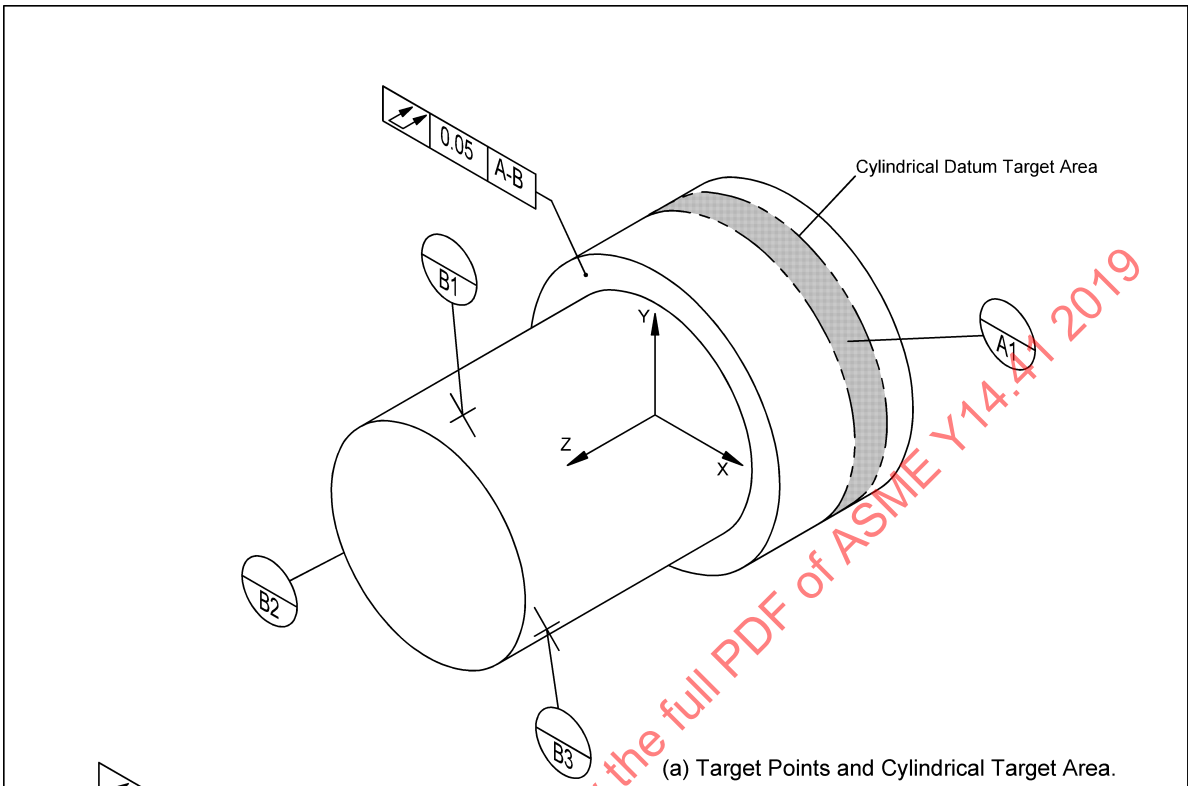
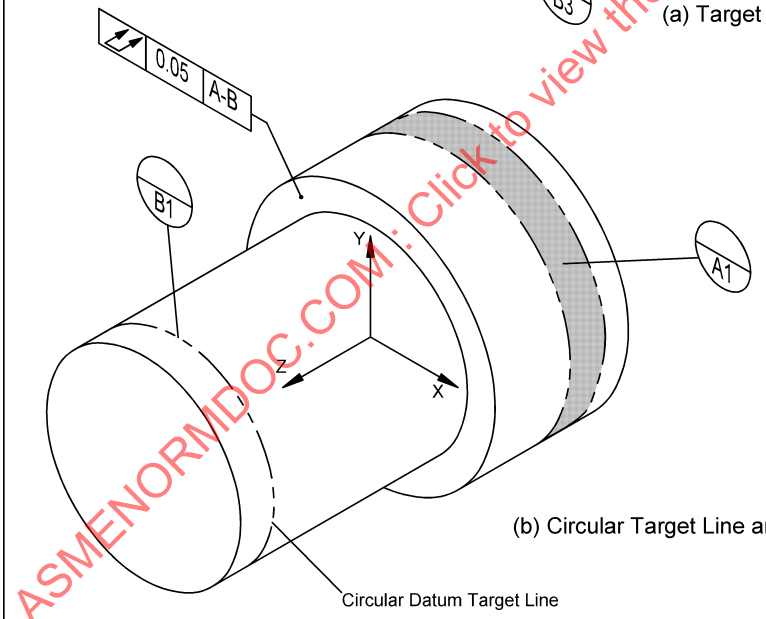


Figure 11-6 Two Cylindrical Features Establish a Datum Axis



(a) Target Points and Cylindrical Target Area.



(b) Circular Target Line and Cylindrical Target Area.

11.2.3(c)
11.2.3(d)
11.2.3(e)
11.2.3(f)

Figure 11-7 Pattern of Features Establish a Datum Axis

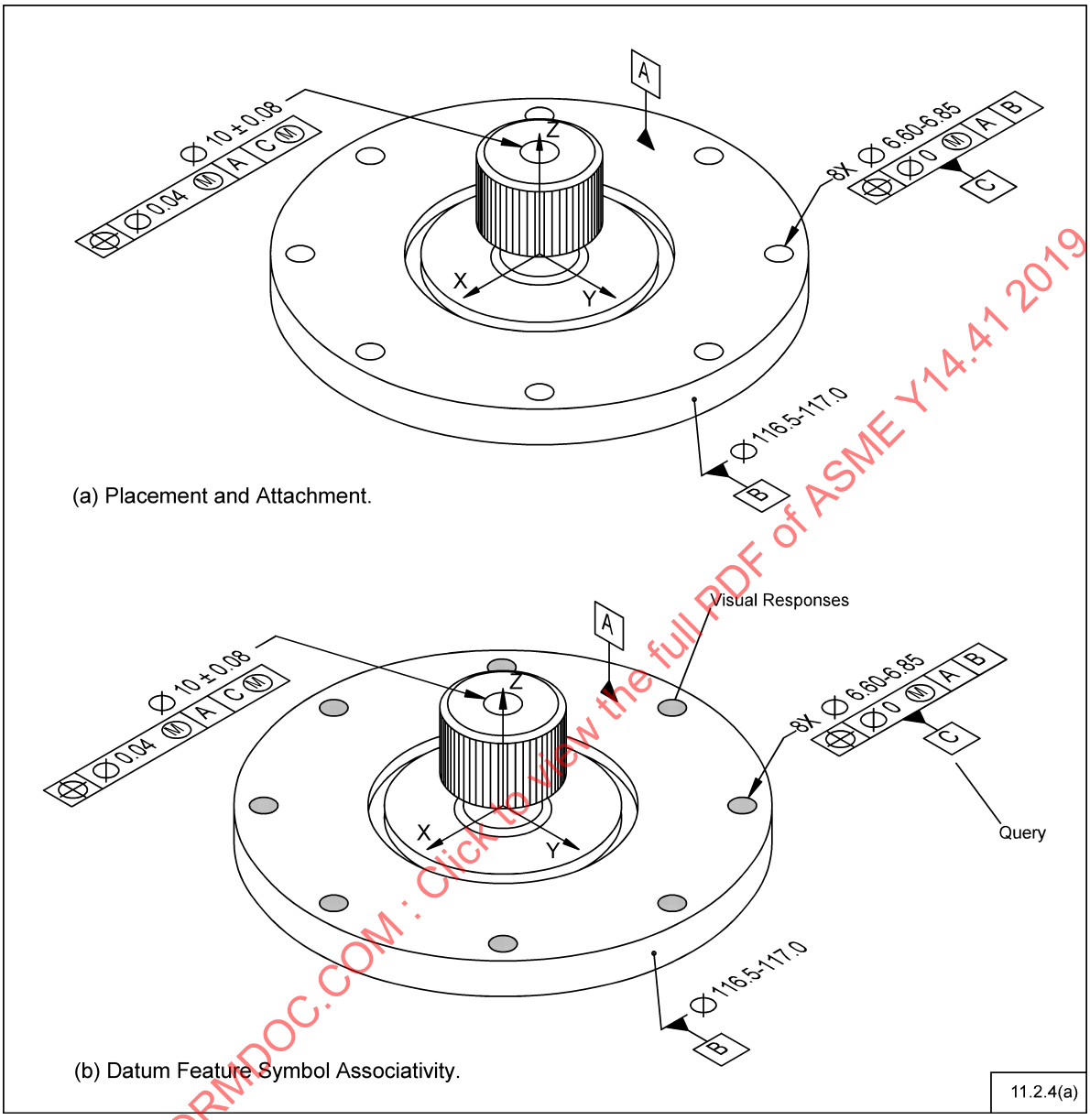


Figure 11-8 Two Coaxial Features Establish a Datum Axis

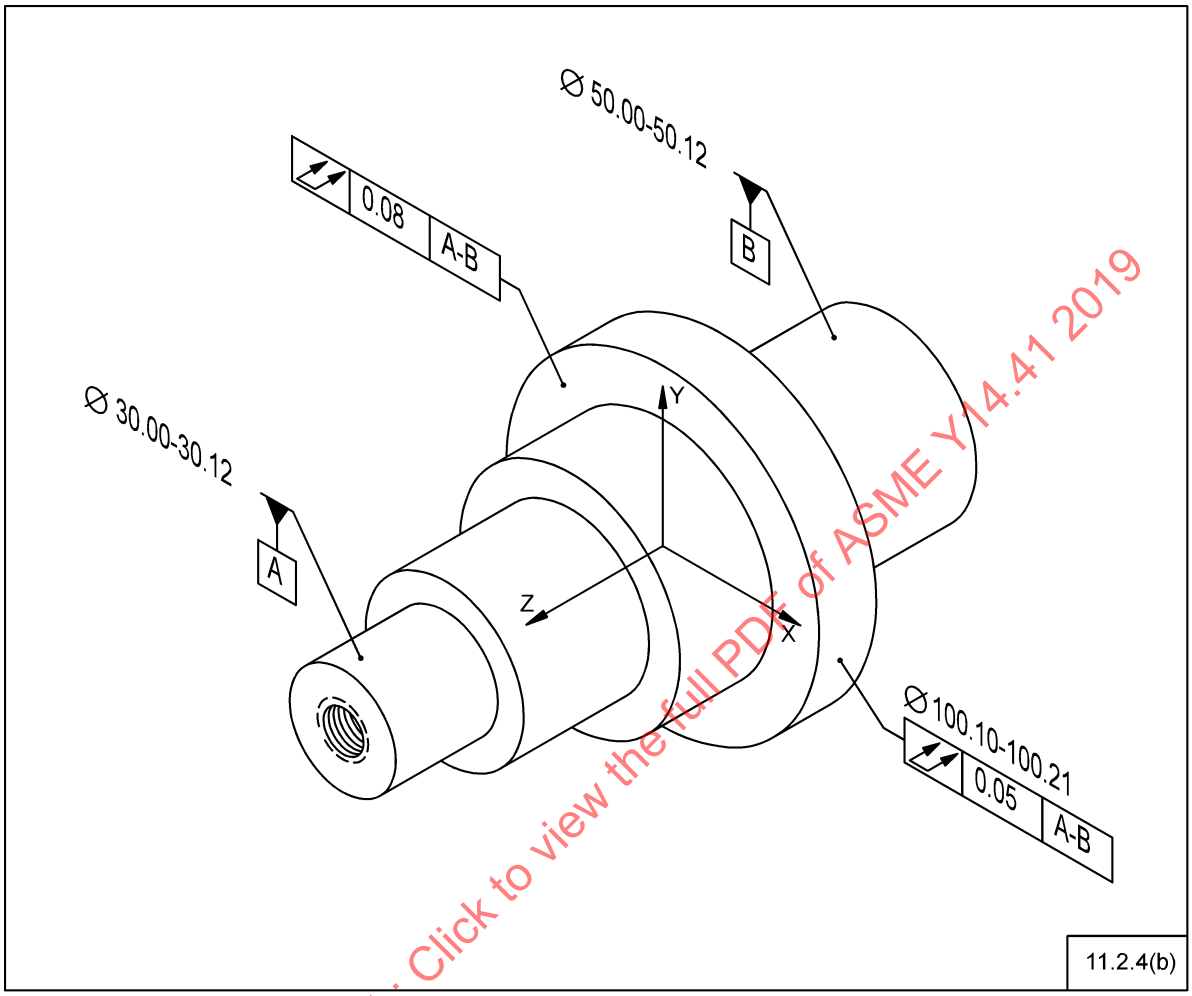


Figure 11-9 Coplanar Surfaces Establish a Datum Plane

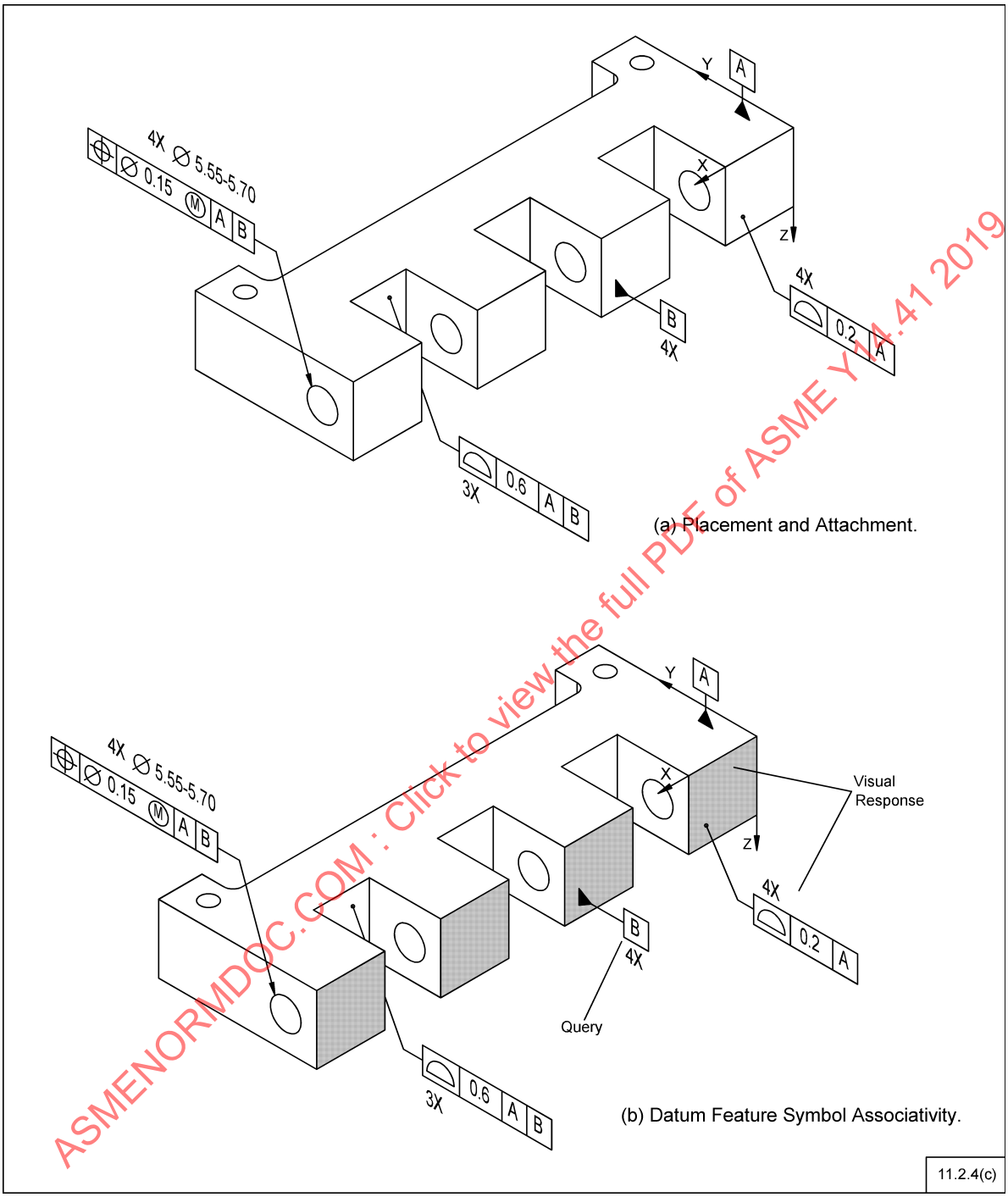


Figure 11-10 Separated Surfaces Establish a Datum Plane

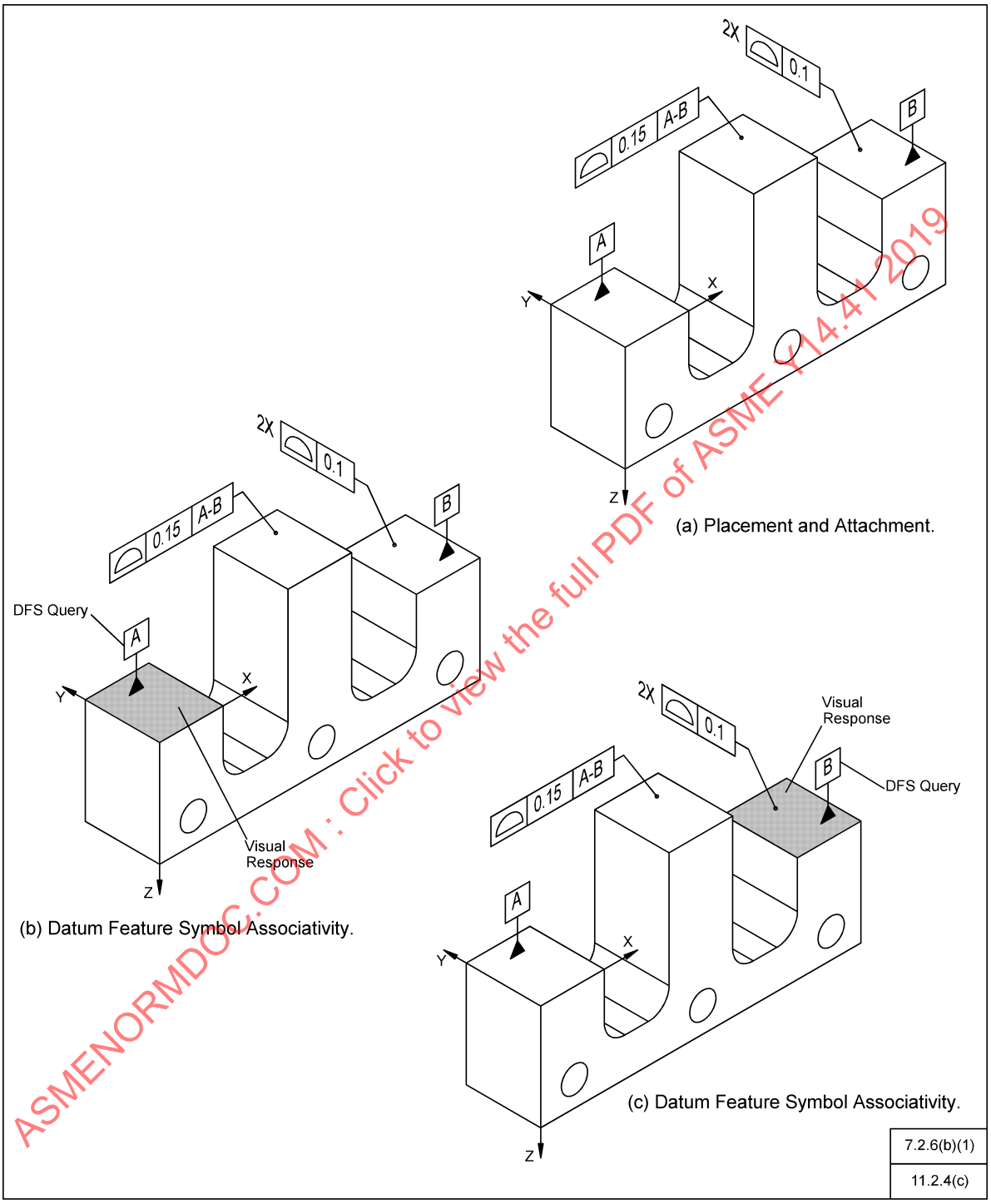
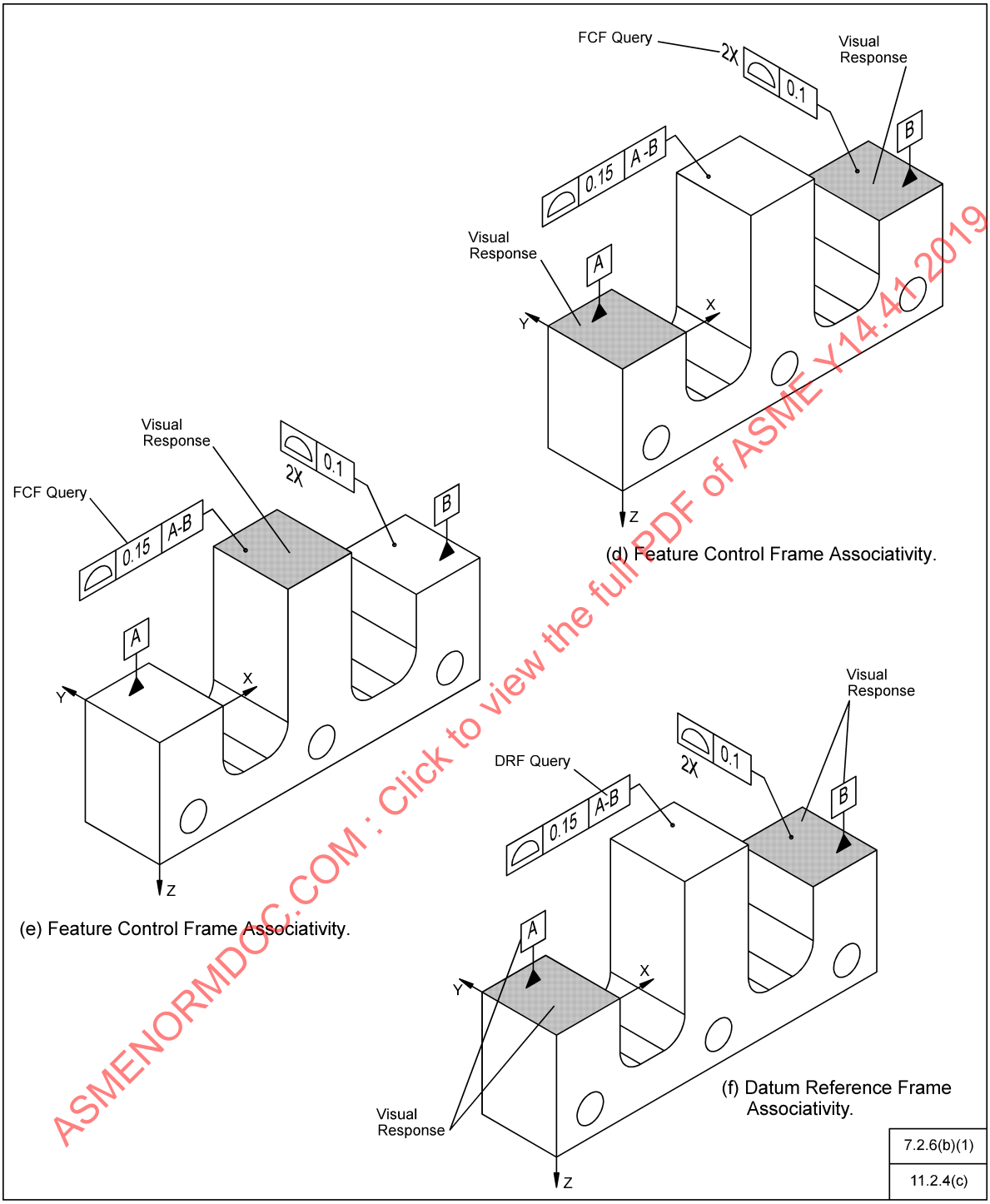


Figure 11-10 Separated Surfaces Establish a Datum Plane (Cont'd)



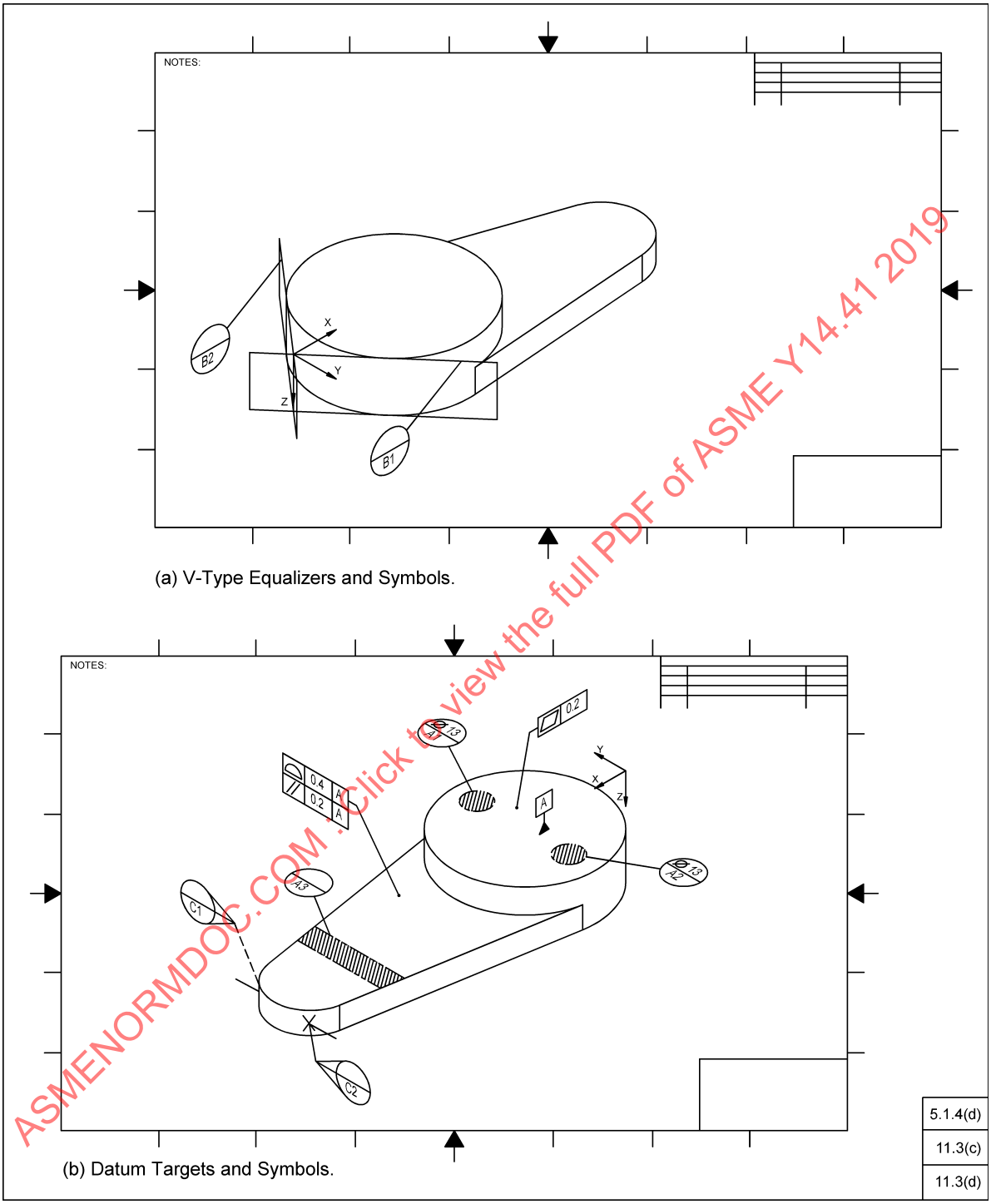
(d) Feature Control Frame Associativity.

(e) Feature Control Frame Associativity.

(f) Datum Reference Frame Associativity.

7.2.6(b)(1)
11.2.4(c)

Figure 11-11 Datum Targets and Symbols in an Axonometric View



(a) V-Type Equalizers and Symbols.

(b) Datum Targets and Symbols.

Section 12
Geometric Tolerances

This Section establishes the placement, attachment, and display requirements for geometric tolerances.

12.1 COMMON REQUIREMENTS

A general note defining a geometric tolerance may be specified. More than one tolerance may be specified.

Applying GD&T in notes that are not associated to geometric elements may prohibit the use of automated tools to digitally consume those design requirements. GD&T with associativity should be used.

12.2 ANNOTATED MODEL REQUIREMENTS

Paragraphs 12.2.1 through 12.2.5 address the placement, attachment, and display requirements for geometric tolerances.

12.2.1 Form Tolerances

The feature control frame shall be placed on an annotation plane parallel to, perpendicular to, or coincident with the surface to which it applies. See Figure 12-1. Table 12-1 lists the form tolerances with the type of attachment method used.

(a) Flatness, Limited Area Application. A limited area of application shall be represented on the model geometry using supplemental geometry. The leader directed from the flatness feature control frame shall be attached within the represented area. See Figure 11-3.

(b) Circularity Applied to a Sphere, Cylinder, Cone, or a Surface of Revolution. The feature control frame shall be placed on an annotation plane perpendicular to the feature's axis of revolution, or containing the centerpoint of a sphere. See Figure 12-2.

(c) Straightness Applied to the Line Elements of a Cylindrical or Conical Surface. The feature control frame shall be placed on an annotation plane containing the axis of the feature surface. See Figure 12-6.

12.2.2 Orientation Tolerances

The orientation feature control frame shall be placed on an annotation plane parallel or perpendicular to the referenced primary datum. Table 12-2 lists the orientation tolerances with the attachment method used when an orientation tolerance is directly applied.

(a) Each Element Directed by Line Element. The orientation feature control frame and the EACH ELEMENT qualifier shall be placed on an annotation plane containing the represented line element indicating the direction of application. See Figure 12-9.

(b) Each Element Directed by Ordinate Axis. The orientation feature control frame and the EACH ELEMENT qualifier shall be placed on an annotation plane parallel and perpendicular with the absolute coordinate system or an established user-defined coordinate system. See Figure 12-10.

(c) Orienting an Axis Within a Parallel Planes Tolerance Zone. The orientation feature control frame shall be related to the diametral size and any other geometric tolerance requirement. The orientation of the extension lines defines the orientation of the tolerance zone. See Figure 12-13.

12.2.3 Profile Tolerances

When a profile requirement is specified, it shall be attached using a directed leader. Table 12-3 lists profile applications.

(a) Conical Surface or a Surface of Revolution. The feature control frame shall be placed on an annotation plane perpendicular to or containing the feature's axis of revolution. See Figure 12-14, illustration (b).

(b) Multiple or Coplanar Surfaces. When a profile tolerance applies to multiple surfaces, the features shall be combined into an associated group. The feature control frame shall be placed on an annotation plane parallel or perpendicular to the referenced primary datum. See Figure 12-15.

(c) Between Basis. When the associated geometry is not sufficient to indicate the application, labeled supplemental geometry may be added to indicate the boundary of application. The between symbol may be used to clarify the requirement. See Figure 12-16.

(d) All-Around Application. When the all-around symbol is used, query shall be used to identify the controlled surfaces. See Figure 12-17.

(e) Profile of a Line Directed by Line Element. The feature control frame shall be placed on an annotation plane containing the represented line element, parallel and perpendicular to the absolute coordinate system or an established user-defined coordinate system. See Figure 12-18.

(f) Profile of a Line Directed by Ordinate Axis. The feature control frame shall be placed on an annotation plane parallel and perpendicular to the absolute coordinate system or an established user-defined coordinate system. See Figure 12-19.

(g) All-Over Application. When the all-over symbol is used, all of the appropriate portions of the annotated model should be designated as associated objects for the profile tolerance.

12.2.3.1 Nonuniform Tolerance Zones. A nonuniform tolerance zone is used to define a tolerance zone with boundaries that may be any shape. See Figure 12-20.

(a) Nonuniform Tolerance Zone Geometry. Nonuniform tolerance zone boundaries shall be modeled at the same scale as the model. See para 6.1.1(a). Each nonuniform tolerance zone boundary shall be modeled with the proper relationship to the surface (true profile). Each nonuniform tolerance zone boundary shall be modeled such that it extends along and encompasses the entire toleranced feature(s). The ends of the tolerance zone boundaries may extend beyond the extents of the toleranced feature. See Figure 12-20. Extension of the tolerance zone boundaries may be used to show continuation of a complex contoured surface where the shape of an extended tolerance zone boundary would not otherwise be obvious. See Figure 12-20.

(b) Nonuniform Tolerance Zone Associativity. Nonuniform tolerance zone boundaries shall be associated to the toleranced feature. The nonuniform tolerance zone, nonuniform feature control frame, related annotation, and toleranced feature(s) shall be organized as an associated group.

(c) Nonuniform Tolerance Zone Display. The display of the nonuniform tolerance zone shall not obscure the display of the associated feature(s). Nonuniform tolerance zone boundaries shall be capable of being:

(1) displayed without the model or the annotated model being displayed

(2) displayed or hidden on demand

(3) displayed in conjunction with the nonuniform feature control frame

(4) displayed only in selected views

12.2.4 Location Tolerances

The location feature control frame shall be placed on an annotation plane parallel or perpendicular to the referenced primary datum or on an annotation plane that is perpendicular to or contains the feature axis or centerplane of the toleranced feature. See Figure 7-5. Table 12-4 identifies location tolerance applications and the attachment method used.

(a) Positioning Feature Patterns Individually to Individual Datum Features. Each individual pattern of features and the required individual datum feature shall be collected as an associated group. A coordinate system representing each individual datum system shall be established. See Figure 12-21.

(b) Projected Tolerance Zones. The leader for a position or orientation tolerance applied with a projected tolerance zone shall be directed to the surface from which the tolerance zone projects and terminate with an arrowhead. The feature control frame shall contain the projected tolerance zone symbol and the required projection value. See Figure 12-22.

(c) Closer Control at One End of a Feature. The size dimension and both feature control frames shall be collected as an associated group. For a conical tolerance zone, the leaders for the positional tolerances shall be directed to the surface to which it applies. See Figure 12-23.

(d) Bidirectional Positional Tolerancing for Polar and Rectangular Coordinates. The callouts specifying the bidirectional requirements shall be placed on the same annotation plane as the size specification for the feature. See Figure 12-25.

12.2.5 Runout Tolerances

Table 12-5 lists runout applications and the attachment method that may be used. Applications of circular runout to a spherical, conical, or revolved surface are also listed.

(a) Attachment Methods for Runout Tolerances. The use of multiple leader lines should be avoided when assigning runout tolerances. When the same runout control with the same tolerance value and datum reference (s) is applied to multiple features, one of the following methods may be used:

(1) Create a single runout feature control frame for all identically controlled surfaces, and associate it to all applicable model surfaces. A note indicating the number of surfaces to which the tolerance applies may be included for additional associative emphasis. See Figure 12-27, illustrations (a) and (b).

(2) Define the geometric tolerance in a general note.

(3) Create and attach a separate runout feature control frame to each of the toleranced surfaces. See Figure 12-27, illustration (c).

(b) Circular Runout Applied to a Spherical or Conical Surface, or a Surface of a Revolution. The circular runout feature control frame shall be placed on an annotation plane perpendicular to the conical or revolved feature's axis of revolution, or containing the centerpoint of a sphere. See Figure 12-29.

12.3 DRAWING GRAPHIC SHEET REQUIREMENTS

When using orthographic views, geometric tolerances shall be specified in accordance with ASME Y14.5 unless otherwise specified. When axonometric views are used, paras. 12.3.1 through 12.3.6 provide exceptions and additional requirements.

12.3.1 Requirements Applicable to all Geometric Tolerances

(a) Toleranced Features. A portion of the toleranced feature shall be visible in the view in which the tolerance is applied.

(b) Feature Control Frame Applied to a Feature of Size. When a geometric tolerance is applied to a feature of size, the feature control frame shall be placed below the size dimension. See Figure 12-30, illustration (a).

(c) Feature Control Frame Applied to a Feature. The leader line shall terminate on the surface with a dot. See Figure 12-30, illustration (b).

12.3.2 Form Tolerances

The requirements described in para. 12.2.1 apply unless otherwise specified. Table 12-1 lists the form tolerances with the type of attachment method used.

(a) Flatness, Limited Area Application. A limited area of application shall be represented using supplemental geometry. The leader directed from the flatness feature control frame shall be attached within the represented area. See Figure 12-31.

(b) Straightness Applied to Line Elements of a Cylindrical or Conical Surface. The feature control frame shall be directed to the surface with a leader line. The direction of application is parallel to the axis of the feature. See Figure 12-32, illustration (a).

12.3.3 Orientation Tolerances

The requirements described in para. 12.2.2 apply unless otherwise specified. Table 12-2 lists the orientation tolerances with the attachment method used when an orientation tolerance is directly applied.

(a) Specifying Each Element. The orientation feature control frame and the notation EACH ELEMENT shall be directed to the represented line element indicating the direction of application. See Figure 12-32, illustration (b).

(b) Orienting an Axis With a Parallel Planes Tolerance Zone. The orientation feature control frame shall be attached to the diametral size and any other geometric tolerance requirement. The orientation of the extension lines defines the orientation of the tolerance zone. See Figure 12-33.

12.3.4 Profile Tolerances

The requirements described in para. 12.2.3 apply unless otherwise specified. Table 12-3 lists profile applications.

(a) Profile of a surface may be applied to a feature that is not displayed in a profile view.

(b) When an individual profile requirement is specified, it shall be attached using a directed leader.

(c) Profile of a Surface Applied to Multiple Surfaces. The tolerance shall be specified using one of the following:

(1) the feature control frame shall be directed to all of the toleranced features using one or more leader lines.

(2) a qualifying note such as 2X INDICATED K shall accompany the feature control frame and the appropriate features shall be identified. See Figure 12-34.

(3) the between symbol shall be placed beneath the feature control frame. The features shall be identified with two lines to indicate the limits of the area of application. The lines shall be labeled and referred to with the between symbol. See Figure 12-35.

(d) Profile of a Surface Using the All-Around Symbol. When the all-around symbol is used with a profile of a surface, it shall be shown in an orthographic view that contains the true profile of the toleranced features.

(e) Profile of a Line. When a line profile callout is required, it shall be applied to a represented line element showing the direction of application.

(f) Nonuniform Profile Tolerance. When a nonuniform profile feature control frame is displayed, the nonuniform tolerance zone shall be displayed.

12.3.5 Location Tolerances

Table 12-4 identifies position tolerance applications and the attachment method used.

(a) The requirements described in para. 12.2.4 apply unless otherwise specified.

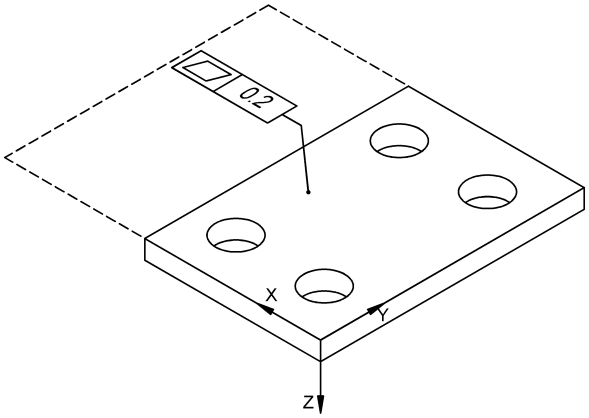
(b) When a boundary control for a noncylindrical feature is required, the applicable geometric tolerances shall be shown in an orthographic view that contains the true profile of the toleranced feature.

12.3.6 Runout Tolerances

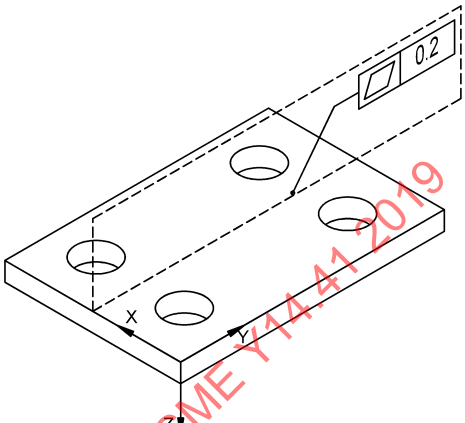
Runout tolerances shall be applied as described in para. 12.2.5. Table 12-5 lists runout applications and the attachment method generally used.

Figure 12-1 General Application of Geometric Tolerances — Coincident or Perpendicular Annotation Plane

NOTE: The annotation planes shown here as dashed lines are for clarification only, and are not part of an actual presentation.



(a) Coincident Annotation Plane.



(b) Perpendicular Annotation Plane.

Table 12-1

12.2.1

Table 12-1 Form Tolerances

Condition	Attachment Technique		Paragraph	Figure
	Size Callout	Directed Leader		
Planar Surface	…	●	12.2.1	12-1
Limited Area	…	●	12.2.1(a)	11-3
Median Plane	●	…	…	12-7(b)
Sphere	…	●	12.2.1(b)	12-2(a)
Cylinder	…	●	12.2.1(b)	12-2(b)
Conical Surface	…	●	12.2.1(b)	12-2(c)
Surface of Revolution	…	●	12.2.1(b)	12-2(d)
Cylinder	…	●	…	12-3(a)
Planar Surface	…	●	…	12-4
	…	●	…	12-5
Cylindrical Surface or Conical Surface	…	●	12.2.1(c)	12-6
Median Line	●	…	…	12-7(a)

5.1.4(a)(1)
12.2.1
12.3.2

Figure 12-2 Circularity — Sphere, Conical, or Revolved Surface

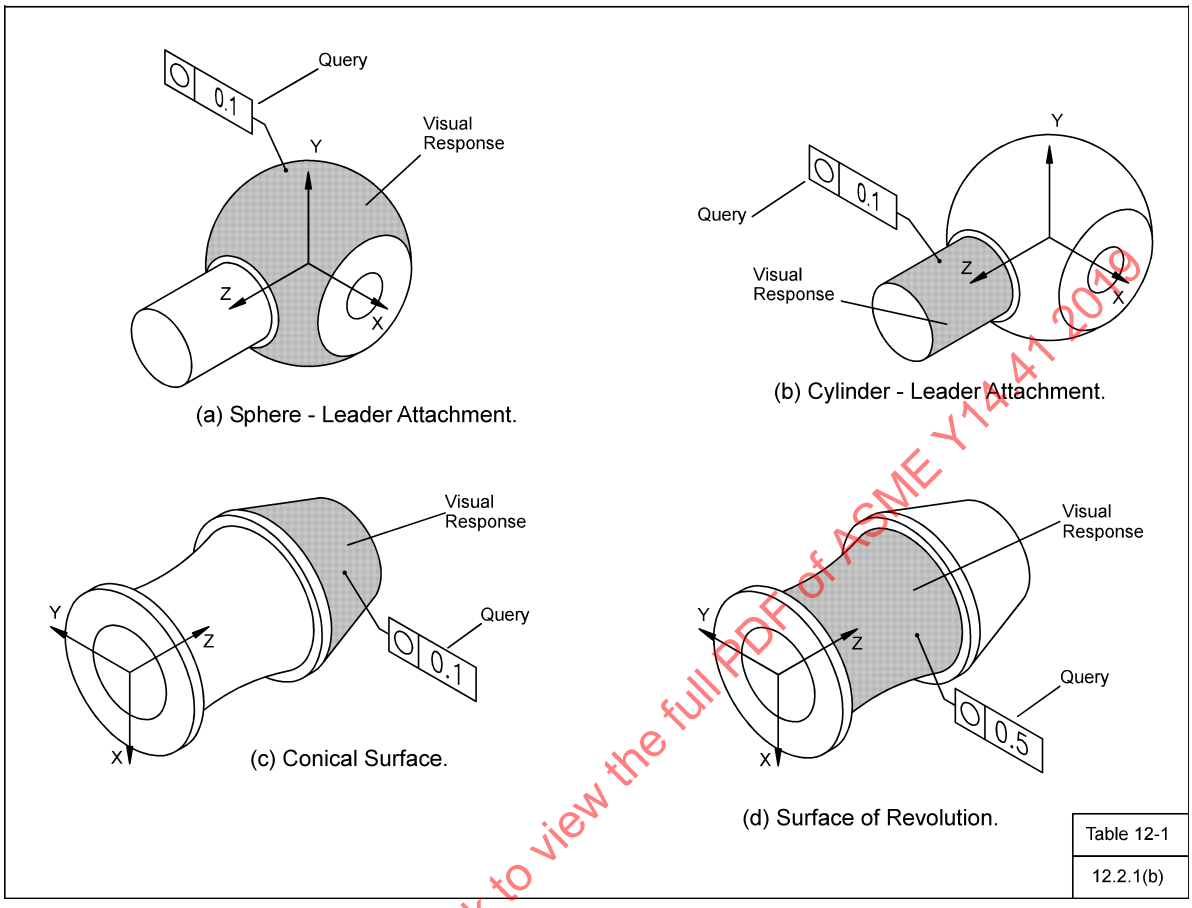


Figure 12-3 Cylindricity

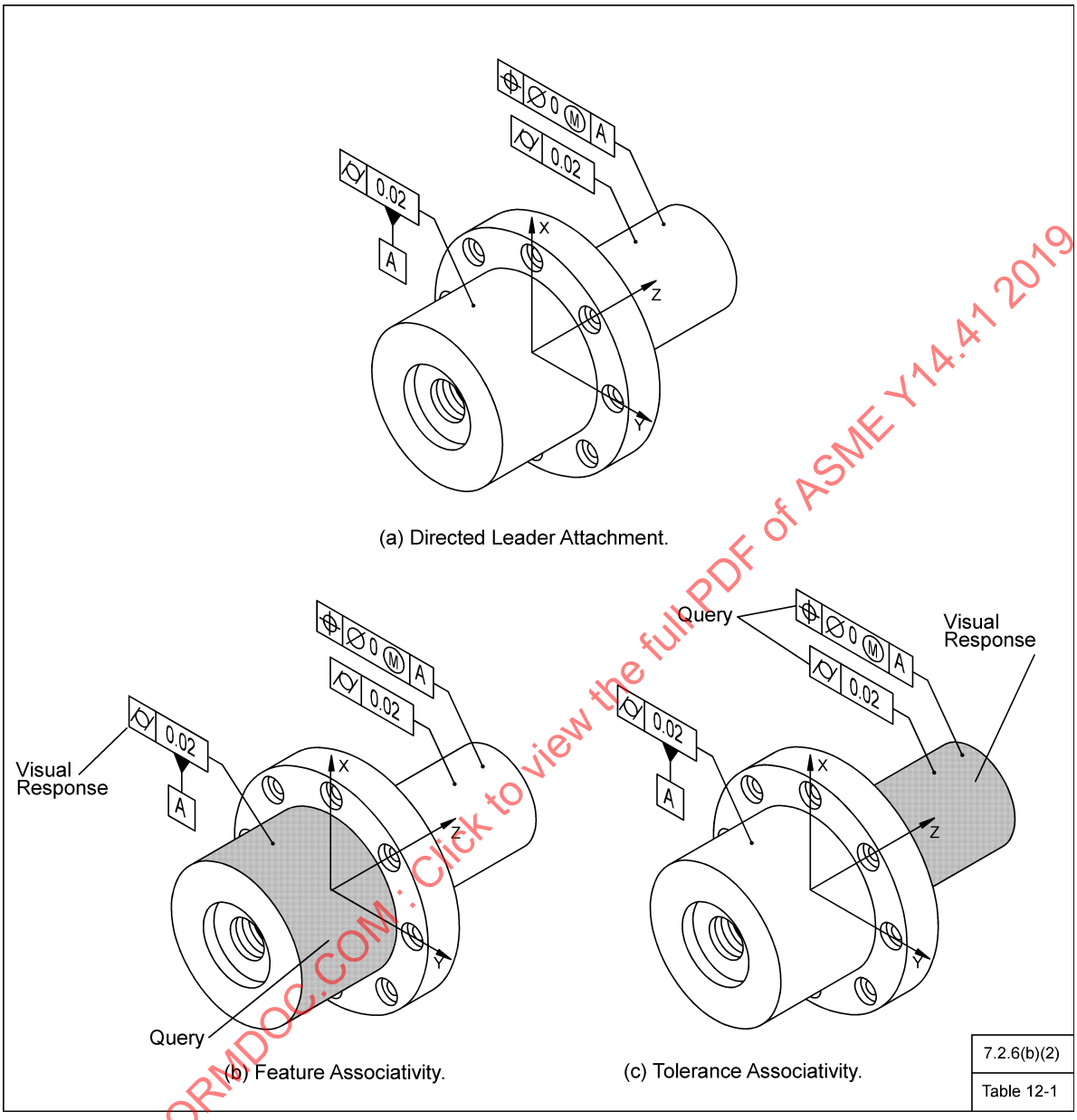


Figure 12-4 Straightness — Directed by Line Element

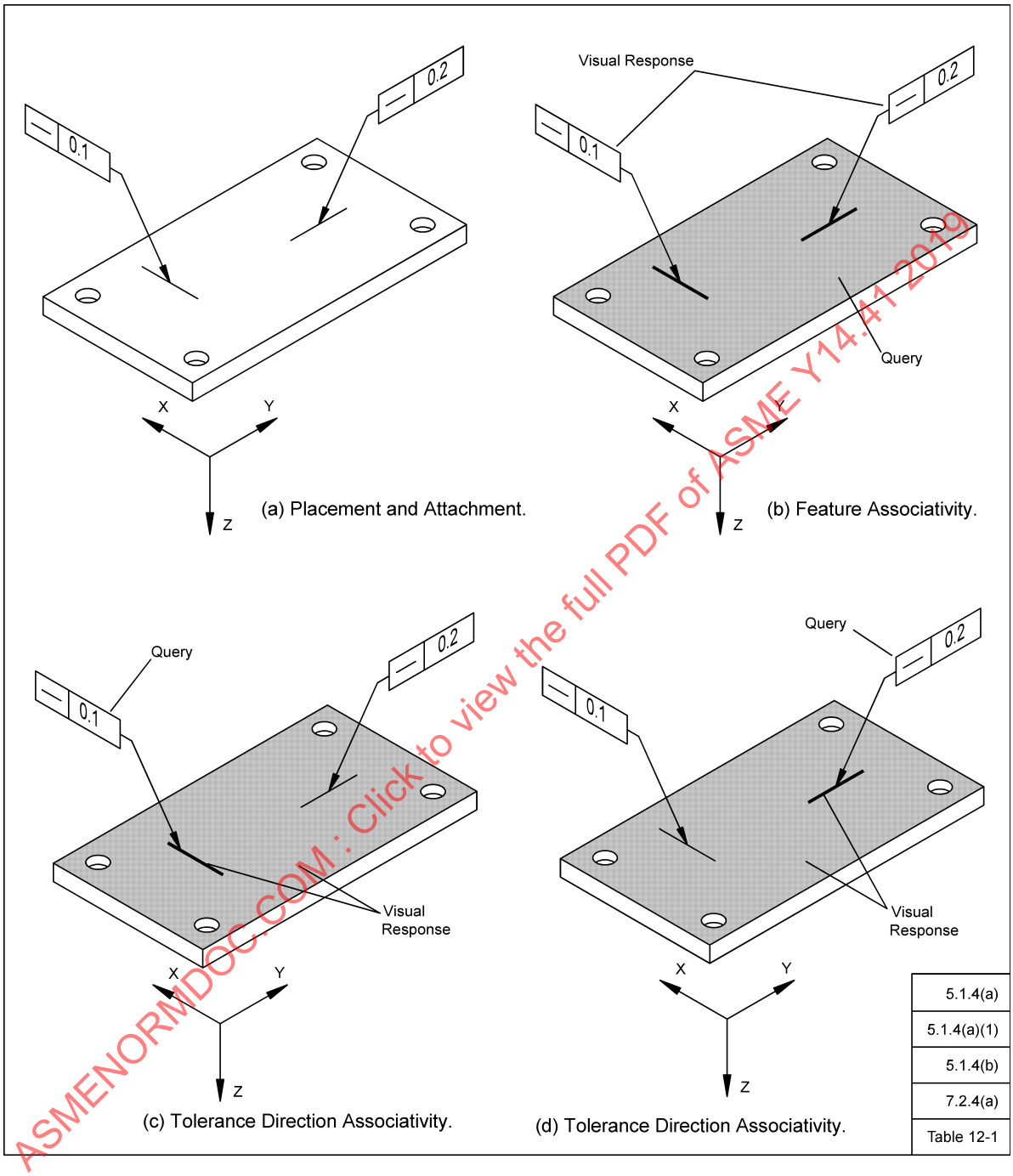


Figure 12-5 Straightness — Directed by Ordinate Axis

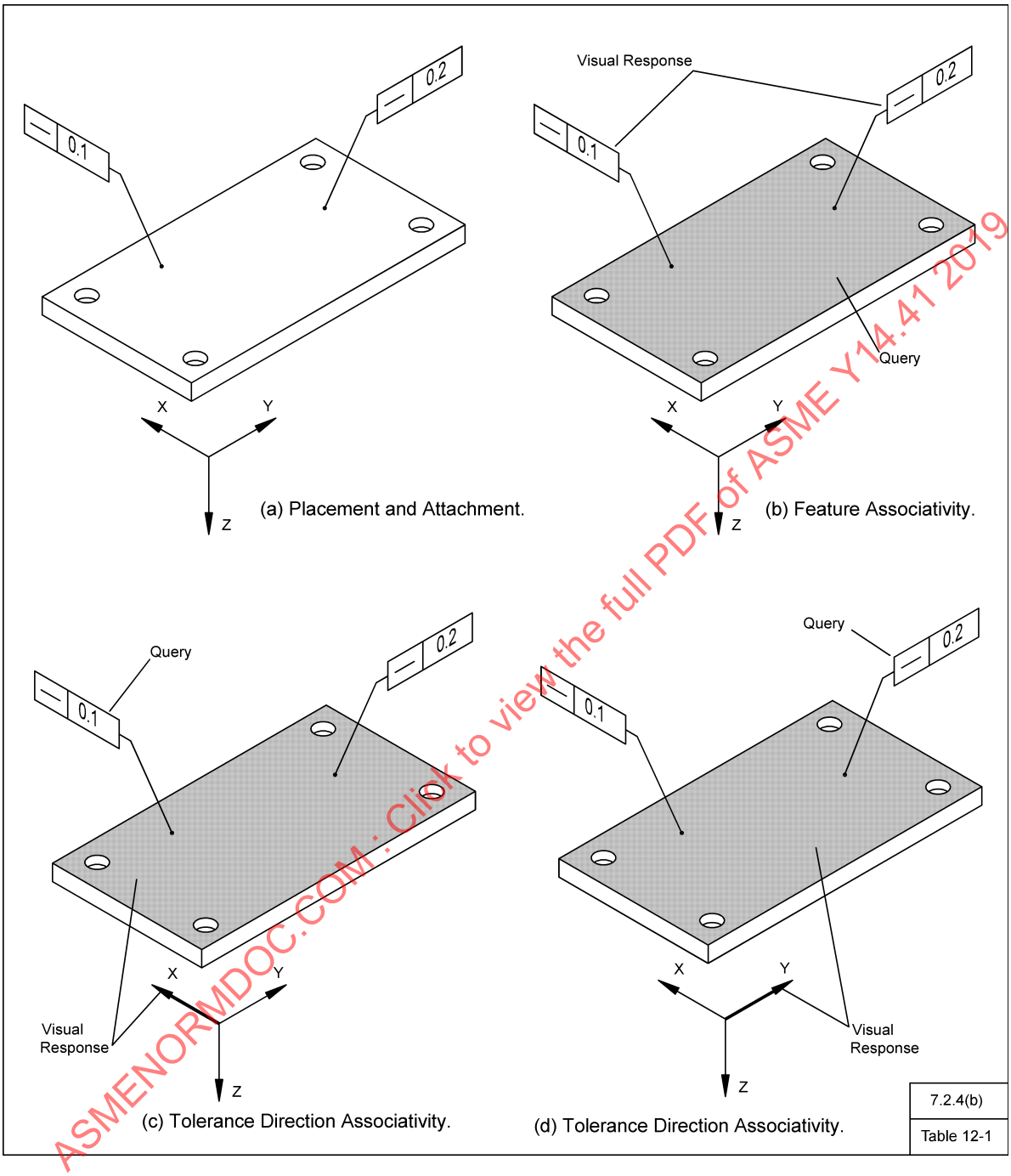
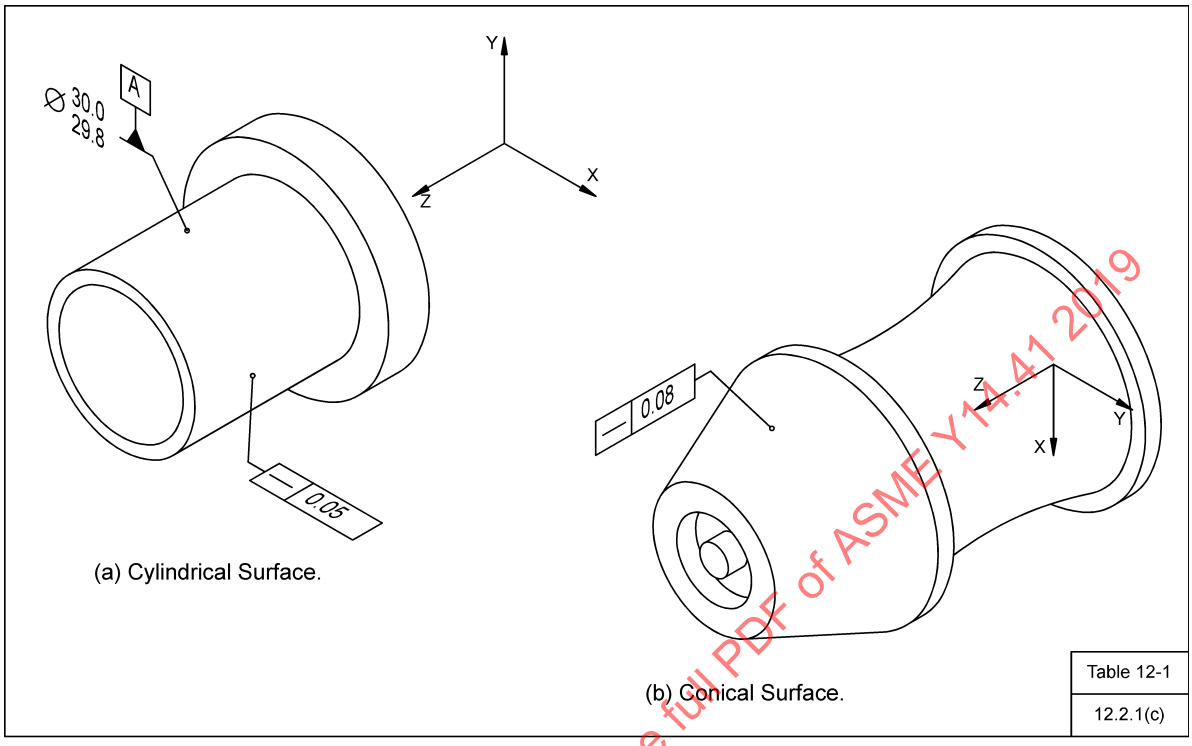


Figure 12-6 Straightness — Cylindrical or Conical Surface

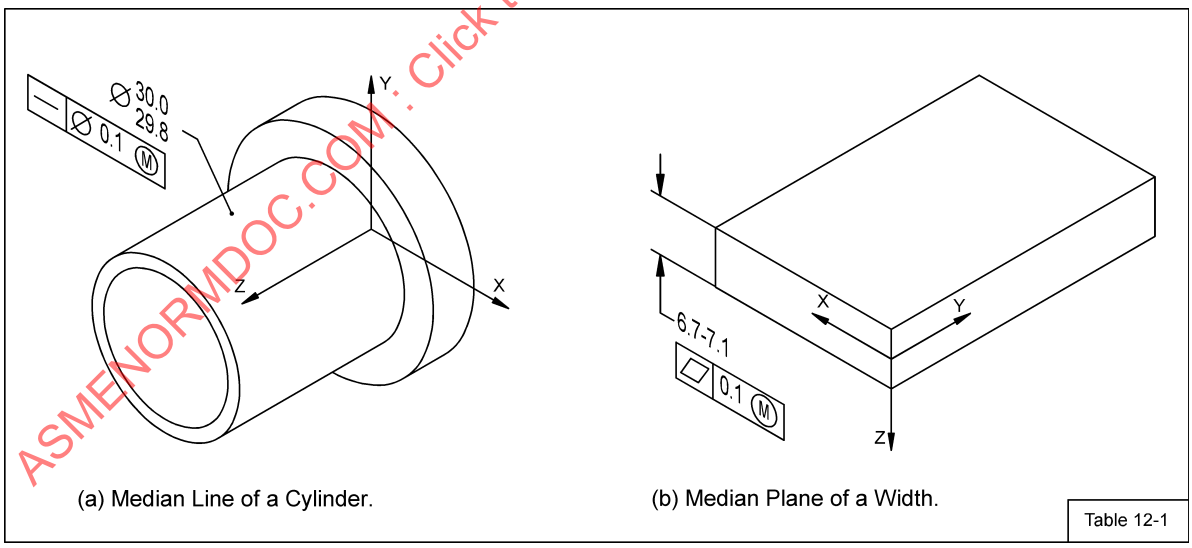


(a) Cylindrical Surface.

(b) Conical Surface.

Table 12-1
12.2.1(c)

Figure 12-7 Straightness — Median Line and Flatness: Median Plane



(a) Median Line of a Cylinder.

(b) Median Plane of a Width.

Table 12-1

Table 12-2 Orientation Tolerances

Condition (1)	Attachment Technique			Paragraph	Figure
	Size Callout	Directed Leader	Extension Lines		
⊥ // ∠ ▭ Planar Surface	…	●	…	…	12-8
⊥ // ∠ ▭ Each Element	…	●	…	12.2.2(a) 12.2.2(b)	12-9 12-10
▭ ∠ Inclined Surface	…	●	…	…	12-11
⊥ // ∠ ▭ Cylinder	●	…	…	…	12-12(a)
	…	●	…	…	12-12(b)
⊥ // ∠ ▭ Width (Set of Opposed, Parallel Surfaces)	●	…	…	…	12-12(c)
	…	…	●	…	12-12(d)
⊥ // ∠ ▭ Axis- Within a Parallel Planes Tolerance Zone	●	…	…	12.2.2(c)	12-13(a)
	…	…	●	12.2.2(c)	12-13(b)

NOTES:
(1) All three symbols are shown when perpendicularity, parallelism and angularity equally apply. 12.2.2 12.3.3

Figure 12-8 Orientation — Planar Surfaces

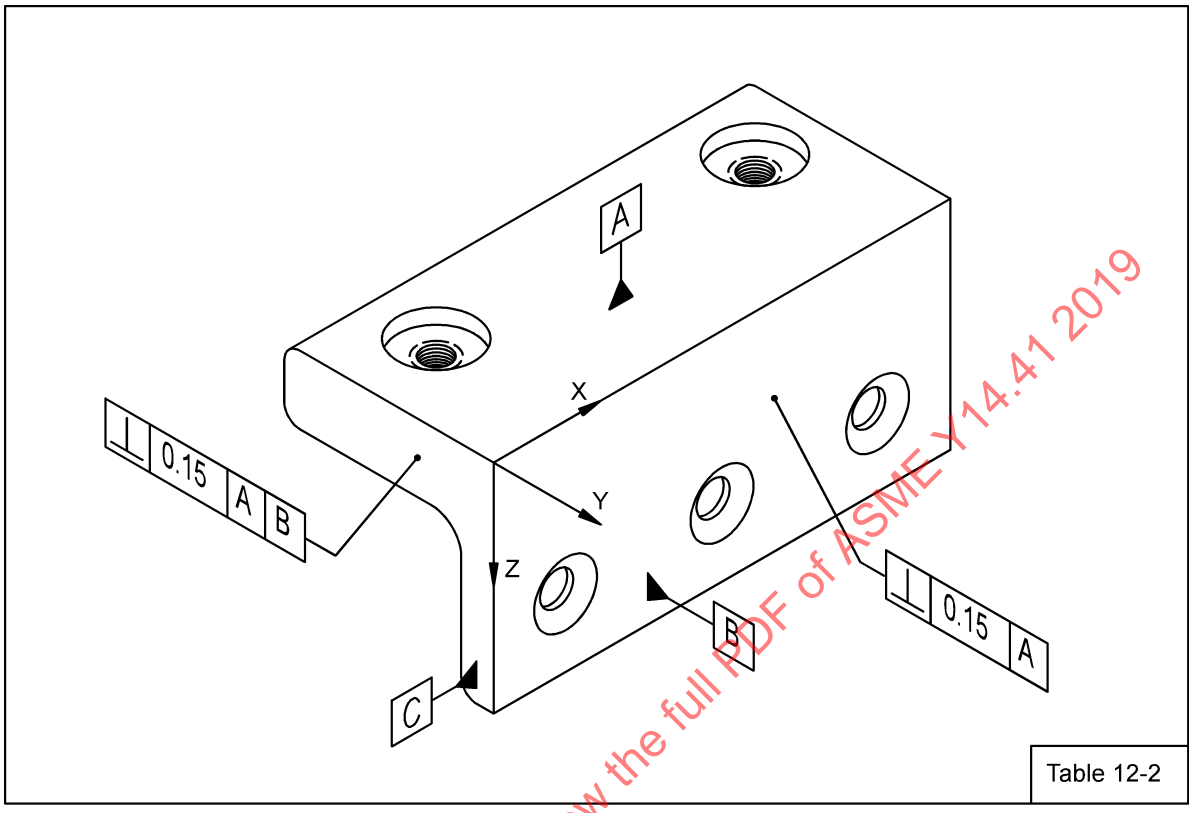
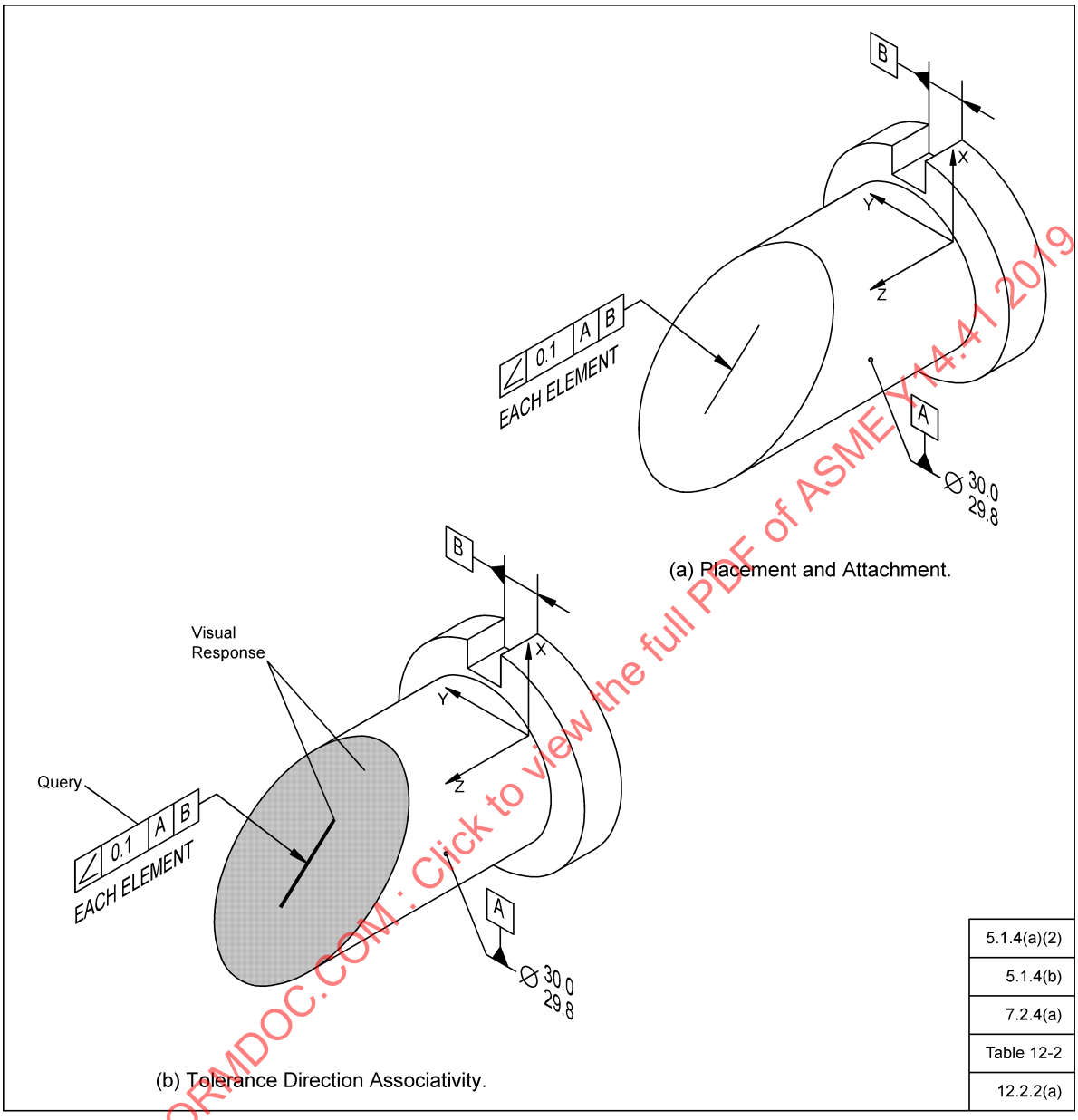
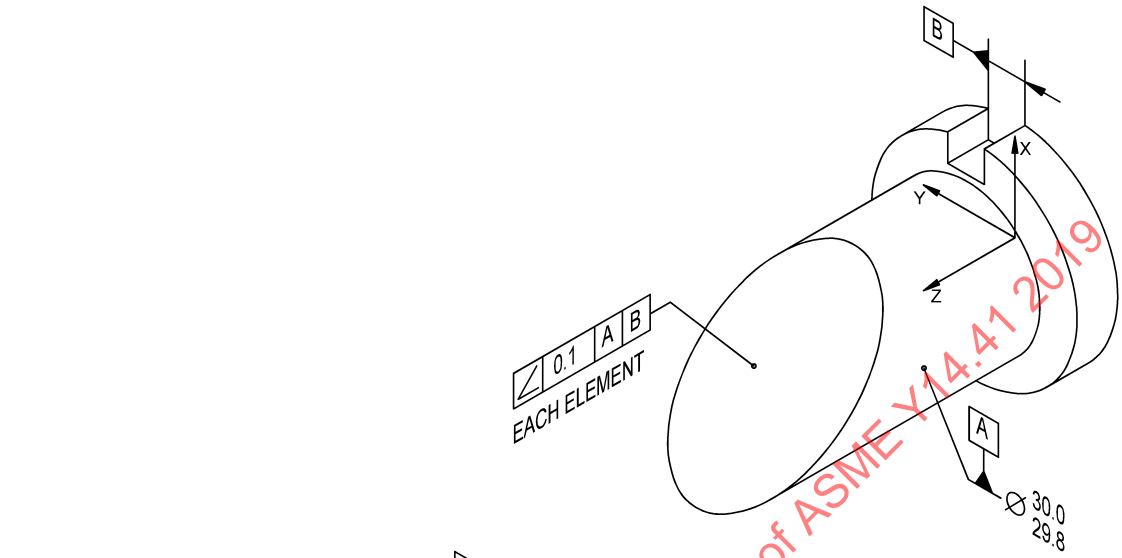


Figure 12-9 Each Element Orientation — Directed by Line Element

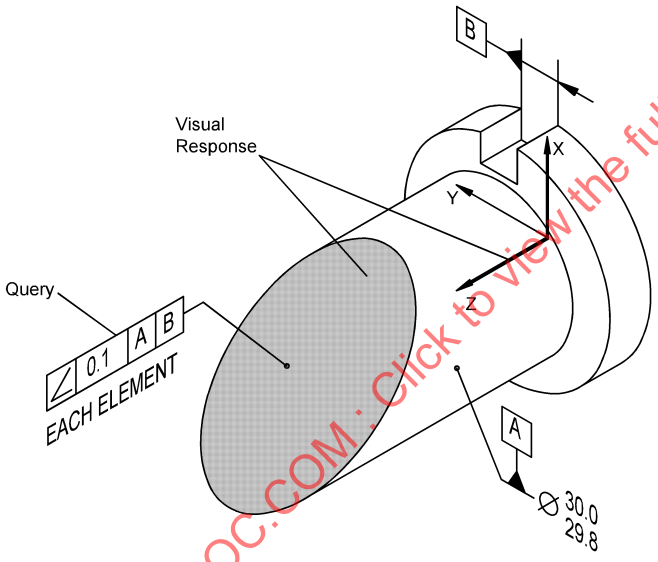


5.1.4(a)(2)
5.1.4(b)
7.2.4(a)
Table 12-2
12.2.2(a)

Figure 12-10 Each Element Orientation — Directed by Ordinate Axis



(a) Placement and Attachment.



(b) Tolerance Direction Associativity.

7.2.4(b)
Table 12-2
12.2.2(b)

Figure 12-11 Orientation — Inclined Surface

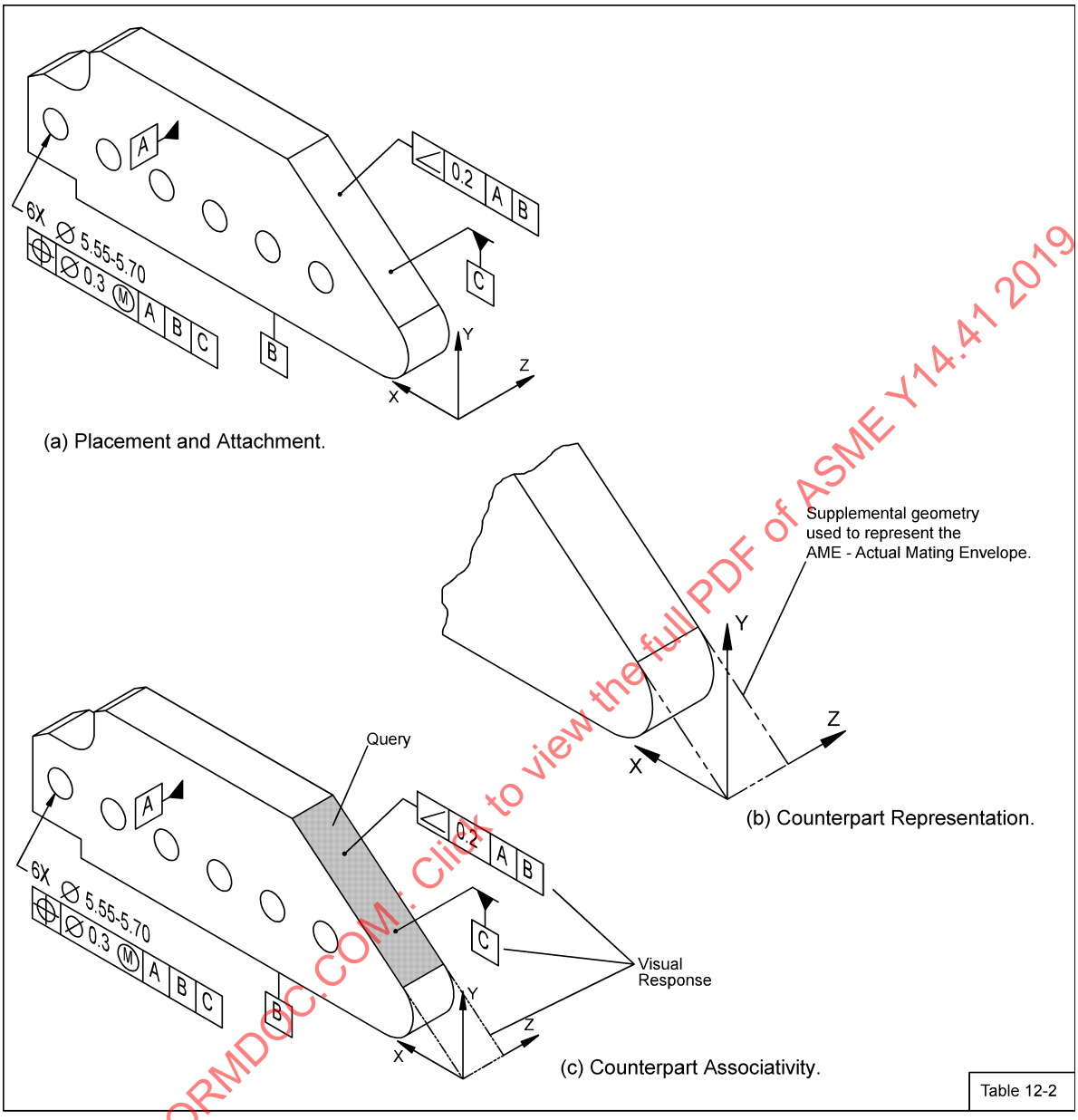
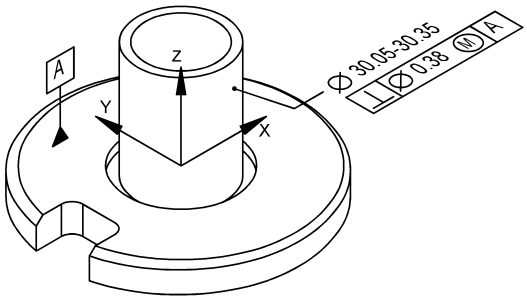
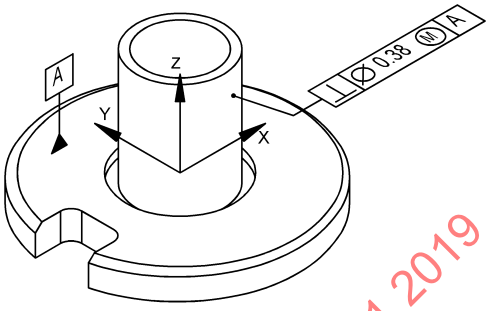


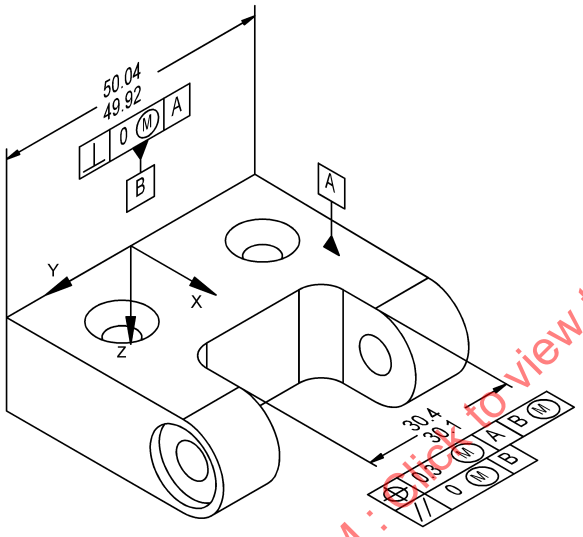
Figure 12-12 Orientation — Cylinder or a Set of Opposed, Parallel Surfaces



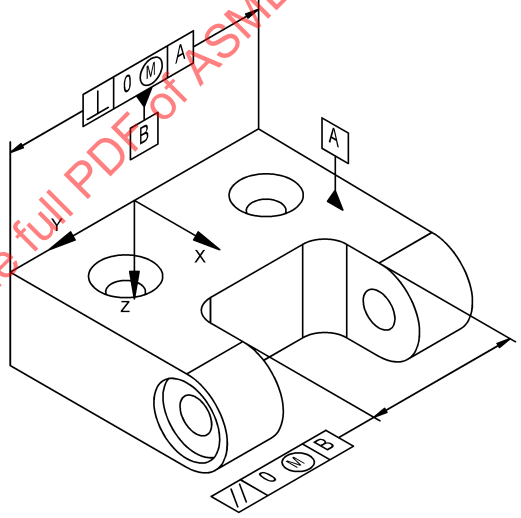
(a) Cylinder - Size Attachment.



(b) Cylinder - Leader Attachment.



(c) Width - Size Attachment.



(d) Width - Extension Lines Atttachment.

Table 12-2

Figure 12-13 Orientation of an Axis With a Parallel Planes Tolerance Zone

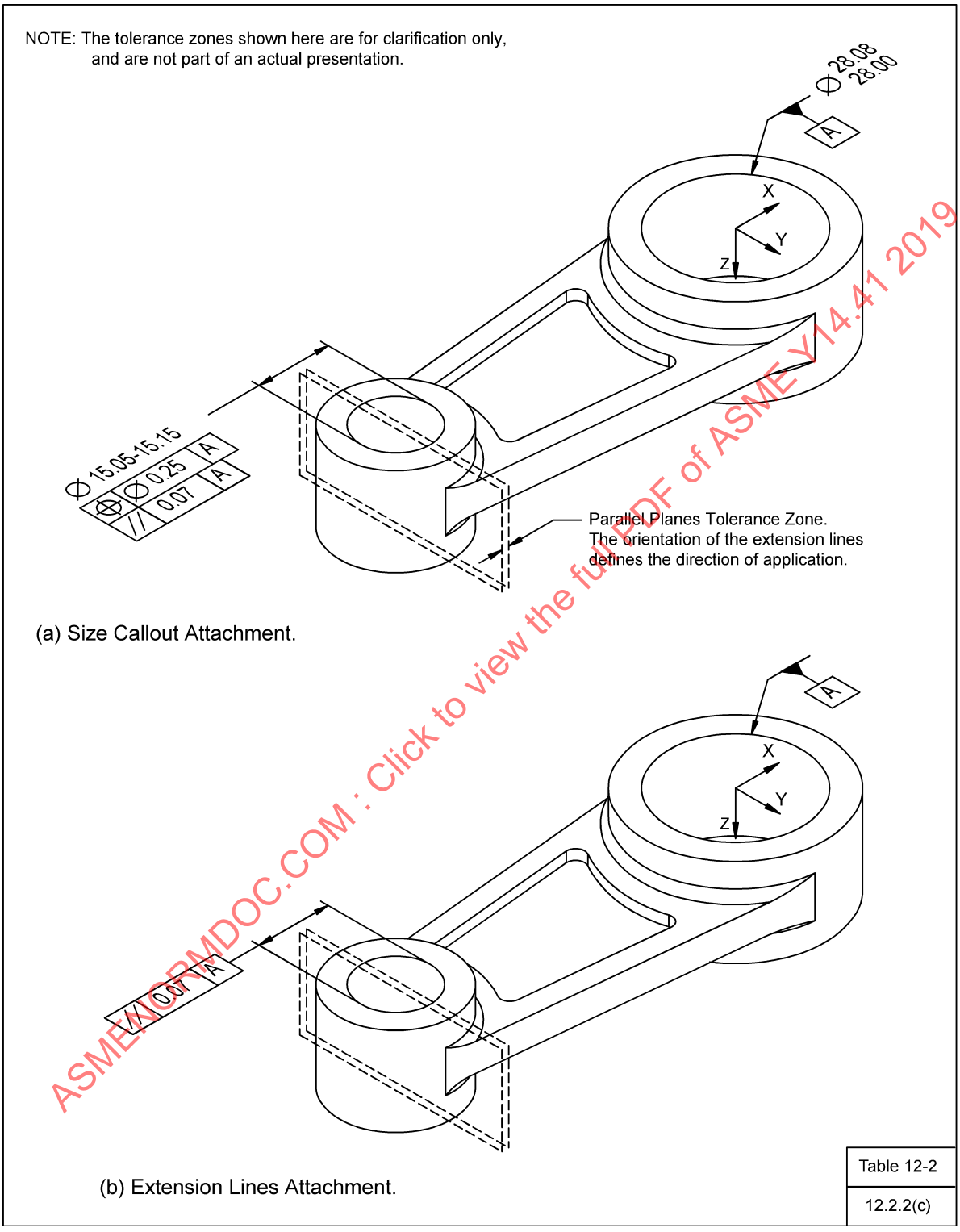


Table 12-3 Profile Tolerances

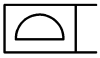
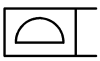
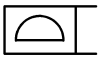
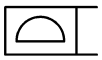
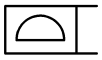
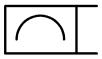
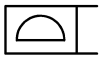
Condition	Attachment Technique: Directed Leader	Paragraph	Figure
 Planar Surface	●	...	12-14(a)
 Conical Surface or Revolved Surface	●	12.2.3(a)	12-14(b)
 Multiple Surfaces or Coplanar Surfaces	●	12.2.3(b)	12-15
 Between Basis	●	12.2.3(c)	12-16
 All Around	●	12.2.3(d)	12-17
 Line Elements	●	12.2.3(e) 12.2.3(f)	12-18 12-19
 All Over Basis	●	12.2.3(g)	...
			12.2.3 12.3.4

Figure 12-14 Profile — Planar, Conical, or Revolved Surface

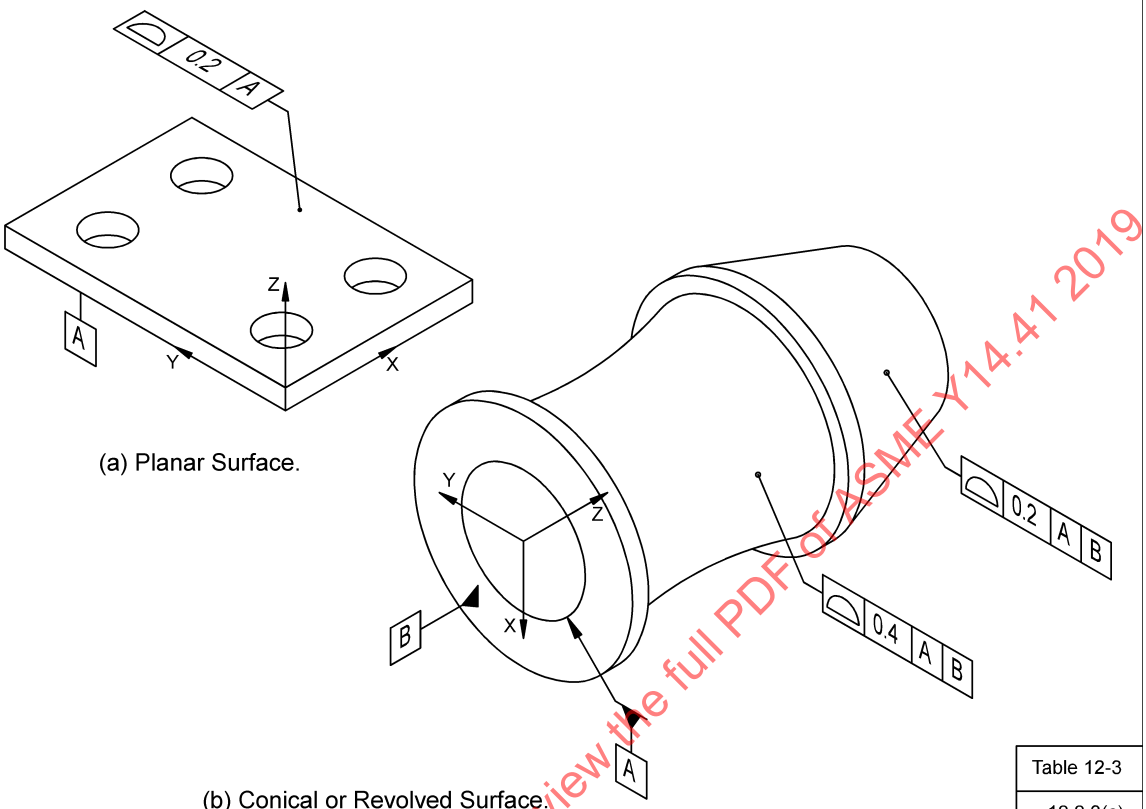
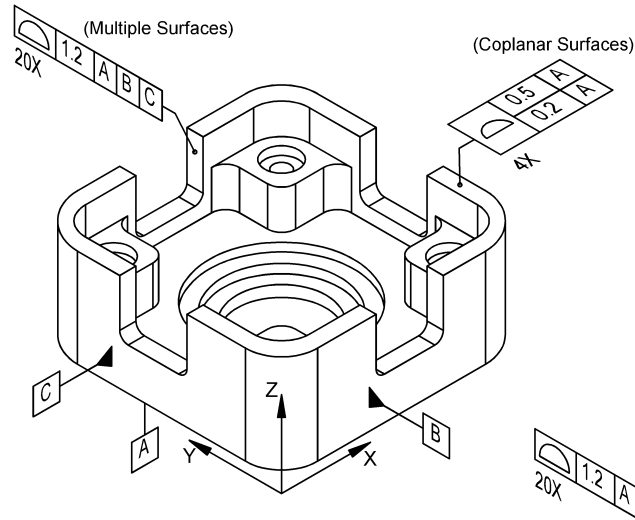
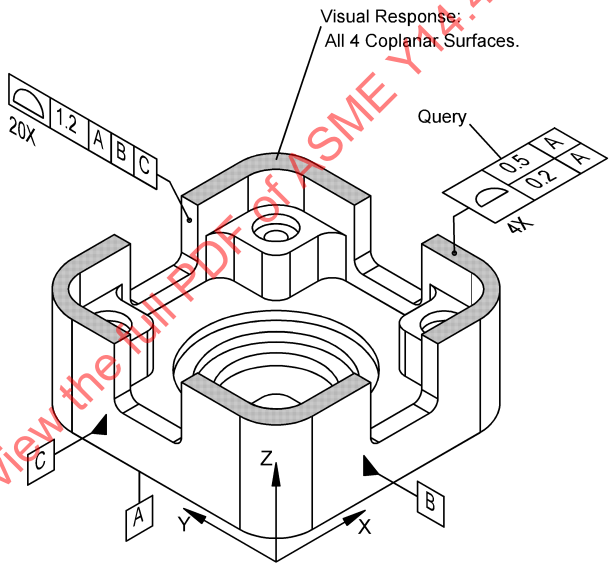


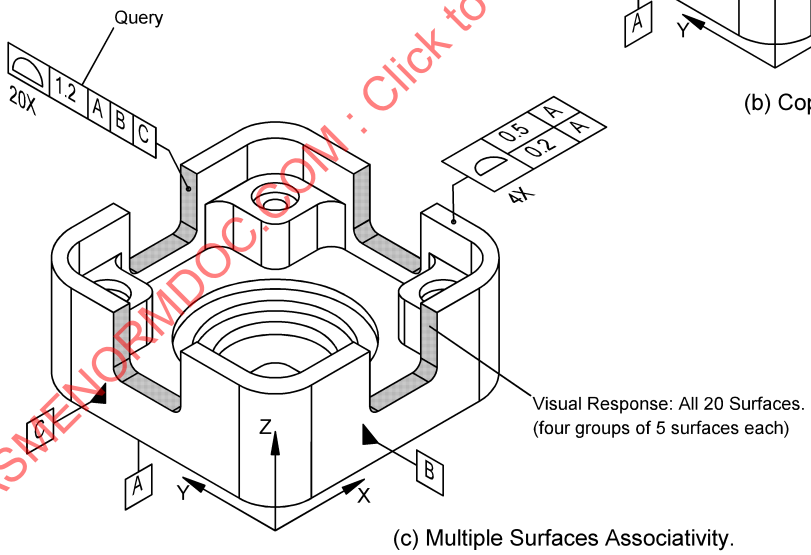
Figure 12-15 Profile — Multiple or Coplanar Surfaces



(a) Placement and Attachment.



(b) Coplanar Surfaces Associativity.



(c) Multiple Surfaces Associativity.

Table 12-3
12.2.3(b)

Figure 12-16 Profile — Between Basis

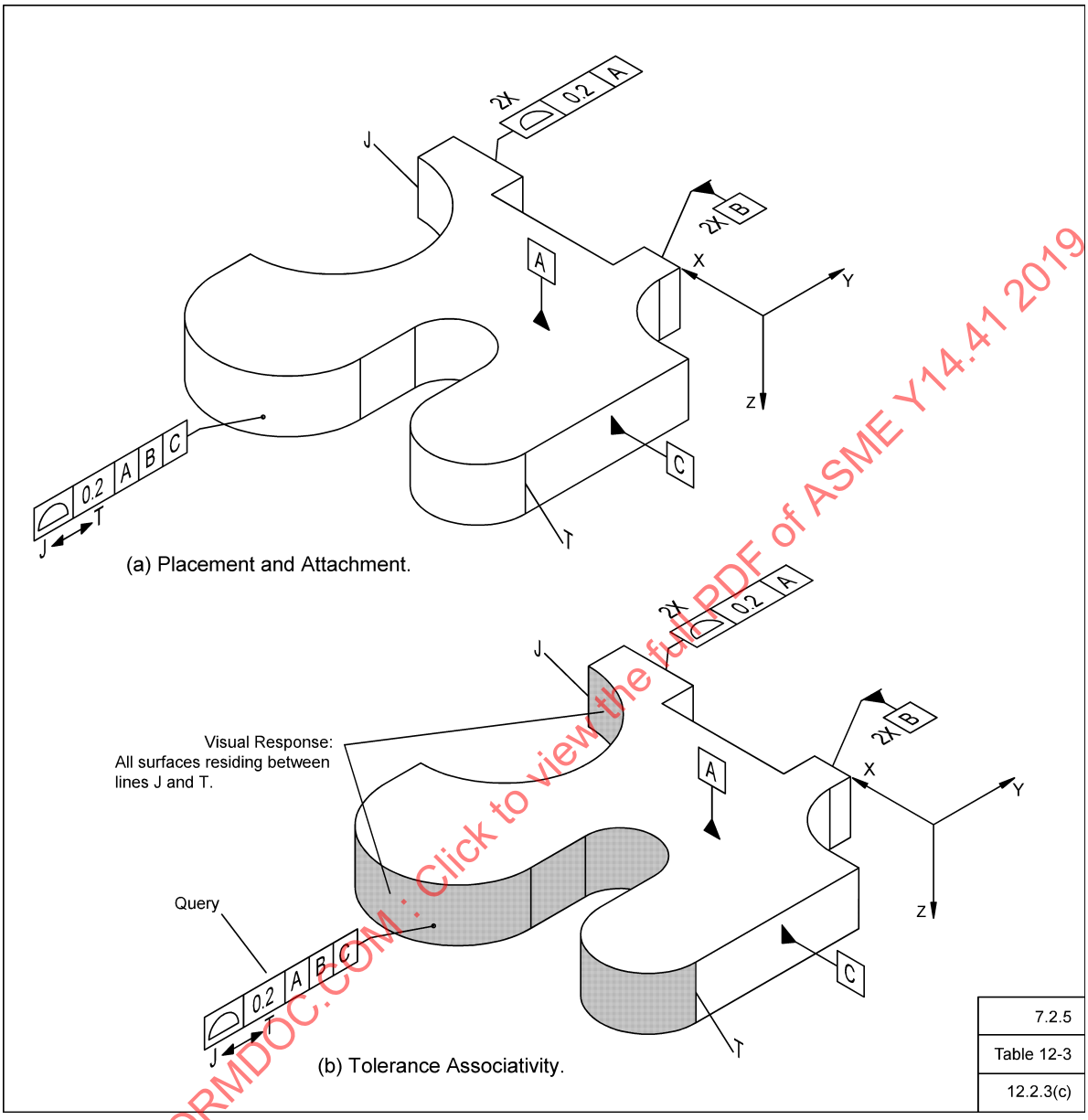


Figure 12-17 Profile — All-Around Applications

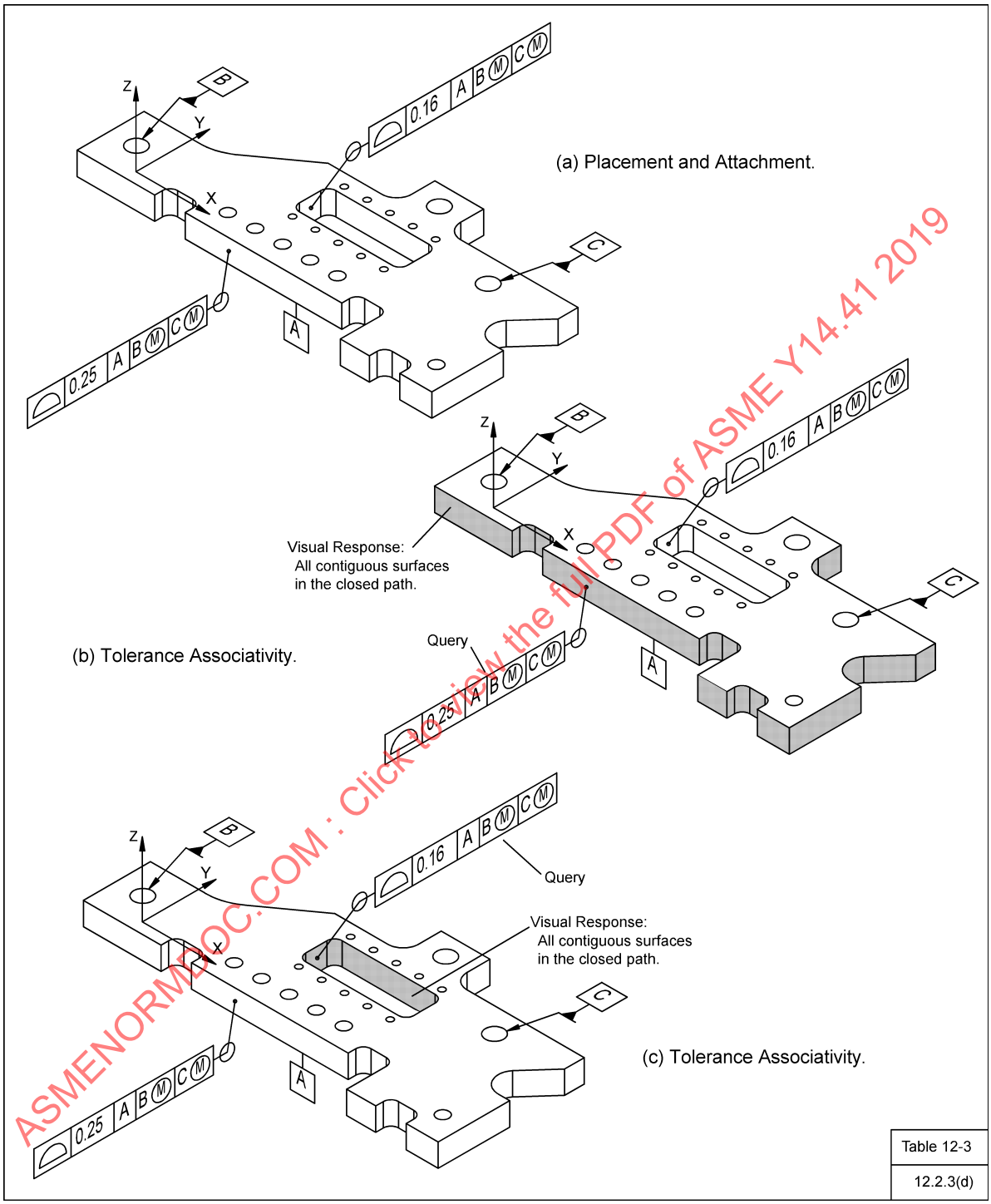
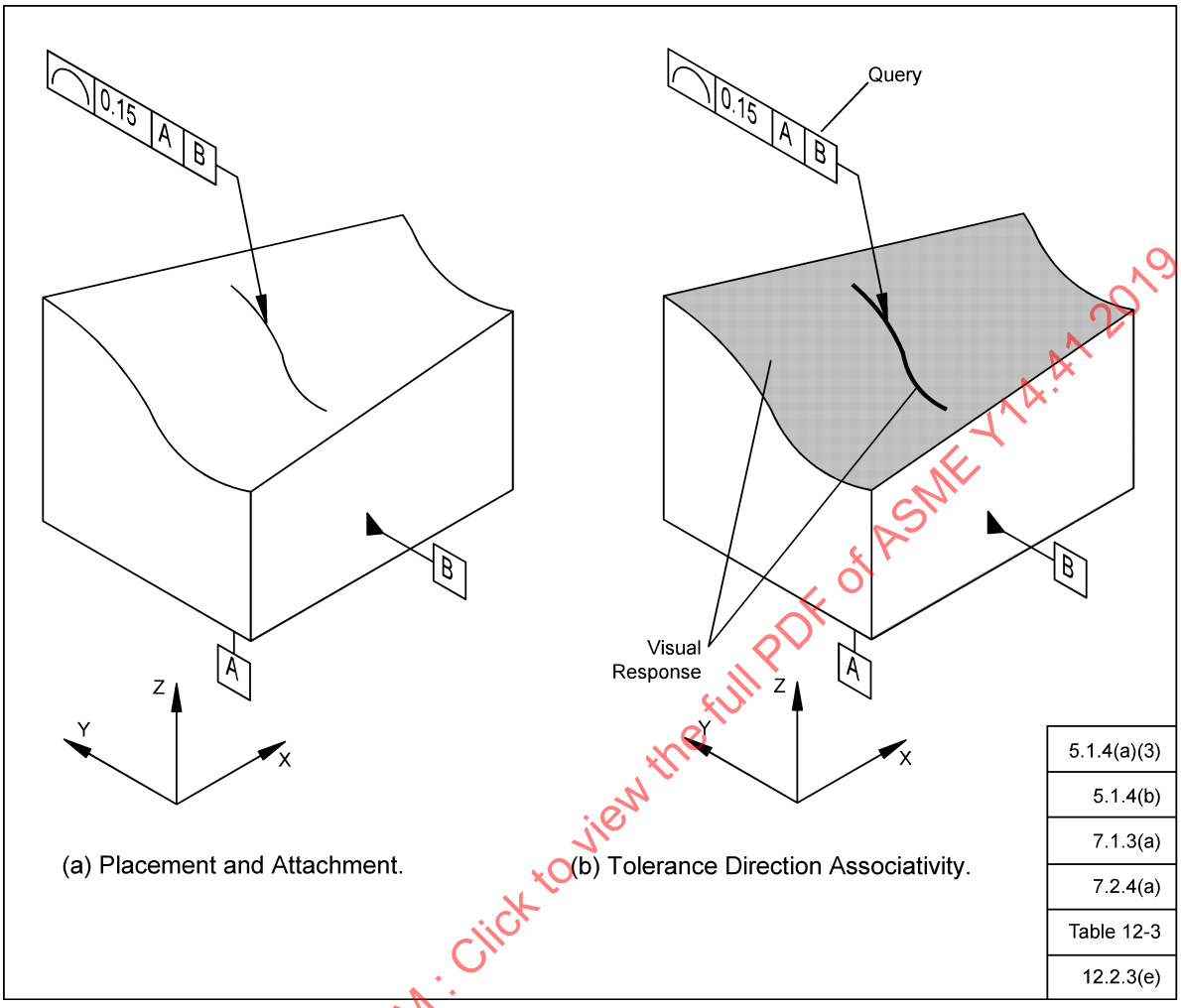


Figure 12-18 Line Profile — Directed by Line Element



5.1.4(a)(3)
5.1.4(b)
7.1.3(a)
7.2.4(a)
Table 12-3
12.2.3(e)

Figure 12-19 Line Profile — Directed by Ordinate Axis

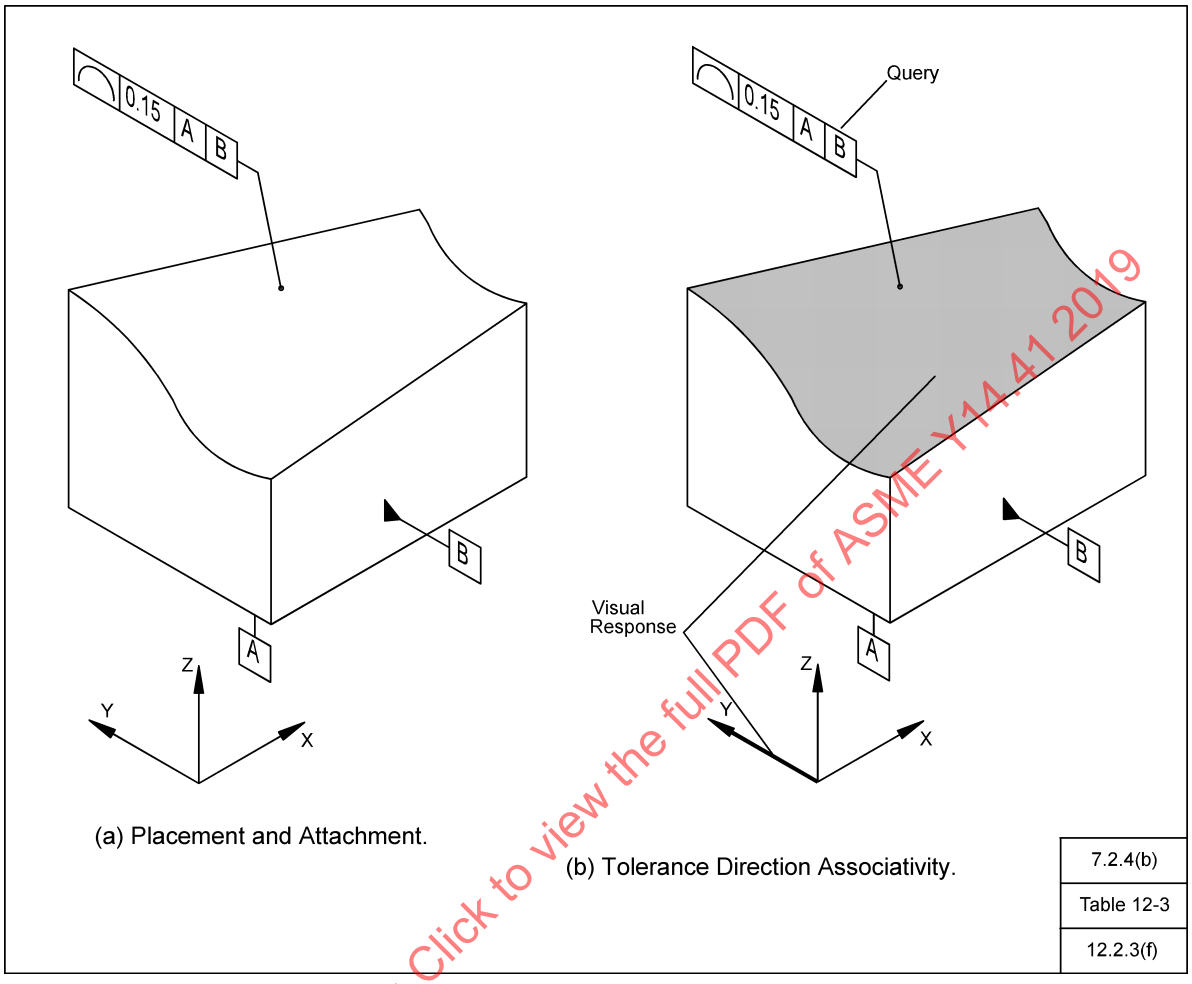


Table 12-4 Location Tolerances

Condition	Attachment Technique			Paragraph	Figure
	Size Callout	Directed Leader	Extension Lines		
Individually, to an Individual Datum	●	…	…	12.2.4(a)	12-21(a)
	…	●	…	12.2.4(a)	12-21(b)
Projected Tolerance Zone	●	…	…	12.2.4(b)	12-22(a)
	…	●	…	12.2.4(b)	12-22(b)
Extremities of Long Holes	●	●	…	12.2.4(c)	12-23
Elongated Holes (Slots) Boundary Basis	●	…	…	…	12-24(a)
	…	●	…	…	12-24(b)
	…	…	●	…	12-24(c)
Bidirectional, Polar or Rectangular Coordinates	…	…	●	12.2.4(d)	12-25
Profile and Boundary Position	…	●	…	…	12-26

12.2.4
12.3.5

Figure 12-20 Nonuniform Profile Tolerance Zones — Use of Supplemental Geometry

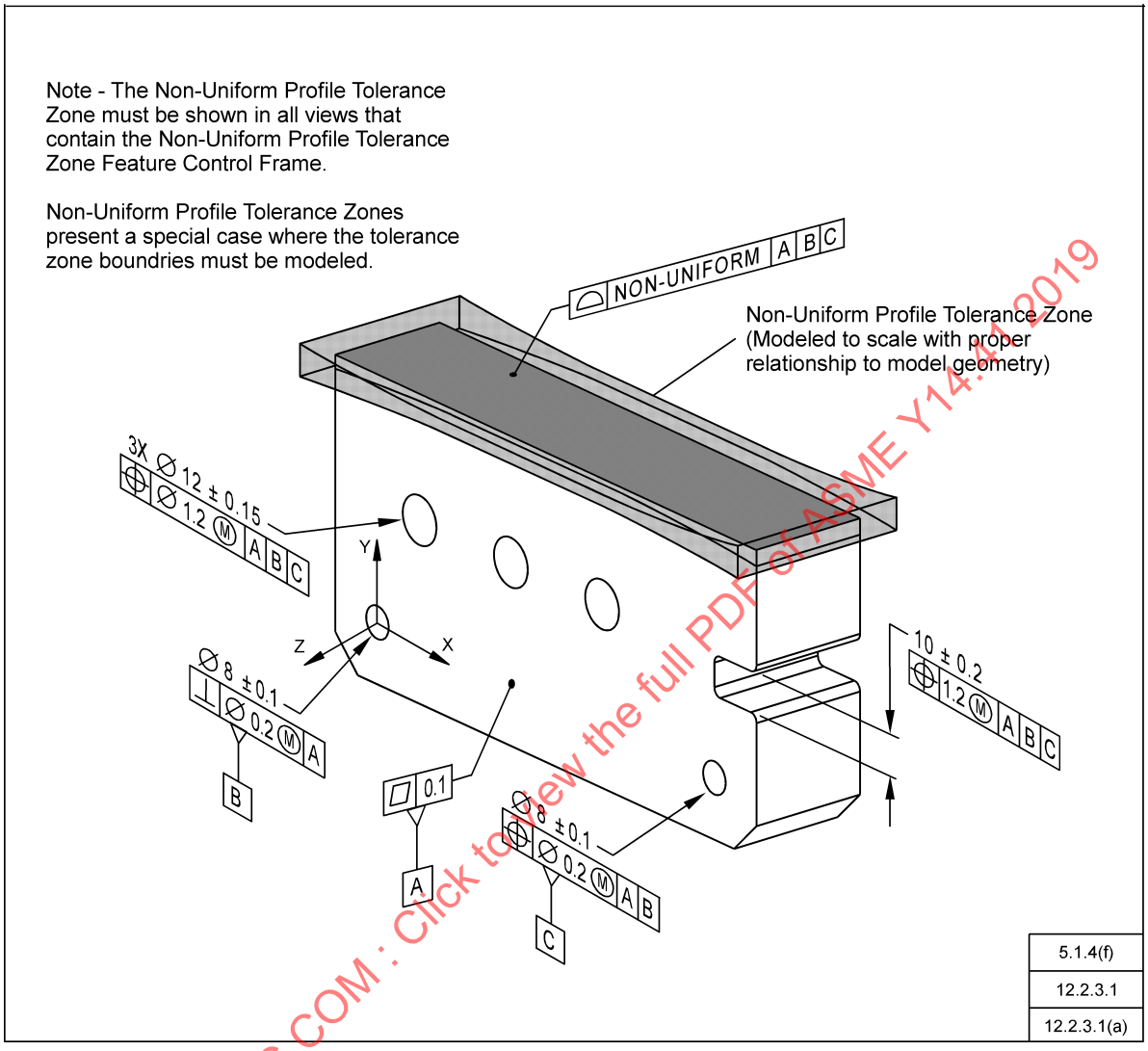


Figure 12-21 Position — Individual Patterns of Features

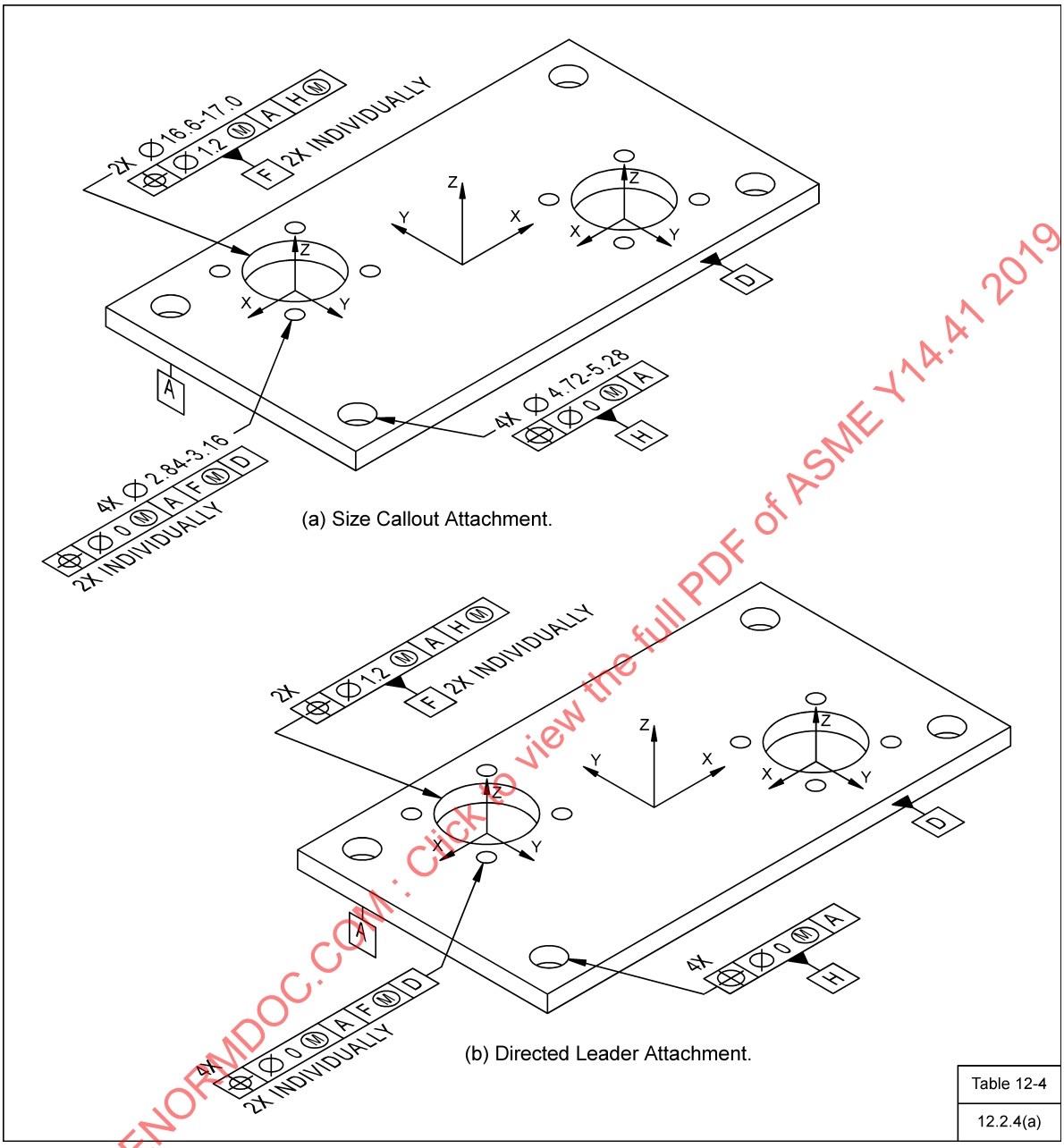


Table 12-4
12.2.4(a)

Figure 12-22 Position — Projected Tolerance Zones

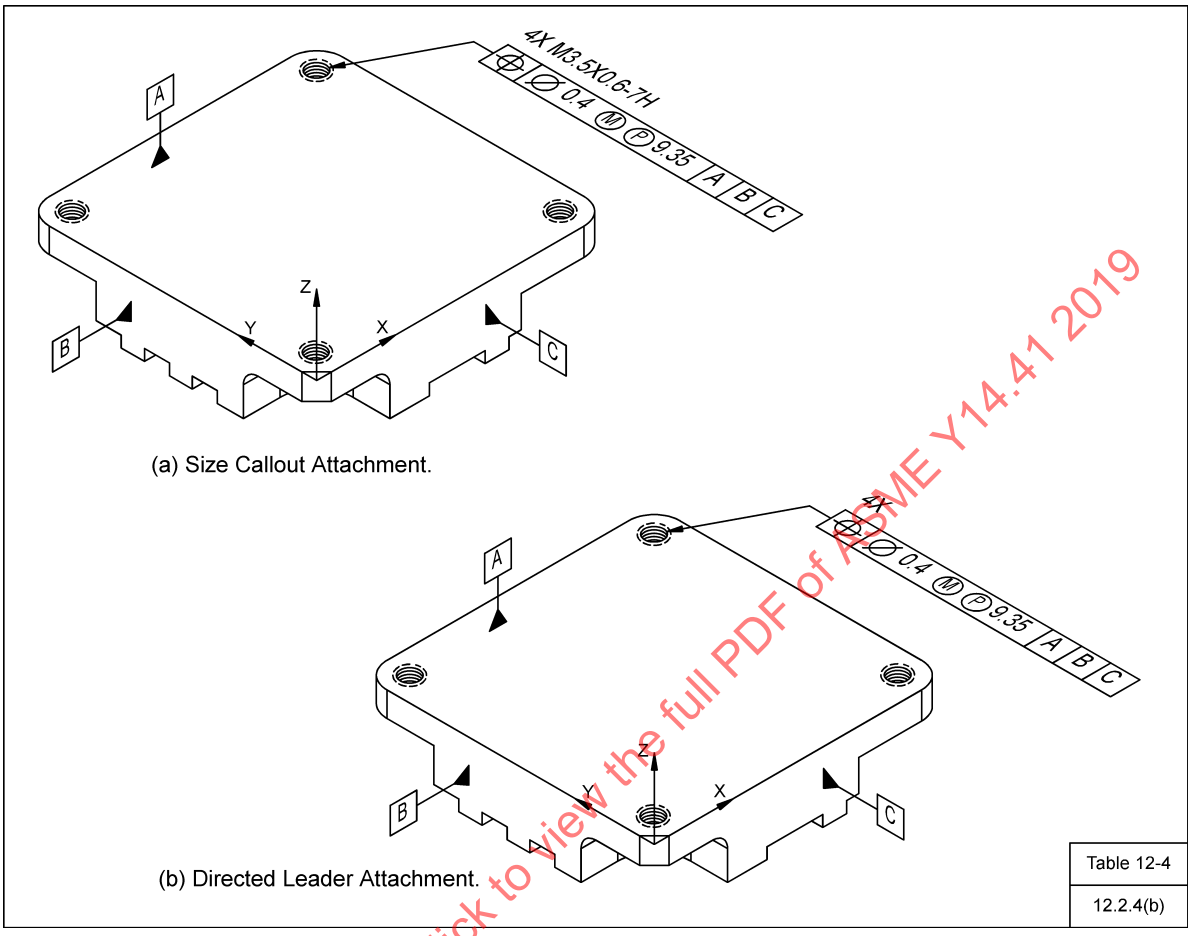


Figure 12-23 Position — Extremities of Long Holes

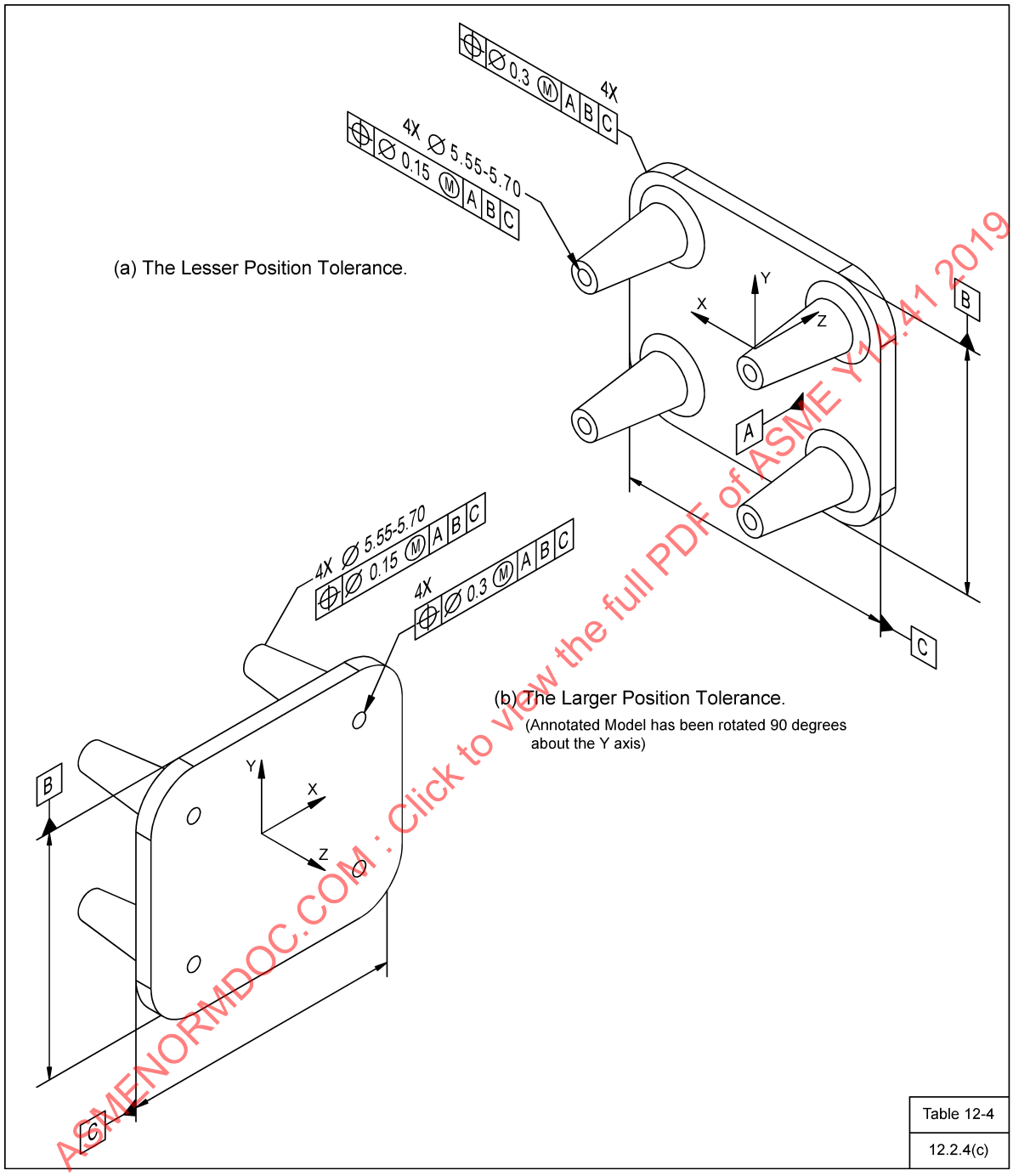
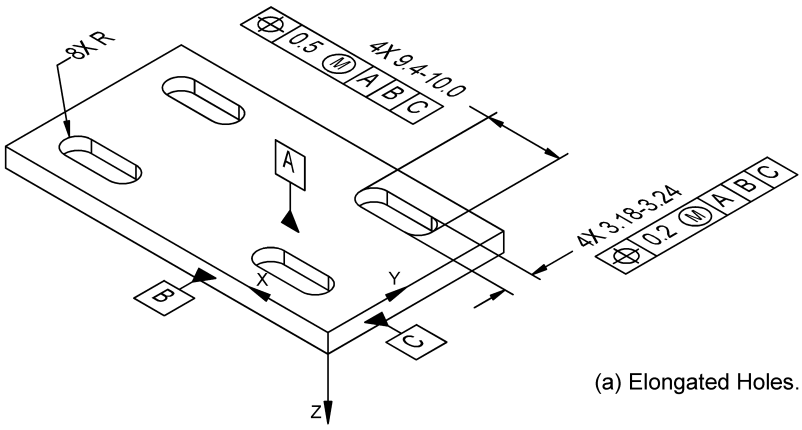
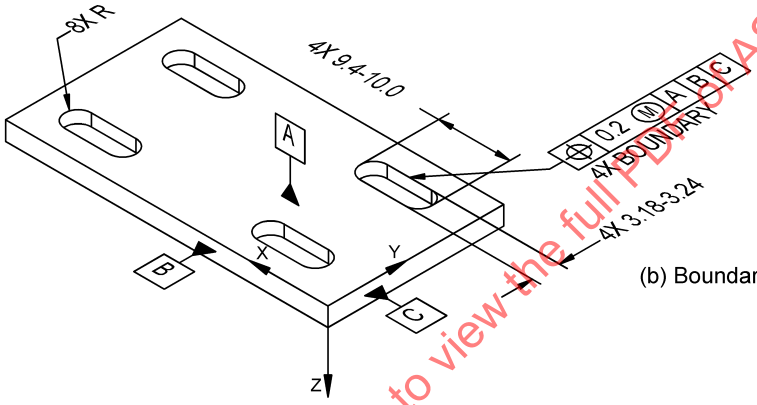


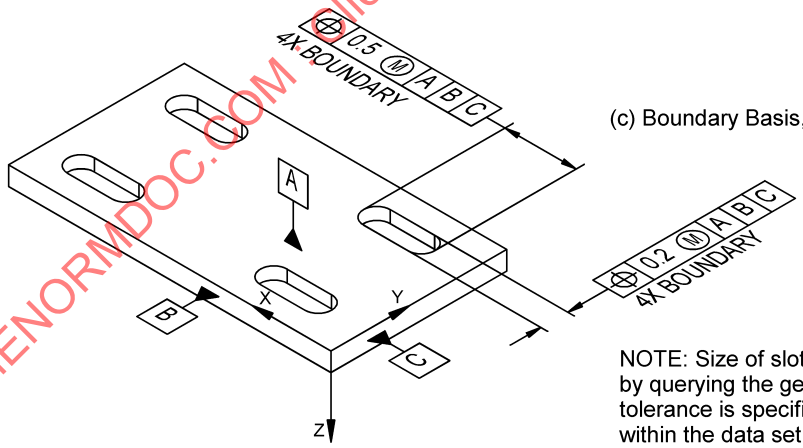
Figure 12-24 Position — Elongated Holes (Slots)



(a) Elongated Holes.



(b) Boundary Basis, Single Tolerance.

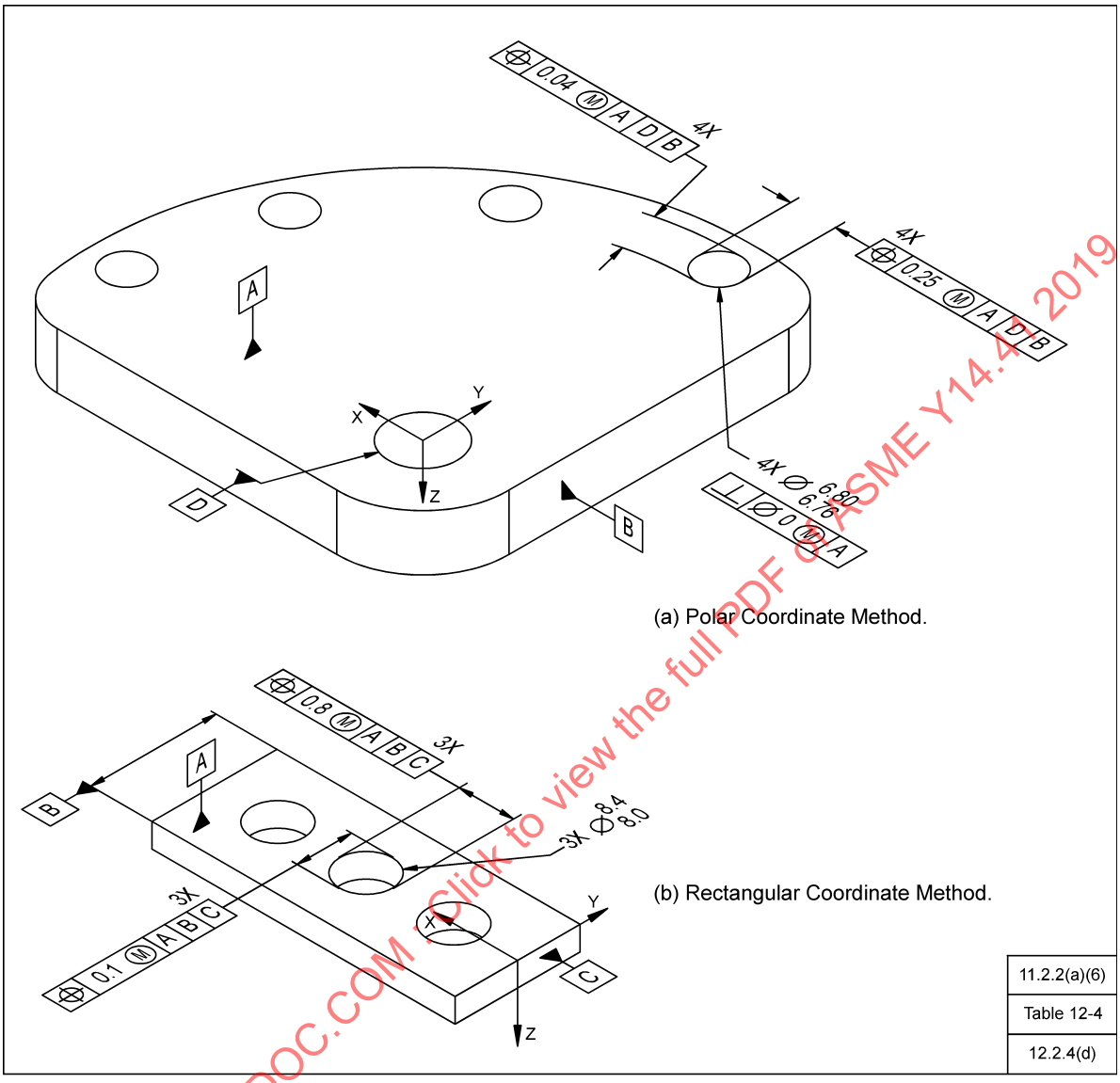


(c) Boundary Basis, Different Tolerances.

NOTE: Size of slot is determined by querying the geometry. The tolerance is specified elsewhere within the data set.

Table 12-4

Figure 12-25 Bidirectional Position — Polar or Rectangular



11.2.2(a)(6)
Table 12-4
12.2.4(d)

Figure 12-26 Position — Combined With Profile

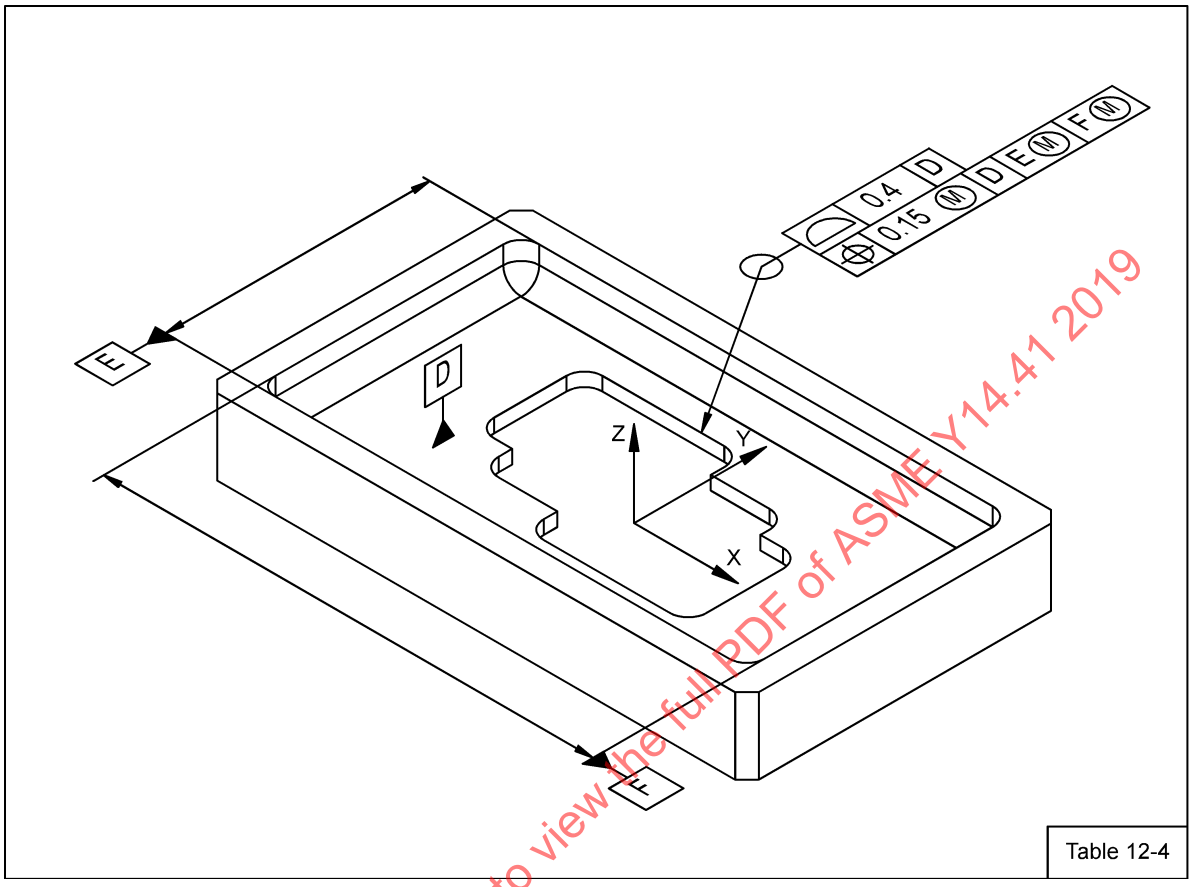
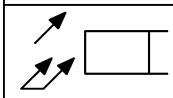
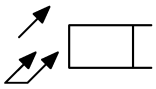
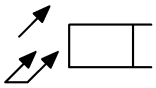


Table 12-5 Runout Tolerances

Condition (1)	Attachment Technique		Paragraph	Figure
	Size Callout	Directed Leader		
 Associativity	●	●	12.2.5(a)(1) 12.2.5(a)(3)	12-27
 Surface, Perpendicular to a Datum Axis	…	●	…	12-28(a)
 Cylindrical Surface	…	●	…	12-28(b)
 Spherical Surface	…	●	12.2.5(b)	12-29(a)
 Conical Surface or Revolved Surface	…	●	12.2.5(b)	12-29(b)

NOTES:

(1) Both symbols are shown when circular and total runout equally apply.

12.2.5
12.3.6