INTERNATIONAL STANDARD ISO 10303-47:1997
TECHNICAL CORRIGENDUM 1

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Industrial automation systems and integration — Product data representation and exchange —

Part 47: Integrated generic resource: Shape variation tolerances

TECHNICAL CORRIGENDUM 1

Systèmes d'automatisation industrielle et intégration — Représentation et échange de données de produits — Partie 47: Ressources génériques intégrées: Tolérances de variation de forme

RECTIFICATIF TECHNIQUE 1

Technical Corrigendum 1 to International Standard ISO 10303-47:1997 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 4, *Industrial data.*

Introduction

This document corrects ISO 10303-47:1997, Product data representation and exchange — Part 47: Integrated generic resource: Shape variation tolerances. The corrected document supersedes ISO 10303-47:1997.

The purpose of the modifications to the text of ISO 10303-47:1997 is to correct errors in the EXPRESS definitions likely to cause compilation problems, to replace a WR that was overly restrictive, to replace the annex for the computer-interpretable EXPRESS with a URL reference, and to replace the object identifier for the document and the applicable schema.

ICS 25.040.40 **Ref. No. ISO 10303-47:1997/Cor.1:2000(E)**

Modifications to the text of ISO 10303-47:1997

Clause 4.4.1, p. 9

The EXPRESS specification for datum does not have a group qualifier for WR1. Without the group qualifier, datum can be ambiguous in complex instances. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY datum
  SUBTYPE OF (shape_aspect);
  identification              :identifier;
INVERSE
  established_by_relationships : SET [1:?] OF shape_aspect_relationship
                                 FOR related_shape_aspect;
WHERE
  WR1: SIZEOF (QUERY (x<*SELF\datum.established_by_relationships |
       SIZEOF (TYPEOF(x\shape_aspect_relationship.relating_shape_aspect)*
       ['SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM_FEATURE',
       'SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM_TARGET']) <> 1))=0;
END_ENTITY;
(*
```

Clause 4.4.3, p. 12

The EXPRESS specification for datum_target does not have a group qualifier for WR1 or WR2. Without the group qualifier, datum_target can be ambiguous in complex instances. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY datum_target
  SUBTYPE OF (shape_aspect);
  target_id              : identifier;
INVERSE
  target_basis_relationship : shape_aspect_relationship FOR
                              relating_shape_aspect;
WHERE
   WR1: SIZEOF (QUERY (sar<* bag_to_set (USEDIN (SELF,
      'PRODUCT_PROPERTY_DEFINITION_SCHEMA.SHAPE_ASPECT_RELATIONSHIP.' +
        'RELATING_SHAPE_ASPECT'))
      | NOT ('SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM' IN TYPEOF
      (sar\shape_aspect_relationship.related_shape_aspect))))=0;
```

```
   WR2: SELF\shape_aspect.product_definitional = TRUE;
END_ENTITY;
(*
```

Clause 4.4.4, p. 13

The EXPRESS specification for datum_feature does not have a group qualifier for WR1 or WR2. Without the group qualifier, datum_feature can be ambiguous in complex instances. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY datum_feature
   SUBTYPE OF (shape_aspect);
INVERSE
   feature_basis_relationship : shape_aspect_relationship
                                FOR relating_shape_aspect;
WHERE
   WR1: SIZEOF (QUERY (sar<* bag_to_set (USEDIN (SELF,
        'PRODUCT_PROPERTY_DEFINITION_SCHEMA.SHAPE_ASPECT_RELATIONSHIP.' +
          'RELATING_SHAPE_ASPECT'))
        | NOT ('SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM' IN TYPEOF
        (sar\shape_aspect_relationship.related_shape_aspect))))=0;
   WR2: SELF\shape_aspect.product_definitional = TRUE;
END_ENTITY;
(*
```

Clause 4.5.2, p. 15

The EXPRESS specification for derived_shape_aspect is incorrect. The INVERSE reference was invalid. The INVERSE was modified and WR1: was added to satisfy the intent of the original INVERSE definition. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY derived_shape_aspect
  SUPERTYPE OF (ONEOF (apex,
                       centre_of_symmetry,
                       geometric_alignment,
                       geometric_intersection,
                       parallel_offset,
                       perpendicular_to,
                       extension,
                       tangent))
```

```
  SUBTYPE OF (shape_aspect);
INVERSE
  deriving_relationships : SET [1:?] OF
          shape_aspect_relationship FOR relating_shape_aspect;
WHERE
   WR1: SIZEOF (QUERY (dr <*
          SELF\derived_shape_aspect.deriving_relationships |
          NOT ('SHAPE_ASPECT_DEFINITION_SCHEMA.' +
               'SHAPE_ASPECT_DERIVING_RELATIONSHIP'
          IN TYPEOF (dr)))) = 0;
END_ENTITY;
(*
```

Remove the Attribute definitions and replace with the following:

Attribute definitions:

deriving_relationships: the identification of **shape_aspect_relationship**s that define the **derived_shape_aspect**.

Add the following after the Attribute definitions:

Formal proposition:

WR1: The **deriving_relationships** shall be **shape_aspect_deriving_relationship**s.

Clause 4.5.4, p. 17

The EXPRESS specification for centre_of_symmetry does not have a group qualifier for WR1. Without the group qualifier, centre_of_symmetry can be ambiguous in complex instances. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY centre_of_symmetry
   SUBTYPE OF (derived_shape_aspect);
WHERE
    WR1: SIZEOF
        (QUERY(sadr<*SELF\derived_shape_aspect.deriving_relationships|
    NOT('SHAPE_ASPECT_DEFINITION_SCHEMA.SYMMETRIC_SHAPE_ASPECT'
     IN TYPEOF
     (sadr\shape_aspect_relationship.related_shape_aspect))))=0;
END_ENTITY;
(*
```

Clause 4.5.12, p. 26
The EXPRESS specification for symmetric_shape_aspect does not have a group qualifier for WR1. Without the group qualifier, symmetric_shape_aspect can be ambiguous in complex instances. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY symmetric_shape_aspect
  SUBTYPE OF (shape_aspect);
INVERSE
  basis_relationships : SET [1:?] OF shape_aspect_relationship
                        FOR relating_shape_aspect;
WHERE
  WR1: SIZEOF (QUERY (x<*SELF\symmetric_shape_aspect.basis_relationships |
       'SHAPE_ASPECT_DEFINITION_SCHEMA.CENTRE_OF_SYMMETRY' IN TYPEOF
       (x\shape_aspect_relationship.related_shape_aspect)))>=1;
END_ENTITY;
(*
```

Clause 5, p. 28
The EXPRESS specification and the NOTE for the shape_dimension_schema did not identify the necessary external references for a shape_dimension_representation formal proposition. Add to the EXPRESS specification:

```
REFERENCE FROM measure_schema
   (measure_with_unit);
REFERENCE FROM representation_schema
   (representation);
```

after:

```
SCHEMA shape_dimension_schema;
```

Add to the NOTE:

measure_schema	ISO 10303-41
representation_schema	ISO 10303-43

before:

qualified_measure_schema	ISO 10303-45

Clause 5.4.8, p. 38
The EXPRESS specification of the shape_dimension_representation does not have a group qualifier for WR1, WR2, or WR3. Without the group qualifier, the shape_dimension_representation WRs can be ambiguous in a complex instance.

WR2 was overly restrictive for utilization in development of application protocols. WR2 was changed from '2' to '3'. In the last paragraph of the definition of 5.4.8, delete the following:
A **shape_dimension_representation** may have many **representation_items**, but two of the **representation_items** shall define a specific **shape_dimension_representation**.

Replace with the following:

A **shape_representation** may have many **representation_items**, but two of the **representation_items** shall define a specific **shape_dimension_representation**.

Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY shape_dimension_representation
                SUBTYPE OF (shape_representation);
  WHERE
   WR1: SIZEOF (QUERY (temp <* SELF\representation.items |
    NOT ('QUALIFIED_MEASURE_SCHEMA.MEASURE_REPRESENTATION_ITEM'
        IN TYPEOF (temp)))) = 0;
   WR2: SIZEOF (SELF\representation.items) <= 3;
   WR3: SIZEOF (QUERY (pos_mri <* QUERY (real_mri <*
        SELF\representation.items | 'REAL' IN TYPEOF
        (real_mri\measure_with_unit.value_component) ) |
     NOT  (pos_mri\measure_with_unit.value_component > 0.0 ))) = 0;
END_ENTITY;
(*
```

Clause 6, p. 40
The EXPRESS specification for the shape_tolerance_schema does not contain the necessary external references due to the changes identified in this Technical Corrigendium for the projected_zone_definition. Delete the following EXPRESS specification:

```
REFERENCE FROM measure_schema
   (measure_with_unit, measure_value);
```

Replace with the following EXPRESS specification:

```
REFERENCE FROM measure_schema
   (derive_dimensional_exponents,
    dimensional_exponents,
    measure_with_unit,
    measure_value);
```

Clause 6.3.2, p. 42

The name of the entity tolerance_select is identical to another entity in another integrated resource of ISO 10303. Therefore, the name of the tolerance_select was changed to shape_tolerance_select. Delete 6.3.2 and replace with the following:

6.3.2 shape_tolerance_select

A **shape_tolerance_select** type indicates that a tolerance can either be a **geometric_tolerance** or a **plus_minus_tolerance**.

EXPRESS specification:

```
*)
TYPE shape_tolerance_select = SELECT
      (geometric_tolerance,
       plus_minus_tolerance);
END_TYPE;
(*
```

Clause 6.4.2, p. 43

The EXPRESS specification of the geometric_tolerance was incomplete for WR1. Delete the current WR1 and replace WR1 with the following:

```
WR1: ('NUMBER' IN TYPEOF
      (magnitude\measure_with_unit.value_component)) AND
      (magnitude\measure_with_unit.value_component >= 0.0);
```

Clause 6.4.5, p. 46

The EXPRESS specification of the geometric_tolerance_with_defined_unit was incomplete for WR1. Delete the current WR1 and replace WR1 with the following:

```
WR1: ('NUMBER' IN TYPEOF
      (unit_size\measure_with_unit.value_component)) AND
      (unit_size\measure_with_unit.value_component > 0.0);
```

Clause 6.4.7, p. 47
The EXPRESS specification of the projected_zone_definition was incomplete for WR1 and did not contain a WR for the dimensional exponents requirement. Remove the EXPRESS specification and replace with the following:

EXPRESS specification:

```
*)
ENTITY projected_zone_definition
  SUBTYPE OF (tolerance_zone_definition);
  projection_end    : shape_aspect;
  projected_length : measure_with_unit;
WHERE
  WR1: ('NUMBER' IN TYPEOF
       (projected_length\measure_with_unit.value_component)) AND
       (projected_length\measure_with_unit.value_component > 0.0);
  WR2: (derive_dimensional_exponents
       (projected_length\measure_with_unit.unit_component)=
        dimensional_exponents(1,0,0,0,0,0,0));
END_ENTITY;
(*
```

Add the following to the Formal propositions after WR1:

WR2: The dimensional exponents of projected_length shall characterize a length unit.

Clause 6.4.12, p. 51
With the renaming of the entity tolerance_select to shape_tolerance_select, the entity tolerance_with_statistical_distribution has the attribute associated_tolerance that has to be changed. Delete the EXPRESS tolerance_with_statistical_distribution and replace with the following:

EXPRESS specification:

```
*)
ENTITY tolerance_with_statistical_distribution;
   associated_tolerance : shape_tolerance_select;
   tolerance_allocation : statistical_distribution_for_tolerance;
END_ENTITY;
(*
```

Clause 6.5.3, p. 55
The EXPRESS specification of the tolerance_value does not have a group qualifier for WR1 or WR2. Without the group qualifier, the tolerance_value WRs can be ambiguous in a complex instance. Remove the EXPRESS specification and replace with the following:

EXPRESS specification

```
*)
ENTITY tolerance_value;
   lower_bound : measure_with_unit;
   upper_bound : measure_with_unit;
WHERE
   WR1: upper_bound\measure_with_unit.value_component >
        lower_bound\measure_with_unit.value_component;
   WR2: upper_bound\measure_with_unit.unit_component =
        lower_bound\measure_with_unit.unit_component;
END_ENTITY;
```

Annex B.1, p. 59

With the changes identified in this Technical Corrigendum, the object identifier for this part of ISO 10303 has changed. Remove the object identifier for the document and replace with the following:

{ iso standard 10303 part(47) version (2) }

Annex B.2.1, p. 59

With the changes identified in this Technical Corrigendum, the object identifier for the shape_aspect_definition_schema has changed. Remove the object identifier for the shape_aspect_definition_schema and replace with the following:

{ iso standard 10303 part(47) version (2) object(1) shape-aspect-definition-schema(1) }

Annex B.2.2, p. 59

With the changes identified in this Technical Corrigendum, the object identifier for the shape_dimension_schema has changed. Remove the object identifier for the shape_dimension_schema and replace with the following:

{ iso standard 10303 part(47) version (2) object(1) shape-dimension-schema(2) }

Annex B.2.3, p. 59

With the changes identified in this Technical Corrigendum, the object identifier for the shape_tolerance_schema has changed. Remove the object identifier for the shape_tolerance_schema and replace with the following:

{ iso standard 10303 part(47) version (2) object(1) shape-tolerance-schema(3) }

Annex C, p. 61

With the changes identified in this Technical Corrigendum, the EXPRESS contained on the diskette is incorrect. Replace the contents of the annex with the following:

This annex provides a listing of the EXPRESS entity names and corresponding short names as specified in this part of ISO 10303. It also provides a listing of the complete EXPRESS schema specified in this part of ISO 10303 without comments or other explanatory text. This annex is available in computer-interpretable form and can be found at the following URLs:

Short names: http://www.mel.nist.gov/div826/subject/apde/snr/
EXPRESS: http://www.mel.nist.gov/step/parts/part047/is/tc1/

If there is difficulty accessing these sites contact ISO Central Secretariat or contact the ISO TC 184/SC4 Secretariat directly at: sc4sec@cme.nist.gov.

NOTE - The information provided in computer-interpretable form at the above URLs is informative. The information that is contained in the body of this part of ISO 10303 is normative.

Annex D, Figure D.7, p. 69
With the change of the TYPE name from tolerance_select to shape_tolerance_select, Figure D.7 has to be changed. Strike out the words, 'tolerance_select' and replace with 'shape_tolerance_select' in Figure D.7.

INTERNATIONAL STANDARD

ISO 10303-47

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Industrial automation systems and integration — Product data representation and exchange —

Part 47:
Integrated generic resource: Shape variation tolerances

Systèmes d'automatisation industrielle et intégration — Représentation et échange de données de produits —

Partie 47: Ressource générique intégrée: Tolérances de variation de forme

Reference number
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75% of the member bodies casting a vote.

International Standard ISO 10303-47 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 4, *Industrial data.*

ISO 10303 consists of the following parts under the general title *Industrial automation systems and integration - Product data representation and exchange*:

— Part 1, Overview and fundamental principles;

— Part 11, Description methods: The EXPRESS language reference manual;

— Part 12, Description method: The EXPRESS-I language reference manual;

— Part 21, Implementation methods: Clear text encoding of the exchange structure;

— Part 22, Implementation method: Standard data access interface specification;

— Part 23, Implementation method: C++ language binding to the standard data access interface;

— Part 24, Implementation method: C language binding to the standard data access interface;

— Part 26, Implementation method: Interface definition language binding to the standard data access;

— Part 31, Conformance testing methodology and framework: General concepts;

— Part 32, Conformance testing methodology and framework: Requirements on testing laboratories and clients;

— Part 34, Conformance testing methodology and framework: Abstract test methods;

— Part 35, Conformance testing methodology and framework: Abstract test methods for SDAI implementations;

— Part 41, Integrated generic resources: Fundamentals of product description and support;

— Part 42, Integrated generic resources: Geometric and topological representation;

— Part 43, Integrated generic resources: Representation structures;

— Part 44, Integrated generic resources: Product structure configuration;

— Part 45, Integrated generic resource: Materials;

— Part 46, Integrated generic resources: Visual presentation;

— Part 47, Integrated generic resource: Shape variation tolerances;

— Part 49, Integrated generic resource: Process structure and properties;

— Part 101, Integrated application resource: Draughting;

— Part 104, Integrated application resource: Finite element analysis;

— Part 105, Integrated application resource: Kinematics;

— Part 106, Integrated application resource: Building construction core model;

— Part 201, Application protocol: Explicit draughting;

— Part 202, Application protocol: Associative draughting;

— Part 203, Application protocol: Configuration controlled design;

— Part 204, Application protocol: Mechanical design using boundary representation;

— Part 205, Application protocol: Mechanical design using surface representation;

— Part 207, Application protocol: Sheet metal die planning and design;

— Part 208, Application protocol: Life cycle management - Change process;

— Part 209, Application protocol: Composite and metallic structural analysis and related design;

— Part 210, Application protocol: Electronic assembly, interconnet, and packaging design;

— Part 212, Application protocol: Electrotechnical design and installation

— Part 213, Application protocol: Numerical control process plans for machined parts;

— Part 214, Application protocol: Core data for automotive mechanical design processes;

— Part 215, Application protocol: Ship arrangement;

— Part 216, Application protocol: Ship moulded forms;

— Part 217, Application protocol: Ship piping;

— Part 218, Application protocol: Ship structures;

— Part 221, Application protocol: Functional data and their schematic representation for process plant;

— Part 222, Application protocol: Exchange of product data for composite structures;

— Part 223, Application protocol: Exchange of design and manufacturing product information for casting parts;

— Part 224, Application protocol: Mechanical product definition for process plans using machining features;

— Part 225, Application protocol: Building elements using explicit shape representation;

— Part 226, Application protocol: Ship mechanical systems;

— Part 227, Application protocol: Plant spatial configuration;

— Part 229, Application protocol: Exchange of design and manufacturing product information for forged parts;

— Part 230, Application protocol: Building structural frame: Steelwork;

— Part 231, Application protocol: Process engineering data: Process design and process specification of major equipment;

— Part 232, Application protocol: Technical data packaging core information and exchange;

— Part 301, Abstract test suite: Explicit draughting;

— Part 302, Abstract test suite: Associative draughting;

— Part 303, Abstract test suite: Configuration controlled design;

— Part 304, Abstract test suite: Mechanical design using boundary representation;

— Part 305, Abstract test suite: Mechanical design using surface representation;

— Part 307, Abstract test suite: Sheet metal die planning and design;

— Part 308, Abstract test suite: Life cycle management - Change process;

— Part 309, Abstract test suite: Composite and metallic structural analysis and related design;

— Part 310, Abstract test suite: Electronic assembly, interconnect, and packaging design;

— Part 312, Abstract test suite: Electrotechnical design and installation;

— Part 313, Abstract test suite: Numerical control process plans for machined parts;

— Part 314, Abstract test suite: Core data for automotive mechanical design processes;

— Part 315, Abstract test suite: Ship arrangement;

— Part 316, Abstract test suite: Ship moulded forms;

— Part 317, Abstract test suite: Ship piping;

— Part 318, Abstract test suite: Ship structures;

— Part 321, Abstract test suite: Functional data and their schematic representation for process plant;

— Part 322, Abstract test suite: Exchange of product data for composite structures;

— Part 323, Abstract test suite: Exchange of design and manufacturing product information for casting parts;

— Part 324, Abstract test suite: Mechanical product definition for process plans using machining features;

— Part 325, Abstract test suite: Building elements using explicit shape representation;

— Part 326, Abstract test suite: Ship mechanical systems;

— Part 327, Abstract test suite: Plant spatial configuration;

— Part 329, Abstract test suite: Exchange of design and manufacturing product information for forged parts;

— Part 330, Abstract test suite: Building structural frame: Steelwork;

— Part 331, Abstract test suite: Process engineering data: Process design and process specification of major equipment;

— Part 332, Abstract test suite: Technical data packaging core information and exchange;

— Part 501, Application interpreted construct: Edge-based wireframe;

— Part 502, Application interpreted construct: Shell-based wireframe;

— Part 503, Application interpreted construct: Geometrically bounded 2D wireframe;

— Part 504, Application interpreted construct: Draughting annotation;

— Part 505, Application interpreted construct: Drawing structure and administration;

— Part 506, Application interpreted construct: Draughting elements;

— Part 507, Application interpreted construct: Geometrically bounded surface;

— Part 508, Application interpreted construct: Non-manifold surface;

— Part 509, Application interpreted construct: Manifold surface;

— Part 510, Application interpreted construct: Geometrically bounded wireframe;

— Part 511, Application interpreted construct: Topologically bounded surface;

— Part 512, Application interpreted construct: Faceted boundary representation;

— Part 513, Application interpreted construct: Elementary boundary representation;

— Part 514, Application interpreted construct: Advanced boundary representation;

— Part 515, Application interpreted construct: Constructive solid geometry;

— Part 517, Application interpreted construct: Mechanical design geometric presentation;

— Part 518, Application interpreted construct: Mechanical design shaded representation.

The structure of this International Standard is described in ISO 10303-1. The numbering of the parts of the International Standard reflects its structure:

— Parts 11 to 12 specify the description methods,

— Parts 21 to 26 specify the implementation methods,

— Parts 31 to 35 specify the conformance testing methodology and framework,

— Parts 41 to 49 specify the integrated generic resources,

— Parts 101 to 106 specify the integrated application resources,

— Parts 201 to 232 specify the application protocols,

— Parts 301 to 332 specify the abstract test suites, and

— Parts 501 to 518 specify the application interpreted constructs.

Annexes A and B form an integral part of this part of ISO 10303. Annexes C, D, and E are for information only.

Introduction

ISO 10303 is an International Standard for the computer-interpretable representation and exchange of product data. The objective is to provide a neutral mechanism capable of describing product data throughout the life cycle of a product, independent from any particular system. The nature of this description makes it suitable not only for neutral file exchange, but also as a basis for implementing and sharing product data bases and archiving.

This International Standard is organized as a series of parts, each published separately. The parts of ISO 10303 fall into one of the following series: description methods, integrated resources, application interpreted constructs, application protocols, abstract test suites, implementation methods, and conformance testing. The series are described in ISO 10303-1. This part of ISO 10303 is a member of the integrated resources series. Major subdivisions of this part of ISO 10303 are:

— shape aspect definition, provides resources for the representations of shapes to which dimensions and tolerances are applied;

— shape dimension, provides resources for the representations of size and relative location to meet the dimensioning requirements found in engineering design;

— shape tolerance, provides resources for the representations of limits within which manufactured shapes are permitted to vary.

This part of ISO 10303 supports all of the dimensioning and tolerancing methods as defined by existing International Standards on technical drawings. These methods include explicit dimensioning, associative dimensioning, plus-minus tolerancing, and geometrical tolerancing.

Industrial automation systems and integration — Product data representation and exchange —

Part 47:
Integrated generic resource: Shape variation tolerances

1 Scope

This part of ISO 10303 specifies the resource constructs for representing dimensions and tolerances of product shapes. The dimensions specify the sizes of a shape and locations of identifiable portions of a shape. The tolerances specify the allowable deviation of a product from its defined shape and dimensions. The representations of dimensions and tolerances provided by this part of ISO 10303 are appropriate for use with both 2D and 3D geometric models of parts.

The following are within the scope of this part of ISO 10303:

— tolerances as constraints on the shape characteristics of a product;

— the specification of the tolerances on a defined shape;

— the representation of geometrical tolerances and plus-minus tolerances;

— the representation of tolerance values;

— the representation of dimensions;

— the assignment of size characteristics to a shape;

— the assignment of location and orientation characteristics to a shape;

— the specification of datums and datum references;

— the identification of derived shape elements such as centre lines and intersections;

— the structure for limit and fit systems for shapes.

The following are outside the scope of this part of ISO 10303:

— the definition of the fundamental principles, concepts and terminology of tolerancing and dimensioning;

— the mathematical definition of tolerances and datums;

— the description of dimensioning or tolerancing practices;

— the specification of dimensional inspection methods;

— the synthesis and analysis of tolerances;

— the tolerancing of product characteristics other than shape;

— the presentation of tolerances on engineering drawings;

— the specification of surface finish or surface roughness.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 10303. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 10303 are encouraged to investigate the possibility of applying the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 129:1985, *Technical drawings - Dimensioning - General principles, definitions, methods of execution and special indications.*

ISO 286-1:1988, *ISO system of limits and fits - Part 1: Bases of tolerances, deviations and fits.*

ISO 286-2:1988, *ISO system of limits and fits - Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts.*

ISO 406:1987, *Technical drawings - Tolerancing of linear and angular dimensions.*

ISO 1101:1983, *Technical drawings - Geometric tolerancing - Tolerancing of form, orientation, location and run-out - Generalities, definitions, symbols, indications on drawings.*

ISO 2692:1988, *Technical drawings - Geometrical tolerancing - Maximum material principle.*

ISO 5458:1987, *Technical drawings - Geometrical tolerancing - Positional tolerancing.*

ISO 5459:1981, *Technical drawings - Geometrical tolerancing - Datums and datum-systems for geometrical tolerances.*

ISO/IEC 8824-1:1995, *Information technology - Abstract Syntax Notation One (ASN.1): Specification of basic notation.*

ISO 10303-1:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 1: Overview and fundamental principles.*

ISO 10303-11:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 11: Description methods: The EXPRESS language reference manual.*

ISO 10303-41:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 41: Integrated generic resources: Fundamentals of product description and support.*

ISO 10303-42:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 42: Integrated generic resource: Geometric and topological representation.*

ISO 10303-43:1994, *Industrial automation systems and integration - Product data representation and exchange - Part 43: Integrated generic resources: Representation structures.*

ISO 10578:1992, *Technical drawings - Tolerancing of orientation and location - Projected tolerance zone.*

3 Definitions

3.1 Terms defined in ISO 129

This part of ISO 10303 makes use of the following terms defined in ISO 129:

— dimension;

— dimensioning;

— feature.

3.2 Terms defined in ISO 286-1

This part of ISO 10303 makes use of the following terms defined in ISO 286-1:

— fit system;

— hole;

— limit system;

— shaft;

— standard tolerance;

— tolerance class.

3.3 Terms defined in ISO 1101

This part of ISO 10303 makes use of the following terms defined in ISO 1101:

— axis;

— geometrical tolerance;

— median plane;

— projected tolerance zone;

— runout tolerance;

— symmetry;

— tolerance;

— tolerance zone;

— total runout tolerance.

3.4 Terms defined in ISO 2692

This part of ISO 10303 makes use of the following terms defined in ISO 2692:

— least material condition;

— maximum material condition.

3.5 Terms defined in ISO 5459

This part of ISO 10303 makes use of the following terms defined in ISO 5459:

— datum;

— datum feature;

— datum system;

— datum target.

3.6 Terms defined in ISO 10578

This part of ISO 10303 makes use of the following term defined in ISO 10578:

— projected tolerance zone.

3.7 Terms defined in ISO 10303-1

This part of ISO 10303 makes use of the following terms defined in ISO 10303-1:

— application context;

— application protocol;

— product;

— resource construct;

— structure.

3.8 Other definitions

For the purposes of this part of ISO 10303, the following definitions apply:

3.8.1 boundary: the surfaces that surround and enclose the physical mass of the product shape.

3.8.2 form tolerance: geometric tolerance applied to a feature or single feature element that requires no datum reference.

3.8.3 profile tolerance: geometric tolerance applied to a uniform boundary along the true profile within which the elements of the surface must lie.

3.8.4 plus-minus tolerance: a tolerance that is defined by two values that represent the minimum and maximum limits of a range within which the toleranced dimension may deviate.

3.8.5 toleranced feature: an identifiable portion of the product shape to which one or more tolerances are applied.

4 Shape aspect definition

The following EXPRESS declaration begins the **shape_aspect_definition_schema** and identifies the necessary external references.

EXPRESS specification:

```
*)
SCHEMA shape_aspect_definition_schema;

REFERENCE FROM product_property_definition_schema
    (shape_aspect,
     shape_aspect_relationship);

REFERENCE FROM measure_schema
    (measure_with_unit);
```

```
REFERENCE FROM support_resource_schema
    (bag_to_set, label, identifier);
(*
```

NOTE - The schemas referenced above can be found in the following parts of ISO 10303:

product_property_definition_schema	ISO 10303-41
measure_schema	ISO 10303-41
support_resource_schema	ISO 10303-41

4.1 Introduction

The subject of the **shape_aspect_definition_schema** is to provide definitions of the spatial characteristics of a shape that are required for dimensioning and tolerancing. This schema provides representations for a **derived_ shape_aspect** and a **datum**. A **derived_shape_aspect** is a **shape_aspect** that is developed from the defined shape of the product, but that is not required for defining the product shape. A **datum** is a **shape_ aspect** that provide the origin from where dimensions and tolerances are referenced. A **derived_shape_aspect** and a **datum** are aspects of the shape that are required for dimensioning and tolerancing the size, the location, the orientation, and the form of a product shape.

4.2 Fundamental concepts and assumptions

The product shape is the concept of shape as a property that characterizes a product. Geometric models and engineering drawings are formal methods used to represent the product shape. Dimensions and tolerances are elements of the product shape definition which are independent from how the shape is represented. Dimensions may be explicitly identified as part of the shape characteristics, implicitly included in a geometric model that represents the shape, or explicitly presented in a two-dimensional drawing.

A **shape_aspect** is an element of a product shape. Dimensions may be specified for both the entire product shape and aspects of the shape. This schema augments the **shape_aspects** and the relationships among them as the definitional mechanism for specifying dimensions and tolerances. A **shape_aspect**, relationships between **shape_aspect** elements, and their specified dimensions and tolerances are always defined in the context of the product shape property. These dimensions and tolerances can be represented as elements of geometric models or engineering drawings.

For the purpose of identifying dimensions and tolerances, this schema specifies the concept of a derived **shape_ aspect**. A derived **shape_aspect** is a **shape_aspect** that is defined based on the specific way in which it relates to another shape aspect. The derived **shape_aspect** is used in conjunction with their related **shape_ aspect** elements to specify dimensions and tolerances. The specific geometry that can represent the derived **shape_- aspect** and a **shape_aspect** that provide the definitional relationship are not in the scope of this schema. The geometry, the representation structure, and their association to the dimension and tolerance elements specified in this part are defined in ISO 10303-41, ISO 10303-42, and ISO 10303-43. Only the generic concept of derived **shape_aspect** is specified here. Application protocols may specify additional derived **shape_aspect** elements from those provided.

NOTE - Legal values that are computer sensible for attributes of entities in this schema may be specified in application protocols.

4.3 shape_aspect_definition_schema type definition: limit_condition

A **limit_condition** type indicates that a tolerance may have a material modifier condition applied. This modifier allows for the addition of material to, or for the reduction of material from a feature. The use of **limit_condition** applies only to toleranced features and datum features that have size characteristics.

EXAMPLE 1 - The diameter of a hole or of a shaft or the width of a slot are size characteristics which may have a **limit_condition** applied.

EXPRESS specification:

```
*)
TYPE limit_condition = ENUMERATION OF
  (maximum_material_condition,
   least_material_condition,
   regardless_of_feature_size);
END_TYPE;
(*
```

Enumerated item definitions:

maximum_material_condition: the state of a feature when it contains its maximum material with respect to its specified limit of size. Maximum material condition is defined in clause 3.3 of ISO 2692. The methods described in ISO 2692 for applying **maximum_material_condition** to datums and toleranced features shall be followed.

NOTE 1 - For a **shape_aspect** which is void of material, the **maximum_material_condition** is the smallest measure of this feature of size, e.g., the smallest diameter of a hole.

least_material_condition: the state of a feature when it contains its least material with respect to its specified limit of size. Least material condition is defined in clause 3.5 of ISO 2692. The methods described in amendment 1 of ISO 2692 for applying **least_material_condition** to datums and toleranced features shall be followed.

NOTE 2 - For a **shape_aspect** which is void of material, the **least_material_condition** is the largest measure of this feature of size, e.g., the largest diameter of a hole.

regardless_of_feature_size: the state of a feature when the specified tolerance or datum reference applies to any increment of size within the specified limits of the feature.

NOTES

3 - Unlike **maximum_material_condition** and **least_material_condition**, **regardless_of_feature_size** is not dependent on the quantity of material the feature of size contains. **regardless_of_feature_size** means that when geometric tolerance is specified for a feature of size, the specified tolerance is independent of size changes in that feature of size. It does not matter if the feature of size is at its upper tolerance measure, at its lower tolerance measure or any measure between, the specified tolerance or datum reference applies.

4 - The principle of **regardless_of_feature_size** is explained in clause 2.8.1, 4.4.3, 5.3.1, and 5.3.4 of ANSI Y14.5 [1].

4.4 shape_aspect_definition_schema entity definitions: datum

4.4.1 datum

A **datum** is a **shape_aspect** from which dimensions and tolerances are referenced. This **shape_aspect** may, but need not, coincide with the boundary defining the product. A datum is established by a datum feature, a set of datum targets, or a group of features.

NOTE - The use and application of a group of features to establish a datum is identified in clause 9 of ISO 5459. The group of features is established through the use of **shape_aspect_relationship** objects. The concept of a group of **shape_aspect** elements is defined in 4.5.1.

<u>EXPRESS specification</u>:

```
*)
ENTITY datum
  SUBTYPE OF (shape_aspect);
  identification              :identifier;
INVERSE
  established_by_relationships : SET [1:?] OF shape_aspect_relationship
                                 FOR related_shape_aspect;
WHERE
```

```
  WR1: SIZEOF (QUERY (X<*SELF.established_by_relationships |
       SIZEOF (TYPEOF(X.relating_shape_aspect)*
       ['SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM_FEATURE',
       'SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM_TARGET']) <> 1))=0;

END_ENTITY;
(*
```

Attribute definitions:

identification: the name by which the datum is referred.

established_by_relationships: the **datum_feature**, the set of **datum_targets**, or the group of derived **shape_ aspect** that establish the **datum**.

Formal propositions:

WR1: A **datum** shall be established by either **datum_features** or **datum_targets**.

4.4.2 datum_feature

The **datum_feature** is an identified **shape_aspect** on the boundary of the product. One **datum_feature** may be used to establish a single **datum**.

```
*)
ENTITY datum_feature
  SUBTYPE OF (shape_aspect);
INVERSE
  feature_basis_relationship : shape_aspect_relationship
                               FOR relating_shape_aspect;
WHERE
  WR1: SIZEOF (QUERY (sar<* bag_to_set (USEDIN (SELF,
      'PRODUCT_PROPERTY_DEFINITION_SCHEMA.SHAPE_ASPECT_RELATIONSHIP.' +
        'RELATING_SHAPE_ASPECT'))
      | NOT ('SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM' IN TYPEOF
      (sar.related_shape_aspect))))=0;
  WR2: SELF.product_definitional = TRUE;
END_ENTITY;
(*
```

Attribute definitions:

SELF\shape_aspect.product_definitional: an indicator that the **datum_feature** is on the physical boundary of the shape that defines the product.

feature_basis_relationship: the relationship to the datum that the **datum_feature** defines; it is achieved through the **shape_aspect_relationship.**

Formal propositions:

WR1: A **datum_feature** shall be related to a **datum.**

WR2: A **datum_feature** shall lie on the physical boundary of the shape that defines the product.

EXAMPLE 2 - Figure 1 illustrates two cases of **datum_feature.** The **datum_feature** that is a cylindrical feature establishes the **datum** identified as A. This **datum** is the axis of the cylinder. The **datum** identified as B is established from the **datum_feature** that is a planar surface of the product. This **datum** may, but need not, be a plane that is coincident with the **datum_feature**.

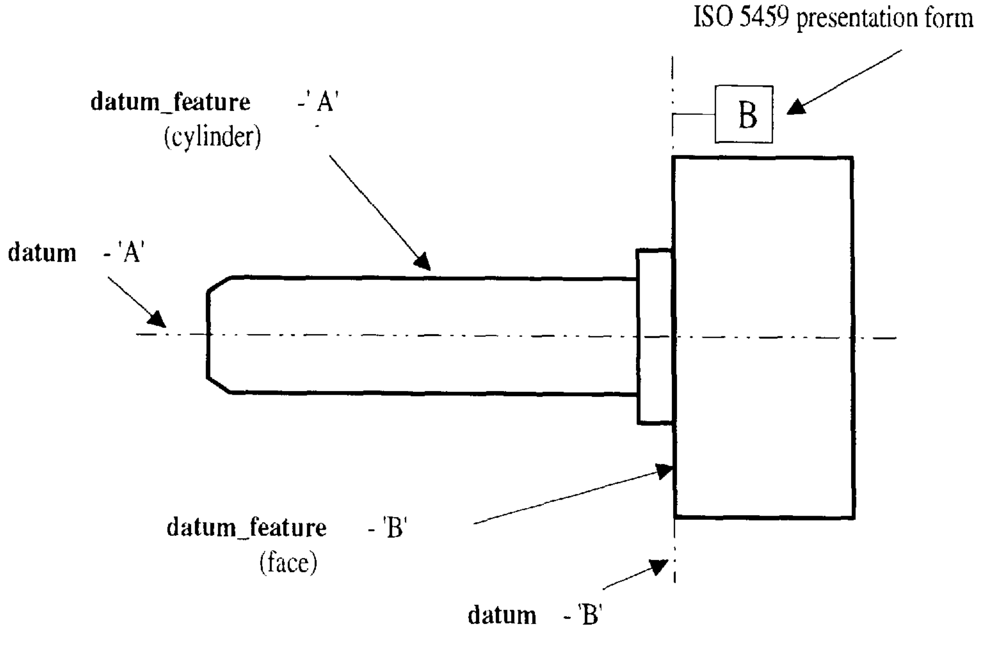


Figure 1 - Examples of datum and datum_feature

4.4.3 datum_target

The **datum_target** is a **shape_aspect** that indicates a datum target on the boundary of a product shape. The **shape_aspect** may be a point, line, or an area. The **datum_target** is defined in addition to the **shape_aspect** elements that define the product shape.

NOTE - The use and application of datum targets is described in clause 7 of ISO 5459.

EXPRESS specification:

```
*)
ENTITY datum_target
  SUBTYPE OF (shape_aspect);
  target_id              : identifier;
  INVERSE
  target_basis_relationship : shape_aspect_relationship FOR
                              relating_shape_aspect;
WHERE
   WR1: SIZEOF (QUERY (sar<* bag_to_set (USEDIN (SELF,
       'PRODUCT_PROPERTY_DEFINITION_SCHEMA.SHAPE_ASPECT_RELATIONSHIP.' +
         'RELATING_SHAPE_ASPECT'))
       | NOT ('SHAPE_ASPECT_DEFINITION_SCHEMA.DATUM' IN TYPEOF
       (sar.related_shape_aspect))))=0;
   WR2: SELF.product_definitional = TRUE;
END_ENTITY;
(*
```

Attribute definitions:

target_id: the name by which the identification of the datum target number is referred.

target_basis_relationship: the relationship to the **datum** that the **datum_target** defines; it is achieved through the **shape_aspect_relationship**.

Formal propositions:

WR1: A **datum_target** shall be related to a **datum**.

WR2: A **datum_target** lies on the physical boundary of the shape that defines the product.

4.4.4 datum_reference

A **datum_reference** is the specification of the use of a **datum**.

EXAMPLE 3 - A **datum** may be used in the definition of multiple **datum** systems. Each use of the **datum** would be a **datum** reference. **Datum** system concepts are described in 6.2 and clause 8 of ISO 5459.

EXPRESS specification:

```
*)
ENTITY datum_reference;
  precedence        : INTEGER;
  referenced_datum : datum;
WHERE
  WR1: precedence > 0;
END_ENTITY;
(*
```

Attribute definitions:

precedence: the priority that is assigned to a **datum** for a specific use.

NOTE - A **datum** may have multiple and distinct uses and have different **precedence** for each use.

referenced_datum: the **datum** that participates in a geometrical tolerance of a product feature.

Formal propositions:

WR1: The value of **precedence** shall be greater than zero.

4.4.5 referenced_modified_datum

A **referenced_modified_datum** is a **datum_reference** where the referenced datum may vary within the specified limits of size.

NOTES

1 - A **datum** may be modified if the **datum_feature** that produced it is a product feature which has size characteristics.

2 - The use and application of a modified **datum** are described in clause 8 of ISO 2692.

EXPRESS specification:

```
*)
ENTITY referenced_modified_datum
  SUBTYPE OF (datum_reference);
  modifier : limit_condition;
END_ENTITY;
(*
```

Attribute definitions:

modifier: the **limit_condition** that is assigned to the **datum** for a specific use of that **datum**.

4.5 shape_aspect_definition_schema entity definitions: derived shapes

4.5.1 composite_shape_aspect

A **composite_shape_aspect** is a **shape_aspect** that associates aspects of the product shape for a specific purpose.

EXPRESS specification:

```
*)
ENTITY composite_shape_aspect
  SUBTYPE OF (shape_aspect);
INVERSE
  component_relationships : SET [2:?] OF shape_aspect_relationship
                            FOR relating_shape_aspect;
END_ENTITY;
(*
```

Attribute definitions:

component_relationships: the set of member **shape_aspects** that form the **composite_shape_aspect**. The **relating_shape_aspect** is the **composite_shape_aspect**, and the **related_shape_aspects** are members of the set.

EXAMPLES

4 - A set of **datum_target_features** are related together to establish a **datum.**

5 - Figure 2 illustrates two instances of **composite_shape_aspect.** First, the **composite_shape_aspect** that contains cylindrical face components may represent a pattern of holes in which a pattern controlling positional geometric tolerance may be applied. The bolt hole pattern is the **composite_shape_aspect.** Second, the **composite_shape_-aspect** that contains connected face components may represent a profile group feature to which a single surface profile geometric tolerance may be applied.

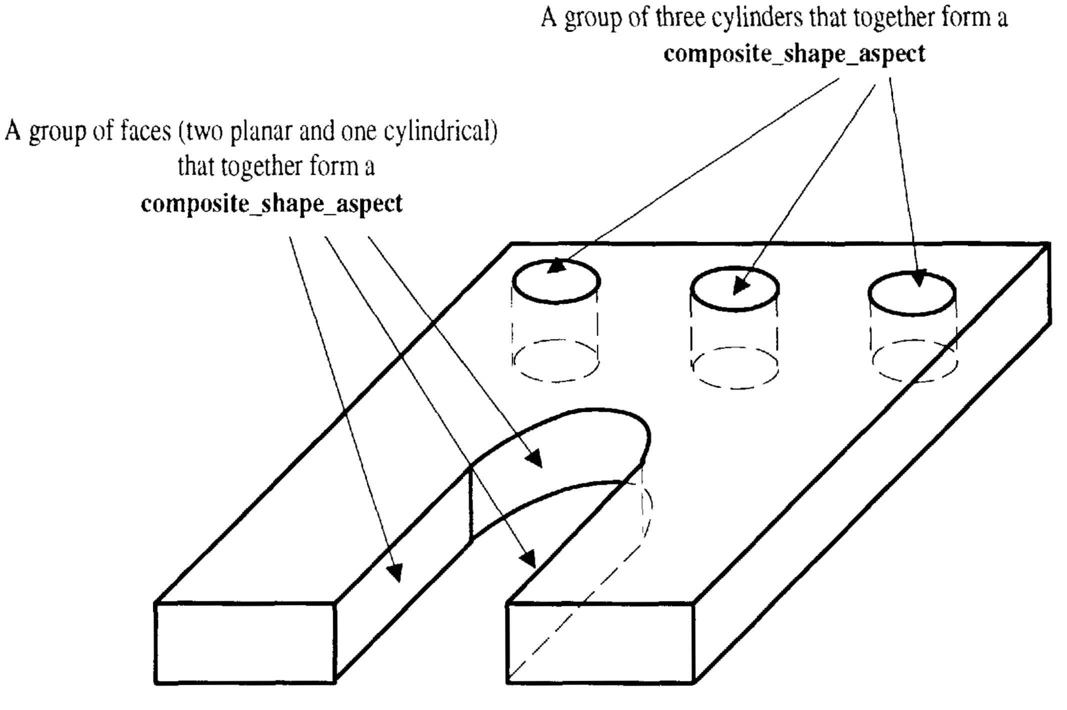


Figure 2 - Composite_shape_aspect

4.5.2 derived_shape_aspect

A **derived_shape_aspect** is a **shape_aspect** that depends on the definition of one or more specific shapes. The existence of the **derived_shape_aspect** depends on and relates to other **shape_aspects.**

NOTE - A derived_shape_aspect may not be on the physical boundary of the product. Its intended purpose is to relate product dimensions and tolerances with the shape_aspects or features of the part.

EXAMPLE 6 - Consider the **shape_aspect** of a cylindrical hole. It is symmetric about an axis, and this axis exists only when the hole exists. The axis is a **derived_shape_aspect**.

EXPRESS specification:

```
*)
ENTITY derived_shape_aspect
  SUPERTYPE OF (ONEOF (apex,
                       centre_of_symmetry,
                       geometric_alignment,
                       geometric_intersection,
                       parallel_offset,
                       perpendicular_to,
                       extension,
                       tangent))
  SUBTYPE OF (shape_aspect);
INVERSE
  deriving_relationships : SET [1:?] OF shape_aspect_deriving_relationship
                           FOR relating_shape_aspect;
END_ENTITY;
(*
```

Attribute definitions:

deriving_relationships: the identification of **shape_aspect_deriving_relationships** that define the **derived_-shape_aspect**.

4.5.3 apex

An **apex** is a **derived_shape_aspect** that defines the point corresponding to the common apex (the location where a plane and conical element intersect at a single point) of one or more conical **shape_aspect** elements. The common intersection of three or more planes or two curves shall be treated as a **geometric_intersection** rather than as an **apex.**

EXPRESS specification:

```
*)
ENTITY apex
  SUBTYPE OF (derived_shape_aspect);
END_ENTITY;
(*
```

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: the **shape_aspect_deriving_relationships** which define the frustum from which the apex is derived. The **relating_shape_aspect** is the **apex**. The **related_shape_-aspects** are **shape_aspects** of the conical surfaces of frustums from which the **apex** is derived.

4.5.4 centre_of_symmetry

A **centre_of_symmetry** is a **derived_shape_aspect** that defines the geometric centre of symmetry of one or more **symmetric_shape_aspects**.

EXAMPLE 7 - Types of geometric representation for a centre_of_symmetry may be an axis for a feature, a center of a sphere, or a plane. In (a) of figure 3, the centre plane is the **centre_of_symmetry** for the two parallel opposing planes. In (b) of figure 3, the axis of a cylinder is the **centre_of_symmetry** for both cylinders.

EXPRESS Specification:

```
*)
ENTITY centre_of_symmetry
  SUBTYPE OF (derived_shape_aspect);
WHERE
        WR1: SIZEOF (QUERY(sadr<*deriving_relationships|
        NOT('SHAPE_ASPECT_DEFINITION_SCHEMA.SYMMETRIC_SHAPE_ASPECT'
         IN TYPEOF
         (sadr.related_shape_aspect))))=0;
END_ENTITY;
(*
```

Formal proposition:

WR1: A **centre_of_symmetry** shall have at least one **symmetric_shape_aspect**.

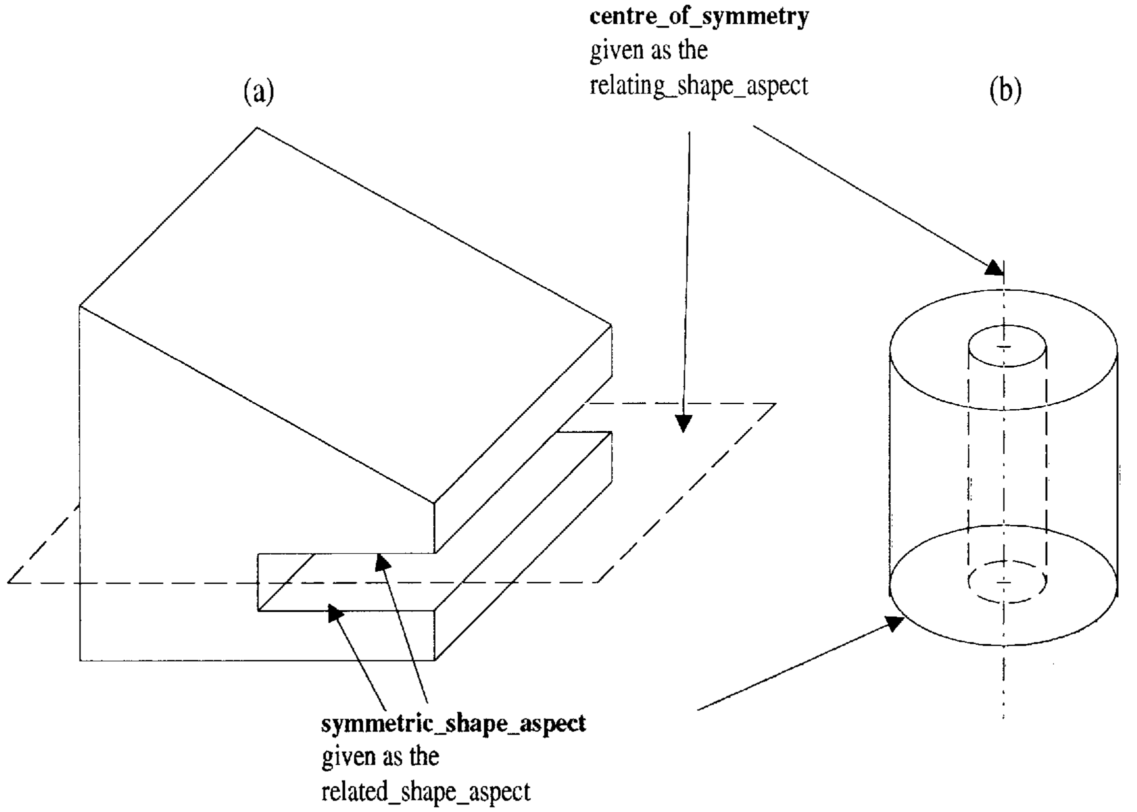


Figure 3 - Symmetry_shape_aspect and centre_of_symmetry

4.5.5 geometric_alignment

A **geometric_alignment** is a **derived_shape_aspect** that defines a planar or linear feature that requires two or more features lying in the same plane or along the same line.

EXPRESS specification:

```
*)
ENTITY geometric_alignment
  SUBTYPE OF (derived_shape_aspect);
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)> 1;
```

```
END_ENTITY;
(*
```

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: the **shape_aspect_deriving_relationship** that associates the linear or planar **derived_shape_aspect** that contains two or more aligned **shape_aspect** elements. The **relating_shape_aspect** is the **geometric_alignment**. The **related_shape_aspects** are the aligned **shape_aspect** elements.

Formal propositions:

WR1: There shall be two or more elements in the set of **deriving_relationships**.

EXAMPLE 8 - Figure 4 illustrates an axis of a cylinder as a linear feature and the face of a cutout as a planar feature. When two or more aligned parallel axes are used for the purpose of dimensioning, a plane may be established to which a dimension is attached, as shown in figure 4.

4.5.6 geometric_intersection

A geometric_intersection is a **derived_shape_aspect** that is the common intersection of two or more **shape_aspect** elements.

NOTE - Since a **geometric_intersection** is a derived shape, the use of intersection here is independent of any specific representation.

EXAMPLE 9 - A **geometric_intersection** is established by the intersection of two planar extensions from the adjacent sides of the block. This **geometric_intersection** may be used as the participating **shape_aspect** in dimensioning the location of the right or bottom planar surfaces as shown in figure 5.

EXPRESS Specification:

```
*)
ENTITY geometric_intersection
  SUBTYPE OF (derived_shape_aspect);
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)> 1;
END_ENTITY;
(*
```

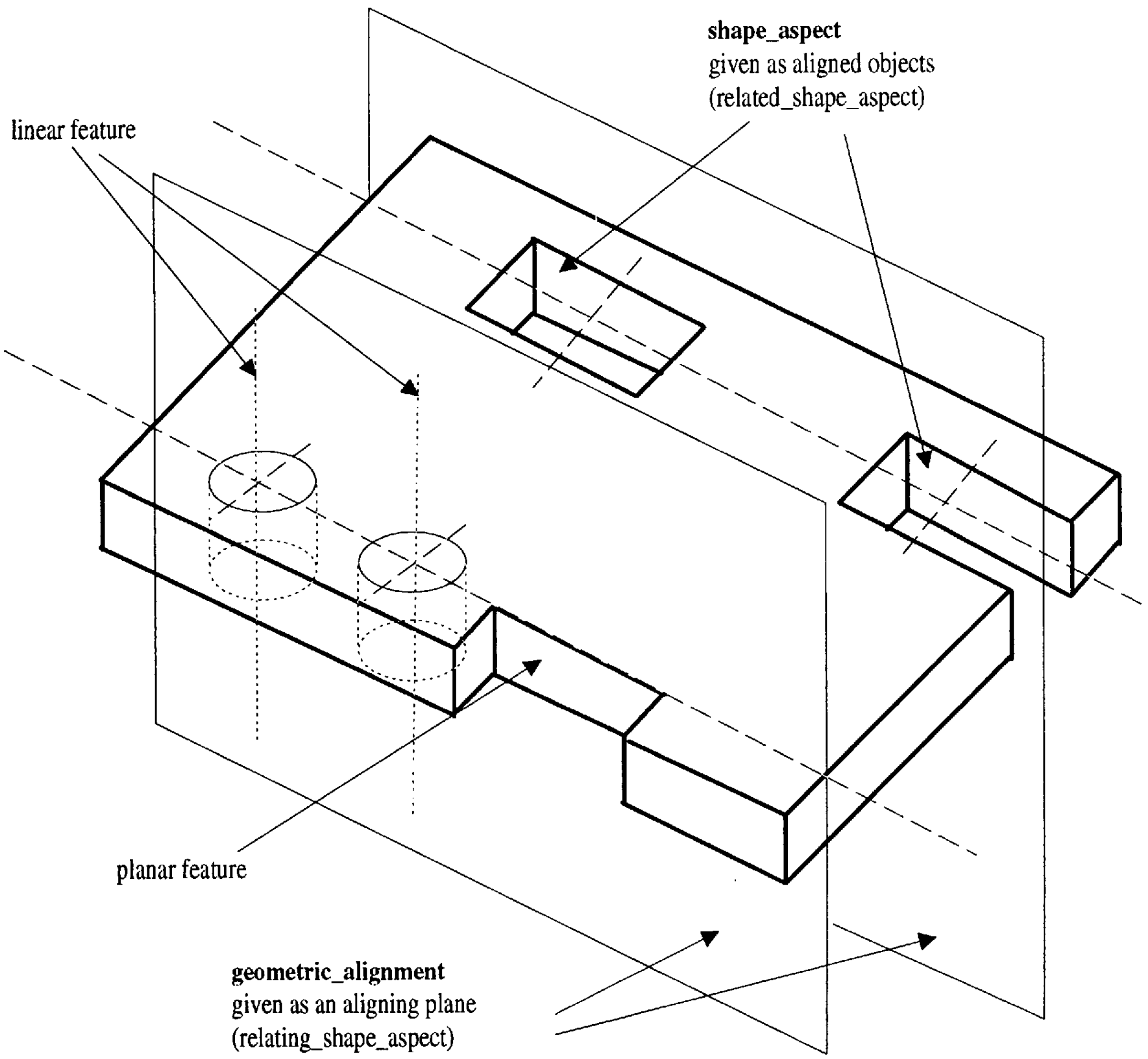


Figure 4 - Geometric_alignment

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: the **shape_aspect_deriving_relationship** that define the common intersection among intersecting **shape_ aspect** elements. The **relating_shape_aspect** is the **geometric_intersection**. The **related_shape_aspects** are the basis of the common intersection.

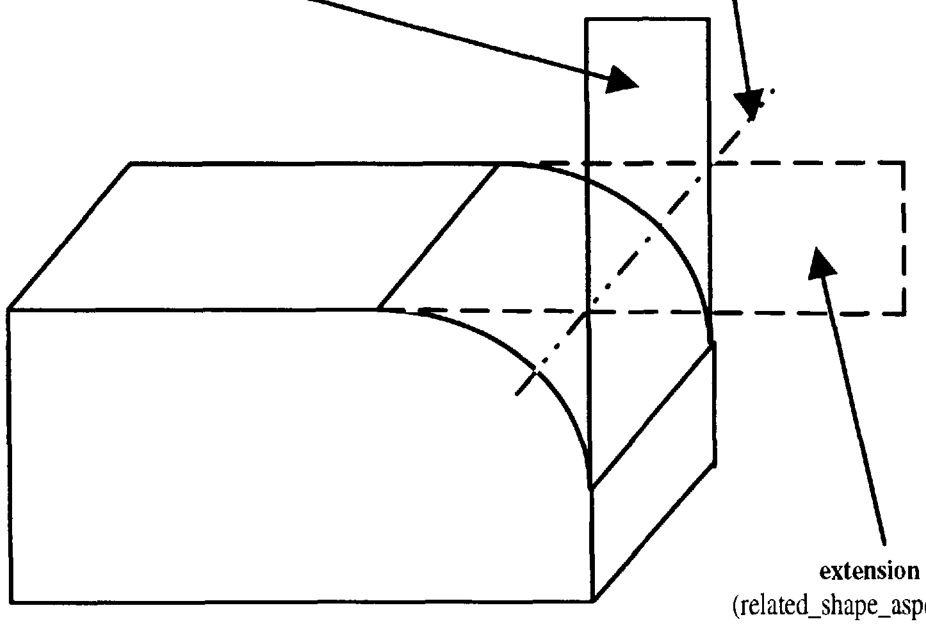


Figure 5 - Geometric_intersection

Formal propositions:

WR1: There shall be two or more members in the set of **deriving_relationships**.

Informal propositions:

IP1: The **shape_aspects** that participate as **relating_shape_aspects** shall intersect.

4.5.7 parallel_offset

A **parallel_offset** is a **derived_shape_aspect** that is located at a constant distance from a **related_shape_-aspect.** If the basis is two dimensional, then all associated **shape_aspect** elements (the parallel offset and the basis shape aspect) lie in some common plane. If the basis is a surface, then all **shape_aspect** elements are embedded in three-dimensional space.

NOTE - The basis shape aspect of a surface divides the space in which it is embedded into two half-spaces.

The **parallel_offset** is formed by the offset of each point of the basis, in a direction perpendicular to the basis by the offset distance (See figure 6).

EXAMPLE 10 - Figure 6 is a partial view of a part; not all details are shown. The **shape_aspect** is the basis **related_-shape_aspect** for the **parallel_offset**. The **offset** is the distance the **parallel_offset** is positioned from its basis.

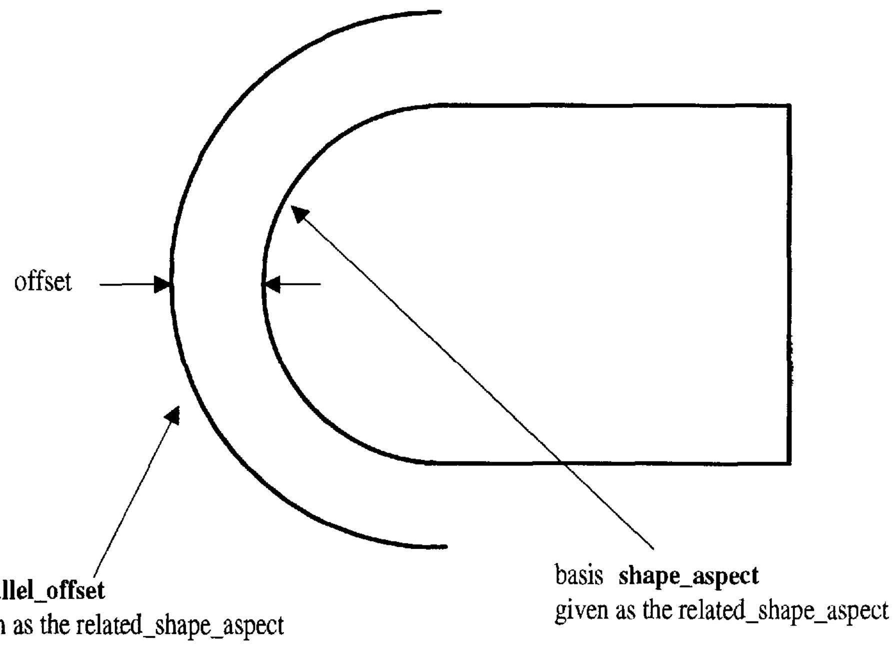


Figure 6 - Parallel_offset

<u>EXPRESS Specification</u>:

```
*)
ENTITY parallel_offset
  SUBTYPE OF (derived_shape_aspect);
  offset              : measure_with_unit;
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)= 1;
END_ENTITY;
```

```
END_ENTITY;
(*
```

Attribute definitions:

offset: the distance between the **parallel_offset** and the **shape_aspect** to which the **parallel_offset** is parallel.

SELF\derived_shape_aspect.deriving_relationships: a **shape_aspect_relationship** that associates the **shape_aspect** which is parallel to another **shape_aspect**. The **parallel_offset** has one **deriving_relationships**. The **relating_shape_aspect** is the **parallel_offset**. The **related_shape_aspect** is the basis from which the **parallel_offset** is defined.

Formal propositions:

WR1: There shall be one member in the set of **deriving_relationships**.

4.5.8 perpendicular_to

A **perpendicular_to** is a **derived_shape_aspect** that is oriented orthogonally to another **shape_aspect**.

NOTE - The **perpendicular_to** need not intersect the **shape_aspect** from which it is established.

EXPRESS specification:

```
*)
ENTITY perpendicular_to
  SUBTYPE OF (derived_shape_aspect);
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)= 1;
END_ENTITY;
(*
```

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: a **shape_aspect_relationship** that associates the **shape_aspect** which is perpendicular to another **shape_aspect**. The **relating_shape_aspect** is the **perpendicular_to**. The **related_shape_aspect** is the **shape_aspect** from which the **perpendicular_to** is derived.

Formal propositions:

WR1: There shall be one member in the set of **deriving_relationships**.

4.5.9 extension

An **extension** is a **derived_shape_aspect** that corresponds to the extension of a curve or surface **shape_aspect** element.

EXAMPLE 11 - Consider the rounded edge of a block as shown in figure 5. To define the square corner at this edge, the two adjacent faces are extended until they intersect. Each of these is an **extension.**

EXPRESS specification:

```
*)
ENTITY extension
  SUBTYPE OF (derived_shape_aspect);
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)= 1;
END_ENTITY;
(*
```

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: a **shape_aspect_relationship** that associates the **shape_aspect** which is extended from other **shape_aspects**. The **relating_shape_aspect** is the **extension**. The **related_shape_aspect** is the basis for the **extension.**

Formal propositions:

WR1: There shall be one member in the set of **deriving_relationships**.

4.5.10 tangent

A **tangent** is a **derived_shape_aspect** that contacts a curve or surface **shape_aspect** at a single point or line.

EXPRESS specification:

```
*)
ENTITY tangent
```

```
  SUBTYPE OF (derived_shape_aspect);
WHERE
  WR1: SIZEOF (SELF\derived_shape_aspect.deriving_relationships)= 1;
END_ENTITY;
(*
```

Attribute definitions:

SELF\derived_shape_aspect.deriving_relationships: a **shape_aspect_relationship** that associates the **shape_aspect** which is tangent to other **shape_aspect**. The **relating_shape_aspect** is the **tangent**. The **related_shape_aspect** is the **shape_aspect** that the **tangent** touches.

Formal propositions:

WR1: There shall be one member in the set of **deriving_relationships**.

4.5.11 shape_aspect_deriving_relationship

A **shape_aspect_deriving_relationship** is another **shape_aspect_relationship** that defines the specific association between a **derived_shape_aspect** and one or more **shape_aspects**.

NOTE - The **relating_shape_aspect** is the **derived_shape_aspect**. The **related_shape_aspects** are the other **shape_aspects** that are the basis for the **derived_shape_aspect**.

EXPRESS specification:

```
*)
ENTITY shape_aspect_deriving_relationship
    SUBTYPE OF (shape_aspect_relationship);
  WHERE
    WR1: 'SHAPE_ASPECT_DEFINITION_SCHEMA.DERIVED_SHAPE_ASPECT' IN TYPEOF
         (SELF\SHAPE_ASPECT_RELATIONSHIP.RELATING_SHAPE_ASPECT);
  END_ENTITY;
(*
```

Formal propositions:

WR1: The **relating_shape_aspect** of **shape_aspect_deriving_relationship** shall be a **derived_shape_aspect**.

4.5.12 symmetric_shape_aspect

A **symmetric_shape_aspect** is a **shape_aspect** of a product that is symmetrical about a geometric element. It may also be a **shape_aspect** defined by a group of identified **shape_aspects** of a product that together have the property of symmetry.

EXAMPLE 12 - A cylinder is symmetric about its axis. A bolt hole pattern is a **composite_shape_aspect** that is symmetric about the axis of the common cylinder that intersects the centre of each hole. See figure 7.

NOTE - Figure 7 illustrates a bolt hole circle pattern of four cylinders that is a **composite_shape_aspect**. Coincidentally, the bolt hole circle pattern is also a **symmetric_shape_aspect** that has a **centre_of_symmetry** about the axis of the common cylinder that intersects the centre of each hole. Furthermore, each hole can be a **symmetric_-shape_aspect** when it is necessary to capture the relationship to the hole's **centre_of_symmetry**.

EXPRESS specification:

```
*)
ENTITY symmetric_shape_aspect
  SUBTYPE OF (shape_aspect);
INVERSE
  basis_relationships : SET [1:?] OF shape_aspect_relationship
                        FOR relating_shape_aspect;
WHERE
  WR1: SIZEOF (QUERY (X<*SELF.basis_relationships |
       'SHAPE_ASPECT_DEFINITION_SCHEMA.CENTRE_OF_SYMMETRY' IN TYPEOF
       (X.related_shape_aspect)))>=1;
END_ENTITY;
(*
```

Attribute definitions:

basis_relationships: identifies relationships to one or more features that are symmetric about centres of symmetry, e.g., point, axis, or median plane. The **related_shape_aspect** is a **centre_of_symmetry**. The **relating_shape_aspect** is the **symmetric_shape_aspect**.

Formal propositions:

WR1: A **symmetric_shape_aspect** shall have at least one **centre_of_symmetry**.

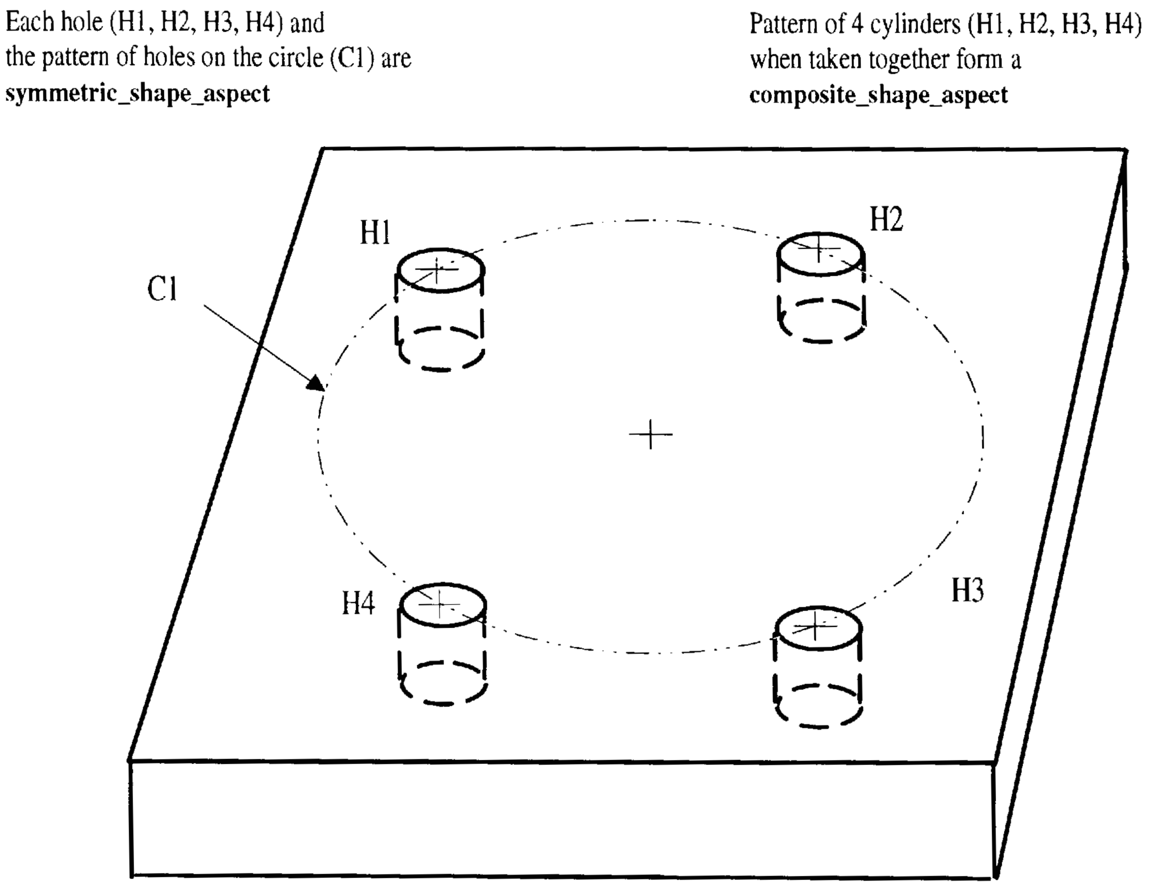


Figure 7 - Symmetric_shape_aspect and composite_shape_aspect

```
*)
END_SCHEMA;  --  shape_aspect_definition_schema
(*
```

5 Shape dimension

The following EXPRESS declaration begins the **shape_dimension_schema** and identifies the necessary external references.

EXPRESS specification:

```
*)
SCHEMA shape_dimension_schema;

REFERENCE FROM qualified_measure_schema

    (measure_representation_item,
           qualified_representation_item);

REFERENCE FROM product_property_representation_schema
    (shape_representation);

REFERENCE FROM product_property_definition_schema
    (shape_aspect,
     shape_aspect_relationship);

REFERENCE FROM support_resource_schema
    (label,
     text);
(*
```

NOTE - The schemas referenced above can be found in the following parts of ISO 10303:

qualified_measure_schema	ISO 10303-45
product_property_representation_schema	ISO 10303-41
product_property_definition_schema	ISO 10303-41
support_resource_schema	ISO 10303-41

5.1 Introduction

The **shape_dimension_schema** provides a representation for the description of location and size dimensions. The measure of a dimension may be either assigned to or derived from other **shape_aspect** elements. The supported types of measurement path for applying a dimension are:

— a linear path;

— a curved path;

— an angular path.

5.2 Fundamental concepts and assumptions

Dimensions that are derived from the geometric representations of **shape_aspects** are considered to be implicitly defined. Dimensions that are assigned to a **shape_aspect**, which may or may not have associated geometric representation, are considered to be explicitly defined. A size or location dimension may be both implicitly and explicitly defined for a given **shape_aspect**.

NOTES

1 - The lower limit of a limit dimension can be represented by either an explicit or assigned, dimension, while the upper limit value may be on an implicit or explicit dimension.

2 - Legal values that are computer sensible for attributes of entities in this schema may be specified in application protocols.

This part of ISO 10303 does not distinguish between intended values (e.g., designed values) and actual values (e.g., measured values) for either dimensions or tolerances. Geometrical tolerances and plus-minus tolerances may be applied to a dimension. Dimensions need not have a tolerance value.

This part of ISO 10303 does not distinguish between uses of dimensions. Uses of dimensions are defined in application protocols using this part of ISO 10303.

EXAMPLE 13 - The specification of a dimension to define the desired product shape and the specification of a dimension to describe as-manufactured product shape are two uses of dimension.

This part of ISO 10303 provides for the representation of dimensions in a manner that is independent of any requirements for draughting presentation.

NOTE 3 - The application and use of basic dimensions or reference dimensions are specified in an application protocol.

A dimensional location is a relationship between two **shape_aspect** elements that identifies a spatial constraint that shall be maintained during any physical transformation, translation, or rotation of the **shape_aspect** elements together. This relationship is either directed from the origin **shape_aspect** or **datum** to the target **shape_aspect**, or it is non-directed. Only non-directed dimensional location is addressed in this part of ISO 10303.

NOTE 4 - The decision as to whether the dimensional location is directed or non-directed is specified in an application protocol.

A dimensional size of a **shape_aspect** identifies a constraint between the relative position of the boundary of the **shape_aspect** with either its axis of symmetry or another boundary of the same **shape_aspect**. The dimensional size is unaffected by any translation or rotation of the **shape_aspect**.

A dimension is applied along a specific measuring path. When the measuring path is not explicitly identified, the dimension will apply along an implicit path. The definition of an implicit measuring path is dependent on the context of use and is specified in an application protocol.

5.3 shape_dimension_schema type definitions

5.3.1 angle_relator

An **angle_relator** type is an identification of an angle. This angle is one of a set of possible angles created by:

— the intersection of two **shape_aspect** elements;

— the virtual intersection formed by extensions of two **shape_aspect** elements;

— the boundaries of a single angular **shape_aspect**.

EXPRESS specification:

```
*)
TYPE angle_relator = ENUMERATION OF
  (equal,
   large,
   small);
END_TYPE;
(*
```

Enumerated item definitions:

equal: the numerical measure of the angles are equal at the point of intersection between two **shape_aspect** elements.

large: the numerical measure of the selected angle at the point of intersection between two **shape_aspect** elements is the larger absolute value.

small: the numerical measure of the selected angle at the point of intersection between two **shape_aspect** elements is the smaller absolute value.

EXAMPLE 14 - Figure 8 illustrates a type of single angular **shape_aspect**. See figure 9 for types of intersections of **shape_aspects**.

5.3.2 dimensional_characteristic

A **dimensional_characteristic** is the selection of the dimension type to which a tolerance or explicit measure value applies.

EXPRESS specification:

```
*)
TYPE dimensional_characteristic = SELECT (dimensional_location,
                                          dimensional_size);
END_TYPE;
(*
```

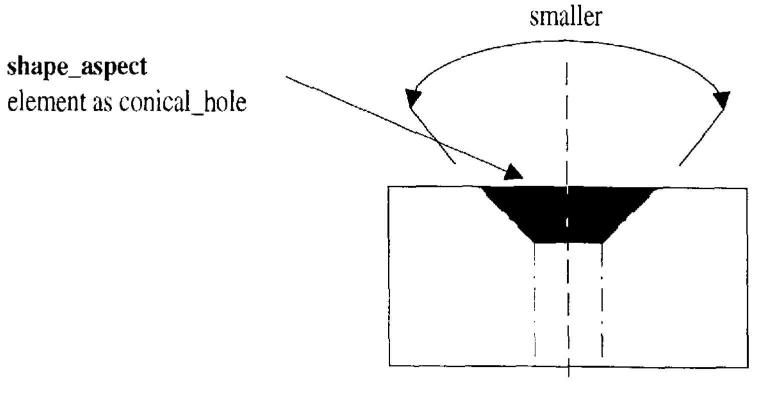


Figure 8 - Single angular shape_aspect

5.4 shape_dimension_schema entity definitions

5.4.1 angular_location

An **angular_location** specifies that a spatial constraint exists between two **shape_aspect** elements that intersect or would intersect if projected. An **angular_location** is a measure of the angle defined by the two **shape_aspect** elements and their common intersection or projected intersection.

NOTE - The application and use of an **angular_location** is illustrated in Figure 9. Figure 9 also illustrates types of intersection of two **shape_aspect** elements(a and b) and virtual intersection formed by **derived_shape_aspects** (c and d).

EXPRESS Specification:

```
*)
ENTITY angular_location
  SUBTYPE OF (dimensional_location);
  angle_selection : angle_relator;
END_ENTITY;
(*
```

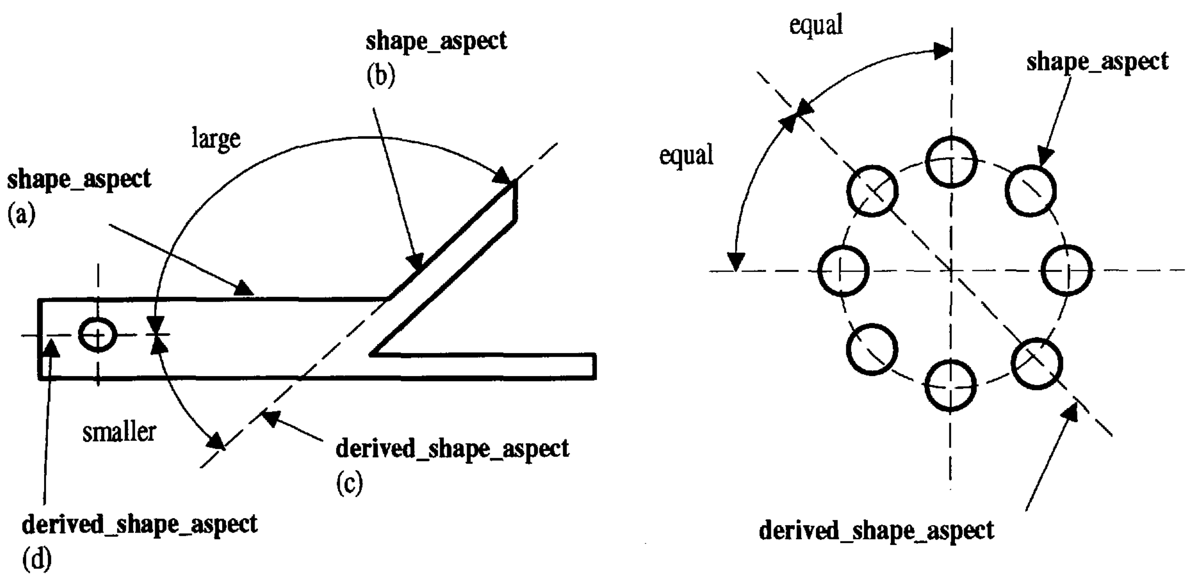


Figure 9 - Angular_location

Attribute definitions:

angle_selection: an indication of the specific angle type at the point of intersection.

5.4.2 angular_size

An **angular_size** is the measure of the angle formed by two boundaries of the **shape_aspect** and their common or projected intersection. An **angular_size** defines an angular spatial characteristic of a **shape_aspect**. An **angular_size** is represented by a single magnitude and is independent of the location of the **shape_aspect** on or within the product.

NOTE - The application and use of an **angular_size** is illustrated in figure 10.

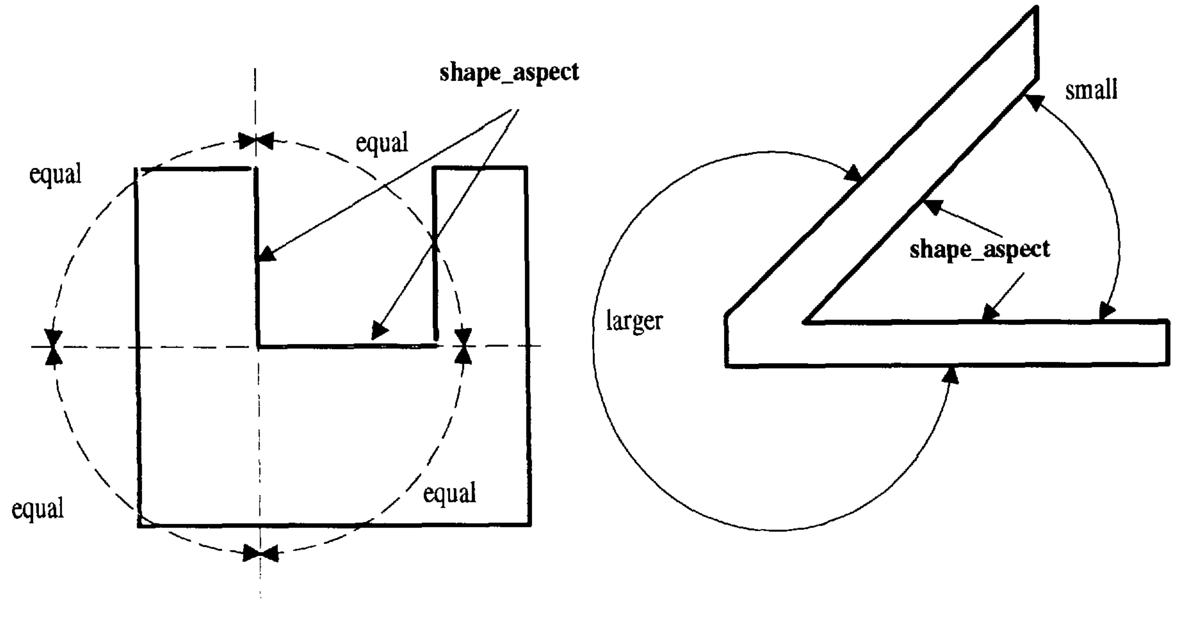


Figure 10 - Angular_size

EXPRESS specification:

```
*)
ENTITY angular_size
```

```
  SUBTYPE OF (dimensional_size);
  angle_selection : angle_relator;
END_ENTITY;
(*
```

Attribute definitions:

angle_selection: an indication of the specific type of angle at the point of intersection.

5.4.3 dimensional_characteristic_representation

A **dimensional_characteristic_representation** is an association of an implicit dimension with an explicit non-geometric representation.

> NOTE - A dimension for a **shape_aspect** may be explicitly represented as an actual value, a scaled value, a precision dependent value, or a pair of values that specify the upper and lower size limits. A **dimensional_characteristic_representation** associates one of the above value types with the implicit dimension value that may be derived from the geometric representation of the **shape_aspect**.

EXPRESS specification:

```
*)
ENTITY dimensional_characteristic_representation;
  dimension      : dimensional_characteristic;
  representation : shape_dimension_representation;
END_ENTITY;
(*
```

Attribute definitions:

dimension: an implicit measurement for which an explicit non-geometric representation is defined.

representation: the explicit non-geometric representation assigned to the dimension.

5.4.4 dimensional_location

A **dimensional_location** specifies that a spatial constraint exists between two **shape_aspect** elements that are represented as a non-directed measure applied along a measurement path.

EXPRESS Specification:

```
*)
ENTITY dimensional_location
  SUPERTYPE OF (ONEOF (angular_location,
                       dimensional_location_with_path))
  SUBTYPE OF (shape_aspect_relationship);
END_ENTITY;
(*
```

NOTES

1 - Representation of a **shape_aspect** participating in the **dimensional_location** relationship implies a measuring direction for the **dimensional_location** through the related and relating **shape_aspect**. The meaning of the direction is specified in an application protocol.

2 - The application and use of **dimensional_location** and **dimensional_size** are shown in figure 11.

5.4.5 dimensional_location_with_path

A **dimensional_location_with_path** specifies that a spatial constraint exists between two **shape_aspect** elements along an explicit path. The **dimensional_location_with_path** is a **dimensional_location** applied along an explicit path that is defined between the **shape_aspect** elements.

EXAMPLE 15 - See figure 12. The location of hole H2 from hole H1 may be defined with either **dimensional_-locations**, X1 and Y1 or, **dimensional_location_with_path**, D1. **Dimensional_locations** X1 and Y1 use implicit measuring paths defined by a coordinate system associated with the product. A **dimensional_location_with_path** applies along the explicit measuring path defined by the line intersecting the centres of the 2 holes.

EXPRESS Specification:

```
*)
ENTITY dimensional_location_with_path
  SUBTYPE OF (dimensional_location);
  path : shape_aspect;
END_ENTITY;
(*
```

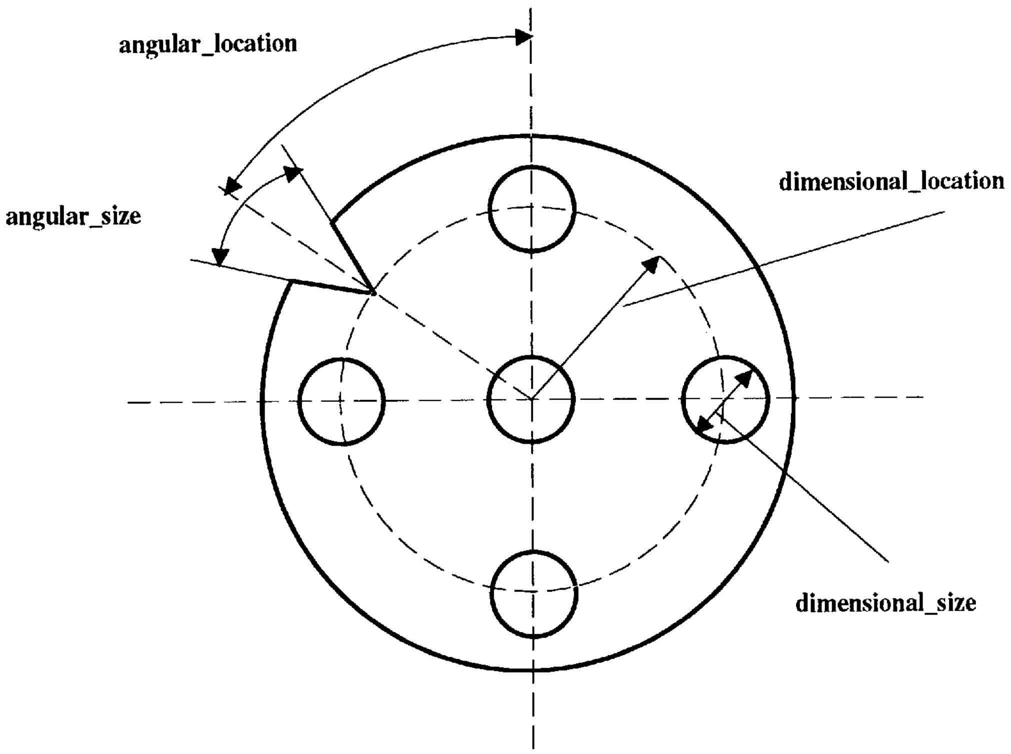


Figure 11 - Dimensional_location and dimensional_size

Attribute definitions:

path: the **shape_aspect** defining the measurement path for the dimension.

5.4.6 dimensional_size

A **dimensional_size** defines a spatial characteristic of a **shape_aspect** that is represented by a measure. This magnitude is independent of the location of the **shape_aspect** on or within the product.

EXPRESS Specification:

```
*)
ENTITY dimensional_size
  SUPERTYPE OF (ONEOF (angular_size,
                       dimensional_size_with_path));
  applies_to : shape_aspect;
```

```
  name        : label;
WHERE
  WR1: applies_to.product_definitional = TRUE;
END_ENTITY;
(*
```

Attribute definitions:

applies_to: the **shape_aspect** being dimensioned.

name: the identification of the application use of the dimension.

EXAMPLE 16 - A size characteristic may be either a radius, a diameter, a length constraint, an angular constraint, a curve **shape_aspect**, an axisymmetric **shape_aspect**, or a circular **shape_aspect**. Use of the name attribute with a value of "radius" clarifies the application use of this dimension.

Formal propositions:

WR1: a **dimensional_size** shall lie on the physical boundary of the shape that defines the product.

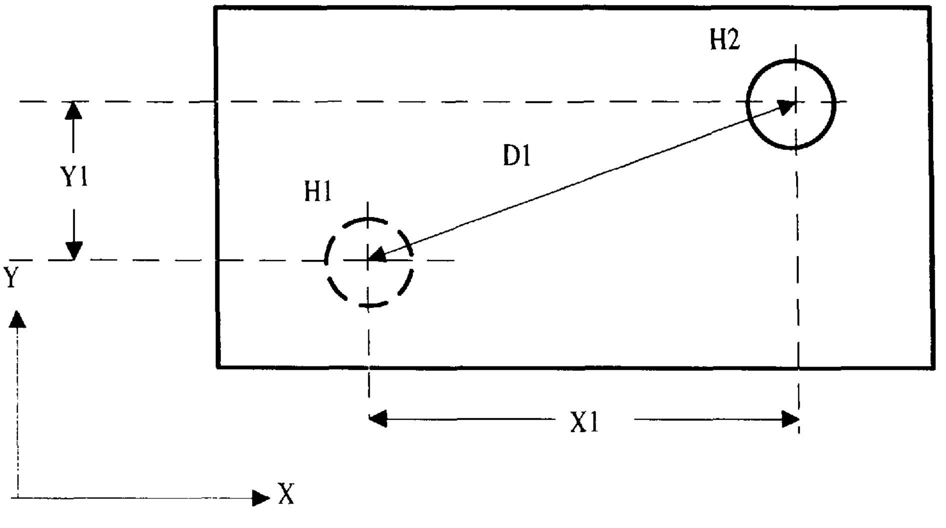


Figure 12 - Dimension_location_with_path

5.4.7 dimensional_size_with_path

A **dimensional_size_with_path** defines a spatial characteristic of a **shape_aspect**. The **dimensional_size_-with_path** is represented by a single magnitude and is independent of the location of the **shape_aspect** on or within the product. It is the non-directed measure derived along an explicit curve path that is defined between the two boundaries of the **shape_aspect**.

EXPRESS specification:

```
*)
ENTITY dimensional_size_with_path
  SUBTYPE OF (dimensional_size);
  path : shape_aspect;
END_ENTITY;
(*
```

Attribute definitions:

path: the **shape_aspect** defining the measurement path for the dimension.

5.4.8 shape_dimension_representation

A **shape_dimension_representation** is a representation of either **dimensional_location** or **dimensional_size**. It is a representation that explicitly describes a dimension of a **shape_aspect** with either a value or a range of values.

NOTE - The tolerance principle of independence, as defined in ISO 8015 [5], has a symbol to identify the envelope requirement on a toleranced dimension. The envelope requirement may be conveyed by using the name attribute in **shape_dimension_representation**.

EXAMPLE 17 - A cylindrical **shape_aspect** is prescribed to have a diameter of 10 centimetres. This specification, "10cm. diameter", is a **shape_dimension_representation** that defines a size characteristic of the **shape_aspect** without requiring a geometric representation.

A **shape_dimension_representation** may have many **representation_items**, but two of the **representation_-items** shall define a specific **shape_dimension_representation**. These represent the upper and lower dimension of a limits of size. Limits of size is defined in 4.3 of ISO 406.

EXAMPLE 18 - The diameter of a hole is defined to allow a physical instance of the hole to vary between 2.00 cm. and 2.01 cm. In the product description, the lower and upper allowable diameters of the hole are represented by a 2.00 cm. geometric cylinder and another representation item with a value of 2.01 cm.

EXPRESS specification:

```
*)
ENTITY shape_dimension_representation
                SUBTYPE OF (shape_representation);
  WHERE
   WR1: SIZEOF (QUERY (temp <* SELF.items |
    NOT ('QUALIFIED_MEASURE_SCHEMA.MEASURE_REPRESENTATION_ITEM'
        IN TYPEOF (temp)))) = 0;
   WR2: SIZEOF (SELF.items) <= 2;
   WR3: SIZEOF (QUERY (pos_mri <* QUERY (real_mri <* SELF.items |
        'REAL' IN TYPEOF
        (real_mri\measure_with_unit.value_component) ) |
      NOT  (pos_mri\measure_with_unit.value_component > 0.0 ))) = 0;
END_ENTITY;
(*
```

Formal propositions:

WR1: the **representation_items** in the set of items for a **shape_dimension_representation** shall be of type **measure_representation_item.**

WR2: there shall be at most two **representation_items** in the set of items for a **shape_dimension_-representation**.

WR3: the **value_component** of the **representation_items** in the set of items for a **shape_dimension_-representation** shall be a positive real number.

```
*)
END_SCHEMA;   --  shape_dimension_schema
(*
```

6 Shape tolerance

The following EXPRESS declaration begins the **shape_tolerance_schema** and identifies the necessary external references.

```
*)
SCHEMA shape_tolerance_schema;

REFERENCE FROM product_property_definition_schema
    (shape_aspect,
     shape_aspect_relationship);

REFERENCE FROM measure_schema
    (measure_with_unit, measure_value);

REFERENCE FROM representation_schema
    (representation);

REFERENCE FROM support_resource_schema
    (label,
     text);

REFERENCE FROM shape_aspect_definition_schema
    (datum_reference,
     limit_condition);

REFERENCE FROM shape_dimension_schema
    (dimensional_characteristic,
     dimensional_location);
(*
```

NOTE - The schemas referenced and used above can be found in the following parts of ISO 10303:

product_property_definition_schema	ISO 10303-41
measure_schema	ISO 10303-41
support_resource_schema	ISO 10303-41
representation_schema	ISO 10303-43
shape_aspect_definition_schema	clause 4 of this part of ISO 10303
shape_dimension_schema	clause 5 of this part of ISO 10303

6.1 Introduction

The **shape_tolerance_schema** provides the constructs for describing tolerances that apply to dimensions and to elements of **shape_aspect**. This schema includes two types of tolerance: plus-minus tolerance and geometrical tolerance. The plus-minus tolerance provides the constructs for specifying tolerances in one of two ways:

— the specification of upper and lower limits within which a dimension may vary;

— the specification of limits and fits as specified in ISO 286-1 and ISO 286-2.

The representation of statistical tolerance may be associated with the direct specification of the upper and the lower limits of the plus-minus tolerance or with a geometric tolerance.

The geometrical tolerance provides the constructs for applying tolerance zones to elements of **shape_aspects**. A tolerance zone defines a region or an area within which a **shape_aspect** may vary and is bounded by a set of tolerance zone elements. These constructs support tolerances for the form, orientation, location, profile, and runout of a **shape_aspect**. A tolerance zone may be represented by specific geometry and is used for various tolerancing methods.

6.2 Fundamental concepts and assumptions

A toleranced dimension is an exact dimension with a plus-minus tolerance. A plus-minus tolerance limits the dimensional variation of a dimension of a product. The plus-minus tolerance range is limited by either assigned values, which define the upper bound and lower bound of a dimension, or a standard tolerance as specified in ISO 286-1 and ISO 286-2. The tolerance with a statistical distribution provides an additional specification of the variation of a dimension and may be used with either a plus-minus tolerance or a geometric tolerance.

Geometrical tolerances constrain the variations in the geometric properties of a product shape. These properties are form, location, orientation, profile, and runout. ISO 1101 specifies geometrical tolerances for form, location, orientation, profile, and runout. ISO 5458 specifies the geometrical tolerance for position. A limit condition modifies a geometrical tolerance such that the size variation of a **shape_aspect** may increase or decrease, as specified in ISO 2692. A geometrical tolerance has a tolerance zone that defines the limits of the variation of a **shape_aspect**. Tolerance zone elements define the boundaries of a geometrical tolerance zone. The tolerance zone for a single **shape_aspect** may be defined as a single zone or in increments that are contiguous with a defined unit or by length or area. The size of the tolerance zone is defined by the measure of the tolerance. Tolerance zones for geometrical tolerances are specified in ISO 1101 and 5458.

A geometrical tolerance may reference a **datum** system which is composed of one or more **datum**s. The **datum** system defines an origin for the geometrical properties.

NOTES

1 - When the tolerance zone is not fully bounded, it is appropriate to assume that the tolerance zone extends to infinity at the unbounded areas.

2 - Legal values that are computer sensible for attributes of entities in this schema may be specified in application protocols.

EXAMPLE 19 - A flatness tolerance zone of a planar surface is bounded by two parallel, infinite planes separated by a distance of the tolerance magnitude.

6.3 shape_tolerance_schema type definitions

6.3.1 tolerance_method_definition

The **tolerance_method_definition** type is the identification of the method used to generate a tolerance value.

EXPRESS specification:

```
*)
TYPE tolerance_method_definition = SELECT
  (tolerance_value,
   limits_and_fits);
END_TYPE;
(*
```

6.3.2 tolerance_select

A **tolerance_select** type indicates that a tolerance can either be a **geometric_tolerance** or a **plus_minus_-tolerance**.

EXPRESS specification:

```
*)
TYPE tolerance_select =SELECT
    (geometric_tolerance,
     plus_minus_tolerance);
END_TYPE;
(*
```

6.4 shape_tolerance_schema entity definitions: geometric tolerance

6.4.1 dimension_related_tolerance_zone_element

A **dimension_related_tolerance_zone_element** is an association of a tolerance zone definition with a locating dimension.

EXAMPLE 20 - A square hole parallel to the Z axis may be toleranced with distinct positional tolerances in the X and Y directions. Each specified positional tolerance is defined by a **tolerance_zone_definition** consisting of two parallel planes. The dimension that locates the centre plane of the square hole in the X axis also specifies the location of the two parallel planes defining the positional tolerance in that axis. The **dimension_related_tolerance_-zone_-element** is the relationship of this dimension, the related_dimension, to the tolerance zone definition, the two parallel planes.

NOTE - The relationship between dimensions and tolerance zone elements is described in 3.6 of ISO 5458.

EXPRESS specification:

```
*)
ENTITY dimension_related_tolerance_zone_element;
  related_dimension  : dimensional_location;
  related_element    : tolerance_zone_definition;
END_ENTITY;
(*
```

Attribute definitions:

related_dimension: a dimension that positions the **tolerance_zone_definition**.

related_element: a **tolerance_zone_definition** that is defined with a specific location.

6.4.2 geometric_tolerance

A **geometric_tolerance** is the specification of the allowable range within which a geometrical property of a product may deviate.

EXPRESS specification:

```
*)
ENTITY geometric_tolerance;
  name                      : label;
  description               : text;
  magnitude                 : measure_with_unit;
  toleranced_shape_aspect : shape_aspect;
WHERE
  WR1: magnitude.value_component >= 0.0;
END_ENTITY;
(*
```

Attribute definitions:

name: the identification of the geometrical tolerance type.

NOTE - This identification may be one of the geometrical tolerance types specified in ISO 1101 when used to represent International Standard geometrical tolerances.

EXAMPLE 21 - Position, straightness, concentricity, parallelism, circular runout, etc., are names for geometrical tolerance types.

description: A supplementary note that shall be used to convey additional requirements associated with geometric tolerance.

NOTE - This description may state requirements that may have an affect on the **geometric_tolerance** for specific applications.

magnitude: the size of a tolerance.

toleranced_shape_aspect: the **shape_aspect** to which the tolerance applies.

Formal propositions:

WR1: The magnitude of the tolerance shall be greater than or equal to 0.0.

6.4.3 geometric_tolerance_relationship

A **geometric_tolerance_relationship** is an association between two **geometric_tolerances**.

EXPRESS specification:

```
*)
ENTITY geometric_tolerance_relationship;
   name                               :label;
   description                        :text;
   relating_geometric_tolerance       : geometric_tolerance;
   related_geometric_tolerance        : geometric_tolerance;
END_ENTITY;
(*
```

Attribute definitions

name: the word or group of words by which the geometric tolerance relationship is referred.

description: text that describes the relationship.

relating_geometric_tolerance: One of the **geometric_tolerances** that takes part in the relationship.

related_geometric_tolerance: The other **geometric_tolerance** that takes part in the relationship. If one of the **geometric_tolerances** is to be dependent on the other, this attribute shall be the dependent one.

6.4.4 geometric_tolerance_with_datum_reference

A **geometric_tolerance_with_datum_reference** is a **geometric_tolerance** that references one or more **datums** for specifying the tolerance condition of a **shape_aspect**.

EXPRESS specification:

```
*)
ENTITY geometric_tolerance_with_datum_reference
   SUBTYPE OF (geometric_tolerance);
   datum_system : SET [1:?] OF  datum_reference;
END_ENTITY;
(*
```

Attribute definitions:

datum_system: the datum or combination of datums that define a reference for a **geometric_tolerance**.

NOTE - This attribute is not equivalent to datum system as defined in clause 3.2 of ISO 5459.

6.4.5 geometric_tolerance_with_defined_unit

A **geometric_tolerance_with_defined_unit** is a **geometric_tolerance** specified on a per unit basis of the **shape_aspect**.

NOTE - The use and application of the per unit basis are described in Clause 9.1 of ISO 1101.

EXAMPLE 22 - A straightness tolerance defines the allowable amount of bending of a product feature on a unit length basis. A flatness tolerance defines the allowable amount of warping of a surface on a per square unit area basis.

EXPRESS specification:

```
*)
ENTITY geometric_tolerance_with_defined_unit
  SUBTYPE OF (geometric_tolerance);
  unit_size : measure_with_unit;
WHERE
  WR1: unit_size.value_component > 0.0;
END_ENTITY;
(*
```

Attribute definitions:

unit_size: the unit measure over which a tolerance applies.

Formal propositions:

WR1: The unit length or area over which the tolerance is applied shall be defined by a positive value.

6.4.6 modified_geometric_tolerance

A **modified_geometric_tolerance** is a **geometric_tolerance** with a material limit condition that applies to the **shape_aspect** being toleranced.

NOTE - See clauses 4 and 5 of ISO 2692. As specified in 4.2 of ISO 2692, this limit condition modifies the tolerance value applied to the toleranced **shape_aspect**.

EXPRESS specification:

```
*)
ENTITY modified_geometric_tolerance
  SUBTYPE OF (geometric_tolerance);
  modifier : limit_condition;
END_ENTITY;
(*
```

Attribute definitions:

modifier: the **limit_condition** that is assigned to a geometrical tolerance.

Informal propositions:

IP1: The **SELF\toleranced_shape_aspect** shall be a **shape_aspect** defining a product feature that has size characteristics.

6.4.7 projected_zone_definition

A **projected_zone_definition** is a **tolerance_zone_definition** that is projected from a feature of a product. The projection is external to the feature and is made from one of the ends of the feature for a specified length. A projected tolerance zone is defined in clause 4 of ISO 10578.

EXPRESS specification:

```
*)
ENTITY projected_zone_definition
  SUBTYPE OF (tolerance_zone_definition);
  projection_end    : shape_aspect;
  projected_length : measure_with_unit;
WHERE
  WR1: projected_length.value_component > 0.0;
END_ENTITY;
(*
```

Attribute definitions:

projection_end: the **shape_aspect** from which the projected tolerance zone originates.

projected_length: the distance from the feature being toleranced.

Formal propositions:

WR1: The value of the projected length shall be greater than 0.0.

6.4.8 runout_zone_definition

A **runout_zone_definition** is a **tolerance_zone_element** that is defined by the orientation of the measurement of the toleranced **shape_aspect** to the **centre_of_symmetry** of a **datum_feature**.

EXAMPLE 23 - Figure 13 illustrates a **runout_zone_definition.**

EXPRESS specification:

```
*)
ENTITY runout_zone_definition
  SUBTYPE OF (tolerance_zone_definition);
  orientation  : runout_zone_orientation;
END_ENTITY;
(*
```

Attribute definitions:

orientation: the orientation of a toleranced **shape_aspect** to the centre of symmetry of a **datum_feature**.

6.4.9 runout_zone_orientation

A **runout_zone_orientation** is the specification of the orientation of the runout tolerance element to the centre of symmetry of a **datum_feature**.

EXAMPLE 24 - Figure 13 illustrates an angle for a **runout_zone_orientation.** Rules specifying how the angle is measured shall be defined in an application protocol.

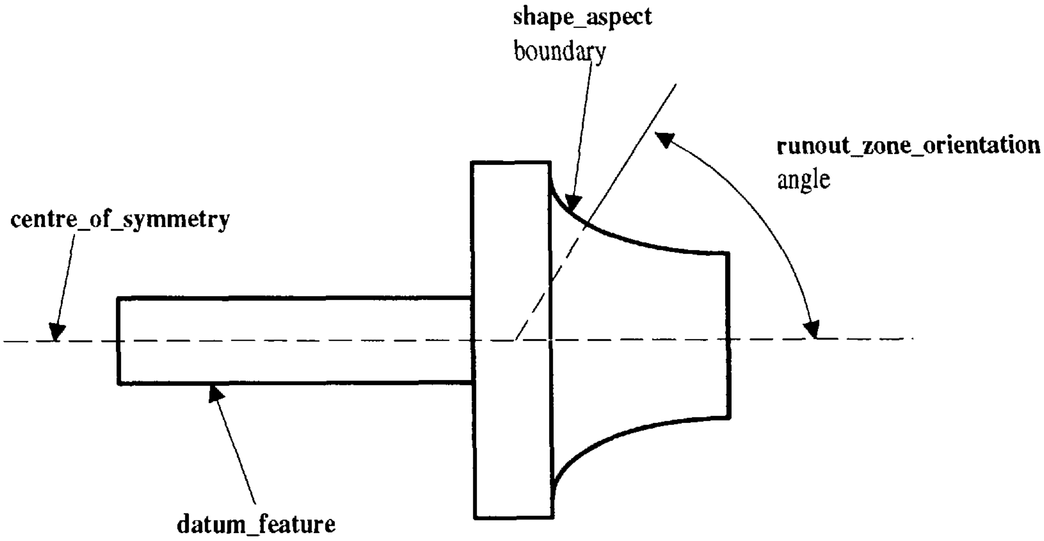


Figure 13 - Runout_zone_definition

EXPRESS specification:

```
*)
ENTITY runout_zone_orientation;
  angle : measure_with_unit;
END_ENTITY;
(*
```

Attribute definitions:

angle: an angle value that orients the tolerance zone from the centre of symmetry of a datum feature to which the runout zone is applied, or a specific value that is the normal to the surface of the **shape_aspect** that is applied to the runout tolerance.

NOTE - If a value other than a numeric value is desired then **angle** may be a **descriptive_measure**.

EXAMPLE 25 - An example of an **angle** defined by a **descriptive_value** may be "normal".

Informal propositions:

IP1: The angle value shall range from 0 to 90 degrees if the angle is a planar angle.

6.4.10 runout_zone_orientation_reference_direction

A **runout_zone_orientation_reference_direction** is a type of **runout_zone_orientation** that specifies the reference direction for the orientation of the angle.

EXPRESS specification:

```
*)
ENTITY runout_zone_orientation_reference_direction
  SUBTYPE OF (runout_zone_orientation);
  orientation_defining_relationship: shape_aspect_relationship;
END_ENTITY;
(*
```

Attribute definitions:

orientation_defining_relationship: the **shape_aspect_relationship** which specifies a directed relationship from the **relating_shape_aspect** to the **related_shape_aspect** to define the reference direction in which the angle is to be oriented.

6.4.11 statistical_distribution_for_tolerance

A **statistical_distribution_for_tolerance** is a type of **representation** that is defined by a set of **measure_-representation_items** that provide the set of distribution parameters. Each distribution parameter is defined by a name and a **measure_with_unit**.

EXPRESS specification:

```
*)
ENTITY statistical_distribution_for_tolerance
  SUBTYPE OF (representation);
WHERE
  WR1: SIZEOF (QUERY (item <* SELF\representation.items |
       NOT ('QUALIFIED_MEASURE_SCHEMA.MEASURE_REPRESENTATION_ITEM'
       IN TYPEOF (item)))) = 0;
```

```
END_ENTITY;
(*
```

Attribute definitions:

SELF\representation.name: The name by which the **statistical_distribution_for_tolerance** is referred.

EXAMPLE 26 - Normal Gaussian, Logarithmic or Rayleigh are names for statistical distributions.

EXAMPLE 27 - Mean and standard deviation are characteristic parameters that define a Normal Gaussian distribution.

Formal proposition:

WR1: The **representation_items** in the set **statistical_distribution_for_tolerence** shall be of type **measure_-representation_item**.

Informal propositions:

IP1: The name of each parameter that is related to the **statistical_distribution_for_tolerance** shall be specified in the name attribute of each respective **representation_item** in the items attribute of the representation.

6.4.12 tolerance_with_statistical_distribution

A **tolerance_with_statistical_distribution** defines the allocation of a tolerance in terms of a probability distribution. The **statistical_distribution_for_tolerance** may be associated with a tolerance value for a **geometric_tolerance** or a range of tolerances for a **plus_minus_tolerance**.

EXAMPLE 28 - The diameter of a shaft is toleranced by a **plus_minus_tolerance**. The **plus_minus_tolerance** specifies the range in which the diameter may vary. The **statistical_distribution_for_tolerance** associated to this **plus_minus_tolerance** specifies that the actual diameter values shall conform to a statistical distribution within the tolerance range.

EXPRESS specification:

```
*)
ENTITY tolerance_with_statistical_distribution;
  associated_tolerance : tolerance_select;
  tolerance_allocation : statistical_distribution_for_tolerance;
END_ENTITY;
(*
```

Attribute definitions:

associated_tolerance: the tolerance that is specified with a statistical distribution.

tolerance_allocation: the statistical distribution that shall apply to the tolerance.

6.4.13 tolerance_zone

A **tolerance_zone** is the region within which the toleranced feature shall be defined. The characteristics of the region are specified by the manner in which the toleranced feature is dimensioned.

EXAMPLE 29 - A geometric location tolerance applied to a hole defines a **tolerance_zone_form** that may be described as cylindrical.

EXPRESS specification:

```
*)
ENTITY tolerance_zone
  SUBTYPE OF (shape_aspect);
  defining_tolerance : SET [1:?] OF geometric_tolerance;
  form               : tolerance_zone_form;
END_ENTITY;
(*
```

Attribute definitions:

defining_tolerance: all geometric tolerances which define a **tolerance_zone** for a **shape_aspect**.

form: the representation of the applied shape that limits the specified tolerance for the **tolerance_zone**.

6.4.14 tolerance_zone_form

A **tolerance_zone_form** is a description of the shape of the **tolerance_zone**.

EXAMPLE 30 - "cylindrical", "spherical", "parallelepiped", and "conical" are examples of descriptions of tolerance zone shapes.

EXPRESS specification:

```
*)
ENTITY tolerance_zone_form;
  name : label;
END_ENTITY;
(*
```

Attribute definitions:

name: the description of a tolerance zone shape.

6.4.15 tolerance_zone_definition

A **tolerance_zone_definition** specifies the defining boundaries of a tolerance zone.

NOTE - A pair of boundaries specified as a single **tolerance_zone_definition** may form either a partial or complete tolerance zone.

EXPRESS specification:

```
*)
ENTITY tolerance_zone_definition
  SUPERTYPE OF (ONEOF (projected_zone_definition,
                       runout_zone_definition));
  zone : tolerance_zone;
  boundaries: SET [1:?] OF shape_aspect;
END_ENTITY;
(*
```

Attribute definitions:

zone: the **tolerance_zone** being defined.

boundaries: a set of **shape_aspects** that define boundaries of the **tolerance_zone**.

EXAMPLE 31 - A geometric location tolerance applied to a hole is defined to be a cylindrical zone in which the axis of the hole may vary. The cylindrical zone is symmetric about its axis. The two defining boundaries of this tolerance zone are the cylindrical surface and its axis. For a **tolerance_zone** defined by two parallel planes (or lines), each plane (or line) defines a boundary of the **tolerance_zone_definition**.

6.5 shape_tolerance_schema entity definitions: range

6.5.1 limits_and_fits

A **limits_and_fits** is a pre-defined fit system for specifying the tolerances associated with the assembly of mating product features.

NOTE - See ISO 286-1 and 286-2 for possible uses of limits and fits.

EXPRESS specification:

```
*)
ENTITY limits_and_fits;
  form_variance    : label;
  zone_variance    : label;
  grade            : label;
  source           : text;
END_ENTITY;
(*
```

Attribute definitions:

form_variance: the algebraic difference between a size and a corresponding basic size.

zone_variance: the designation to which the tolerance class applies.

grade: the designation of the standard tolerance.

source: the description of the place for additional information and requirements on this tolerance.

6.5.2 plus_minus_tolerance

The **plus_minus_tolerance** is the specification of the limits within which the value of a dimension may vary. A **plus_minus_tolerance** may have a range specified by either a **tolerance_value** or a **limits_and_fits**.

EXPRESS specification:

```
*)
ENTITY  plus_minus_tolerance;
  range                : tolerance_method_definition;
```

```
  toleranced_dimension : dimensional_characteristic;
UNIQUE
  UR1: toleranced_dimension;
END_ENTITY;
(*
```

Attribute Definitions:

range: the limits that, when applied to the dimension value, define the allowable variation for the dimension.

toleranced_dimension: the dimension to which the **plus-minus tolerance** applies.

Formal propositions:

UR1: There shall be only one **plus_minus_tolerance** for a dimension.

6.5.3 tolerance_value

The **tolerance_value** is the representation of plus-minus tolerances for a dimension. A **tolerance_value** specifies the numeric values added to the nominal dimension of a **shape_aspect**.

The **lower_bound** and **upper_bound** are applied to the value of the dimension to determine the acceptable range of measured values. A **tolerance_value** may be either assigned by the user or specified according to ISO 286-1 and ISO 286-2.

EXAMPLE 32 - Since the only constraint on the attribute values is that the upper bound be greater than the lower bound, the specification of a **plus_minus_tolerance** (e.g., 10.0 +0.10 +0.05) is permitted. In this case, the nominal dimension, 10.0, is not bounded by its associated tolerance zone.

EXPRESS specification:

```
*)
ENTITY tolerance_value;
  lower_bound : measure_with_unit;
  upper_bound : measure_with_unit;
WHERE
  WR1: upper_bound.value_component > lower_bound.value_component;
  WR2: upper_bound.unit_component = lower_bound.unit_component;
END_ENTITY;
(*
```

Attribute Definitions:

lower_bound: the value of the tolerance that is added to the dimension value to establish the minimum deviation from the boundary toleranced from the nominal dimension.

upper_bound: the value of the tolerance that is added to the dimension value to establish the maximum deviation from the boundary toleranced from the nominal dimension.

Formal propositions:

WR1: The value of the **upper_bound** shall be greater than the value of the **lower_bound**.

WR2: The **upper_bound** and the **lower_bound** shall have the same unit.

```
*)
END_SCHEMA;    -- End of shape_tolerance_schema
(*
```

Annex A
(normative)

Short names of entities

Table A.1 provides the short names of entities specified in this part of ISO 10303. Requirements on the use of the short names are found in the implementation methods included in ISO 10303.

Table A.1 - Short names of entities

Entity Names	Short Names
ANGULAR_LOCATION	ANGLCT
ANGULAR_SIZE	ANGSZ
APEX	APEX
CENTRE_OF_SYMMETRY	CNOFSY
COMPOSITE_SHAPE_ASPECT	CMSHAS
DATUM	DATUM
DATUM_FEATURE	DTMFTR
DATUM_REFERENCE	DTMRFR
DATUM_TARGET	DTMTRG
DERIVED_SHAPE_ASPECT	DRSHAS
DIMENSIONAL_CHARACTERISTIC_REPRESENTATION	DMCHRP
DIMENSIONAL_LOCATION	DMNLCT
DIMENSIONAL_LOCATION_WITH_PATH	DLWP
DIMENSIONAL_SIZE	DMNSZ
DIMENSIONAL_SIZE_WITH_PATH	DSWP
DIMENSION_RELATED_TOLERANCE_ZONE_ELEMENT	DRTZE
EXTENSION	EXTNSN
GEOMETRIC_ALIGNMENT	GMTALG
GEOMETRIC_INTERSECTION	GMTINT
GEOMETRIC_TOLERANCE	GMTTLR
GEOMETRIC_TOLERANCE_RELATIONSHIP	GMTLRL
GEOMETRIC_TOLERANCE_WITH_DATUM_REFERENCE	GTWDR
GEOMETRIC_TOLERANCE_WITH_DEFINED_UNIT	GTWDU
LIMITS_AND_FITS	LMANFT

Table A.1 - Short names of entities (concluded)

Entity Names	Short Names
MODIFIED_GEOMETRIC_TOLERANCE	MDGMTL
PARALLEL_OFFSET	PRLOFF
PERPENDICULAR_TO	PRPT
PLUS_MINUS_TOLERANCE	PLMNTL
PROJECTED_ZONE_DEFINITION	PRZNDF
REFERENCED_MODIFIED_DATUM	RFMDDT
RUNOUT_ZONE_DEFINITION	RNZNDF
RUNOUT_ZONE_ORIENTATION	RNZNOR
RUNOUT_ZONE_ORIENTATION_REFERENCE_DIRECTION	RZORD
SHAPE_ASPECT_DERIVING_RELATIONSHIP	SADR
SHAPE_DIMENSION_REPRESENTATION	SHDMRP
STATISTICAL_DISTRIBUTION_FOR_TOLERANCE	SDFT
SYMMETRIC_SHAPE_ASPECT	SYSHAS
TANGENT	TNGNT
TOLERANCE_VALUE	TLRVL
TOLERANCE_WITH_STATISTICAL_DISTRIBUTION	TWSD
TOLERANCE_ZONE	TLRZN
TOLERANCE_ZONE_DEFINITION	TLZNDF
TOLERANCE_ZONE_FORM	TLZNFR

Annex B
(normative)

Information object registration

B.1 Document identification

To provide for unambiguous identification of an information object in an open system, the object identifier

{ iso standard 10303 part(47) version(0) }

is assigned to this part of ISO 10303. The meaning of this value is defined in ISO 8824-1, and is described in ISO 10303-1.

B.2 Schema identification

B.2.1 shape_aspect_definition_schema identification

To provide for unambiguous identification of the shape_aspect_definition_schema in an open information system, the object identifier

{ iso standard 10303 part(47) version(0) object(1) shape_aspect_definition-schema(1) }

is assigned to the shape_aspect_definition_schema schema (see clause 4). The meaning of this value is defined in ISO 8824-1, and is described in ISO 10303-1.

B.2.2 shape_dimension_schema identification

To provide for unambiguous identification of the shape_dimension_schema in an open information system, the object identifier

{ iso standard 10303 part(47) version(0) object(1) shape_dimension-schema(2) }

is assigned to the shape_dimension_schema schema (see clause 5). The meaning of this value is defined in ISO 8824-1, and is described in ISO 10303-1.

B.2.3 shape_tolerance_schema identification

To provide for unambiguous identification of the shape_tolerance_schema in an open information system, the object identifier

{ iso standard 10303 part(47) version(0) object(1) shape_tolerance-schema(3) } is assigned to the shape_tolerance_schema schema (see clause 6). The meaning of this value is defined in ISO 8824-1, and is described in ISO 10303-1.

Annex C
(informative)

EXPRESS listing

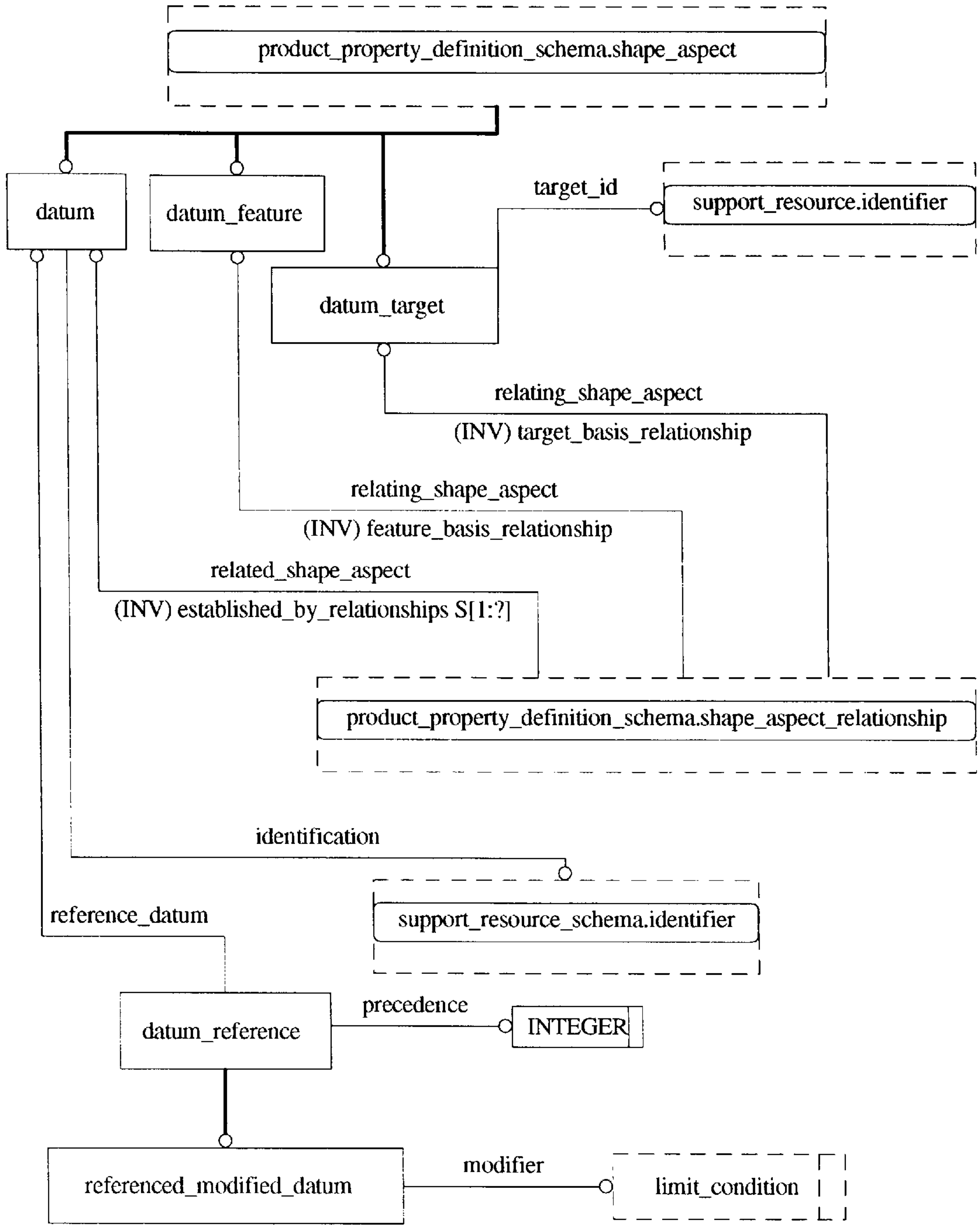
This annex provides a listing of the short names and a listing of the EXPRESS specified in this part of ISO 10303. No text or annotation is included. This annex is provided only in computer-interpretable form.

— The information provided on this diskette is informative; the normative text is that contained in the body of this part of ISO 10303.

Annex D
(informative)

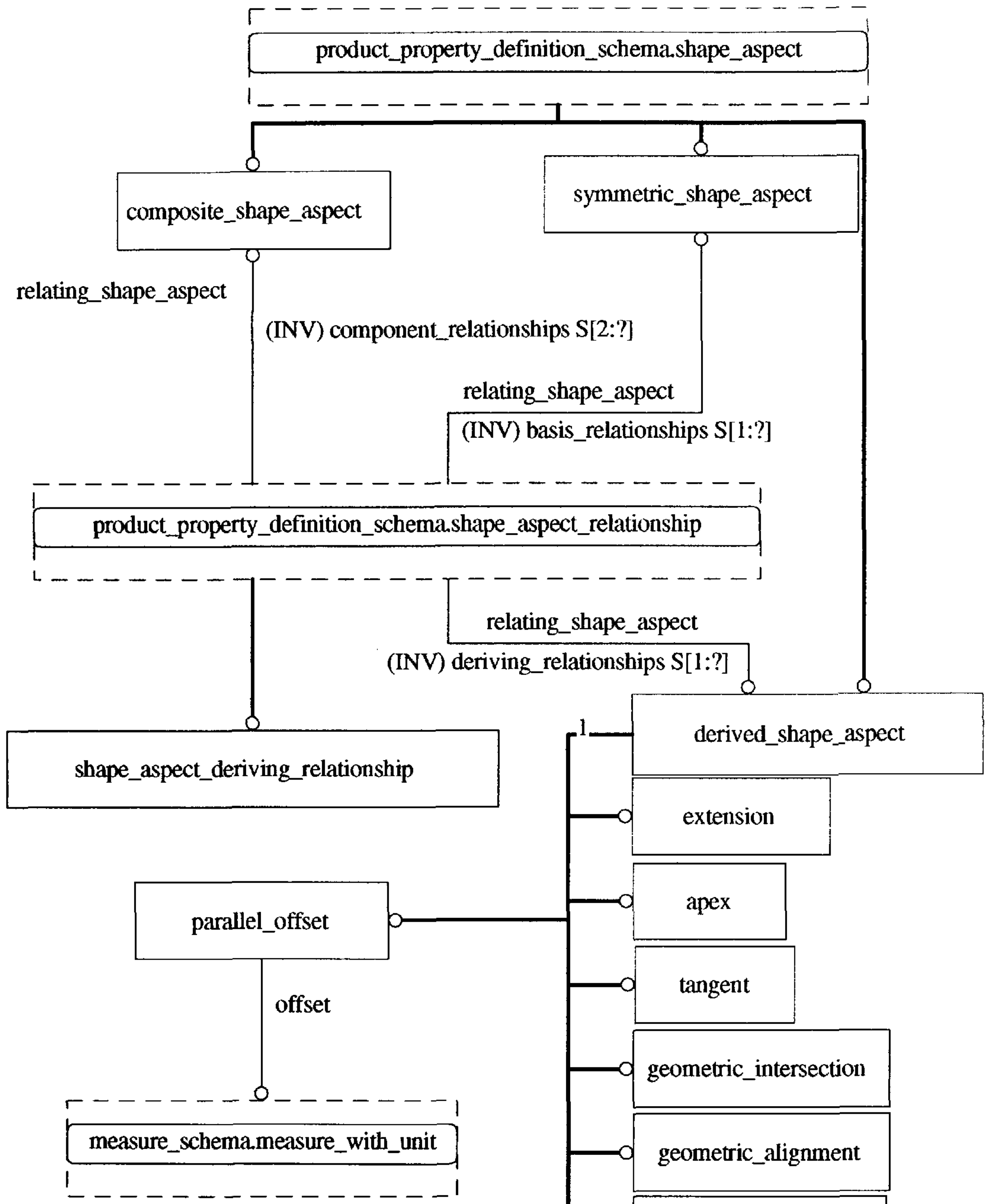
EXPRESS-G figures

Figures D.1 through D.7 correspond to the EXPRESS listing given in annex C. The figures use the EXPRESS-G graphical notation for the EXPRESS language. EXPRESS-G is defined in annex A of ISO 10303-11.



NOTE - shape_aspect_relationship has only one attribute named relating_shape_aspect. However to display the INVERSE relationships for datum_feature and datum_target, it is displayed twice.

Figure D.1 - Shape_aspect_definition schema (see also figure D.2)



NOTE - shape_aspect_relationship has an attribute named relating_shape_aspect. However to display the INVERSE relationships for composite_shape_aspect derived_shape_aspect, and symmetric_shape_aspect, it is displayed three times.

Figure D.2 - Shape_aspect_definition schema (see also figure D.1)

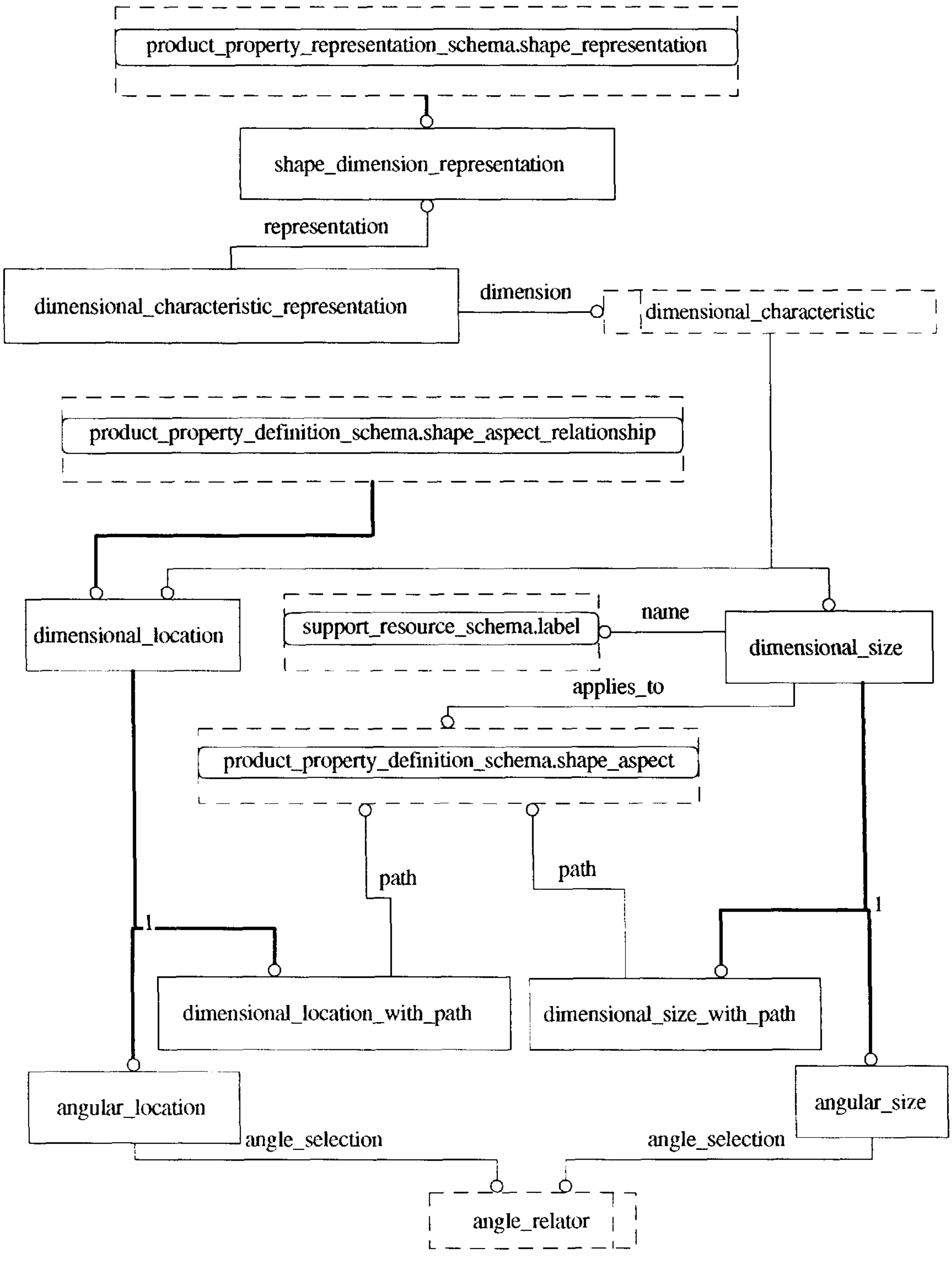


Figure D.3 - Shape_dimension schema

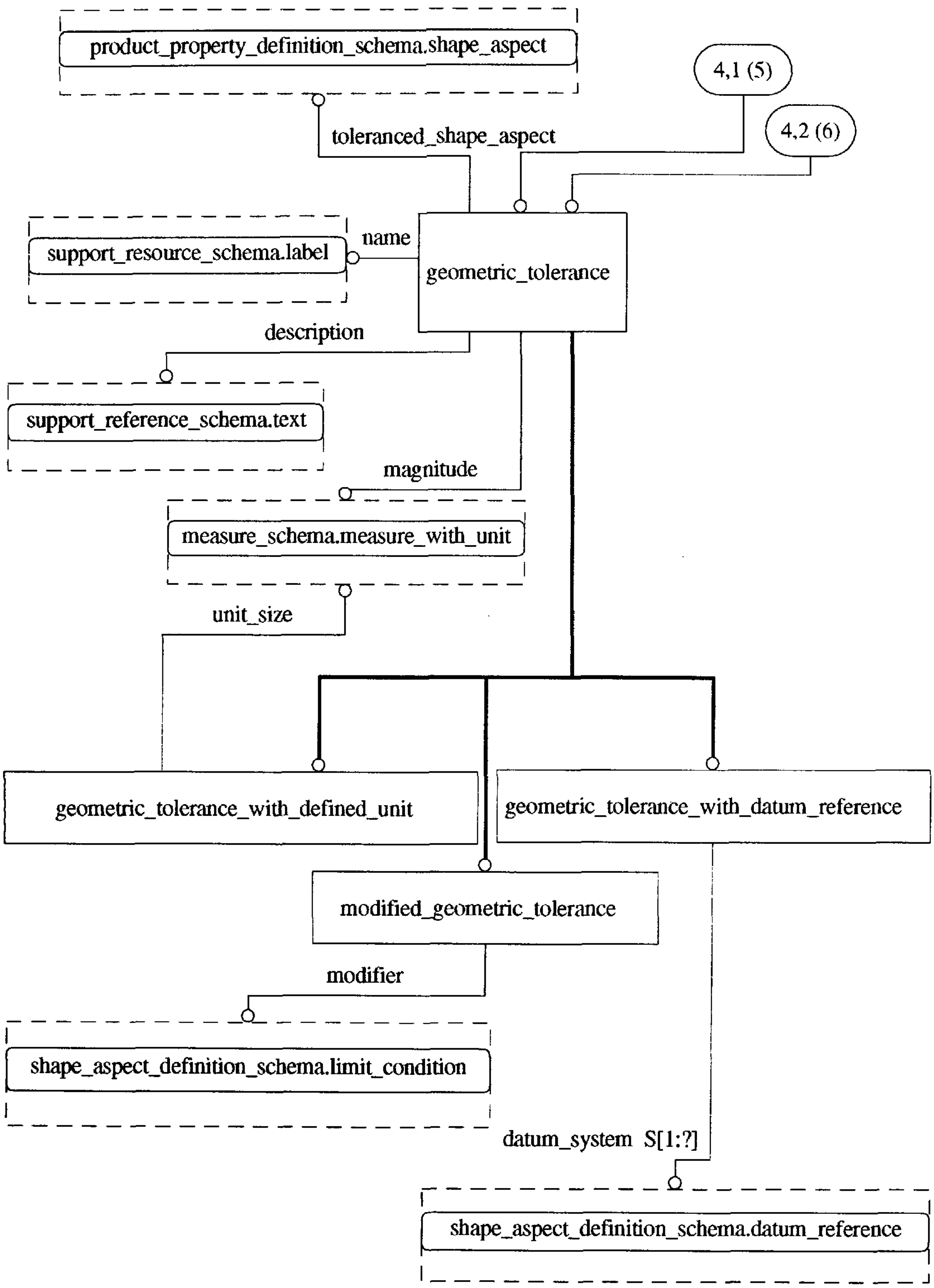


Figure D.4 - Shape_tolerance schema (see also figure D.5 and D.6)

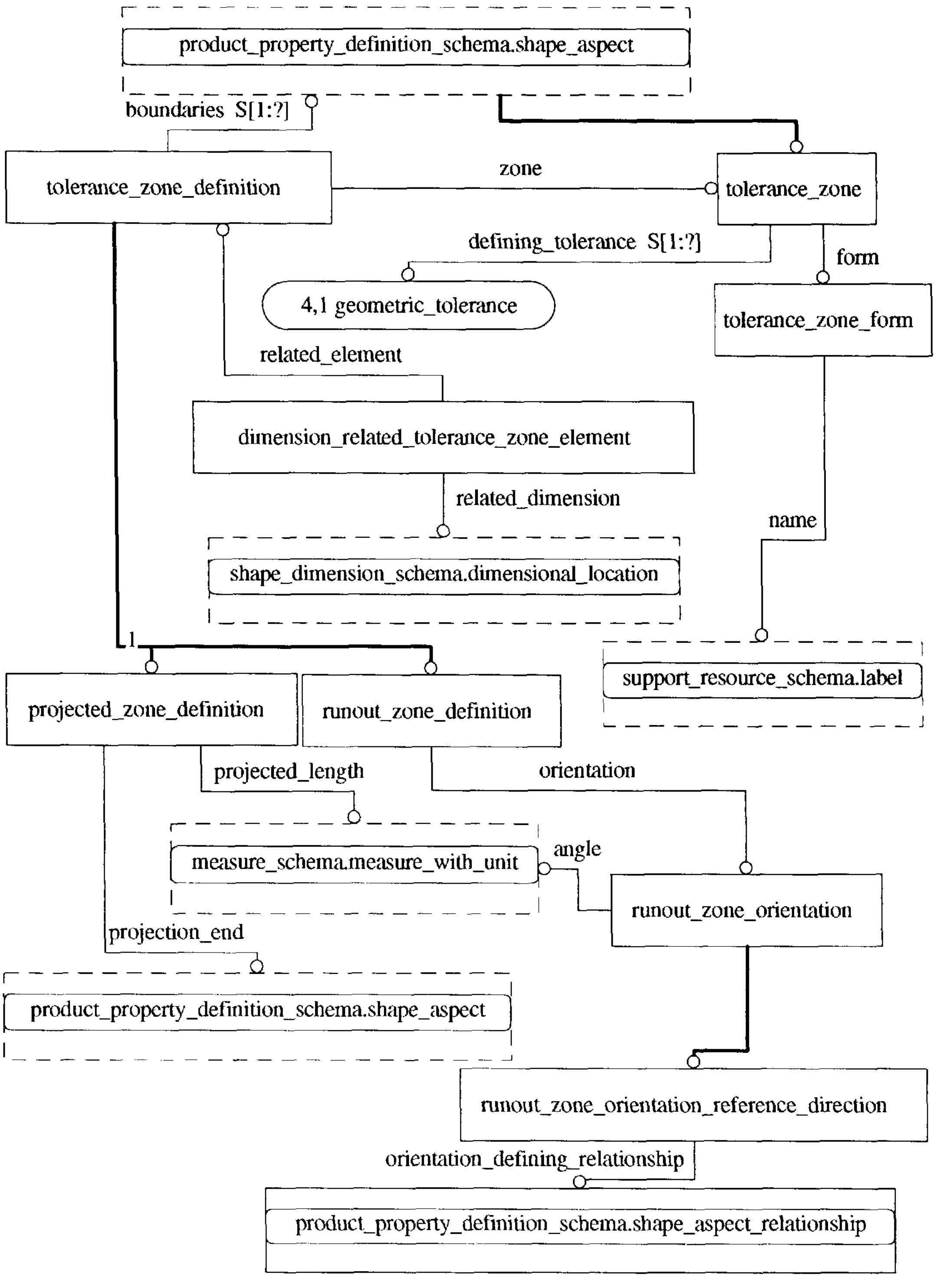


Figure D.5 - Shape_tolerance schema (see also figure D.4 and D.6)

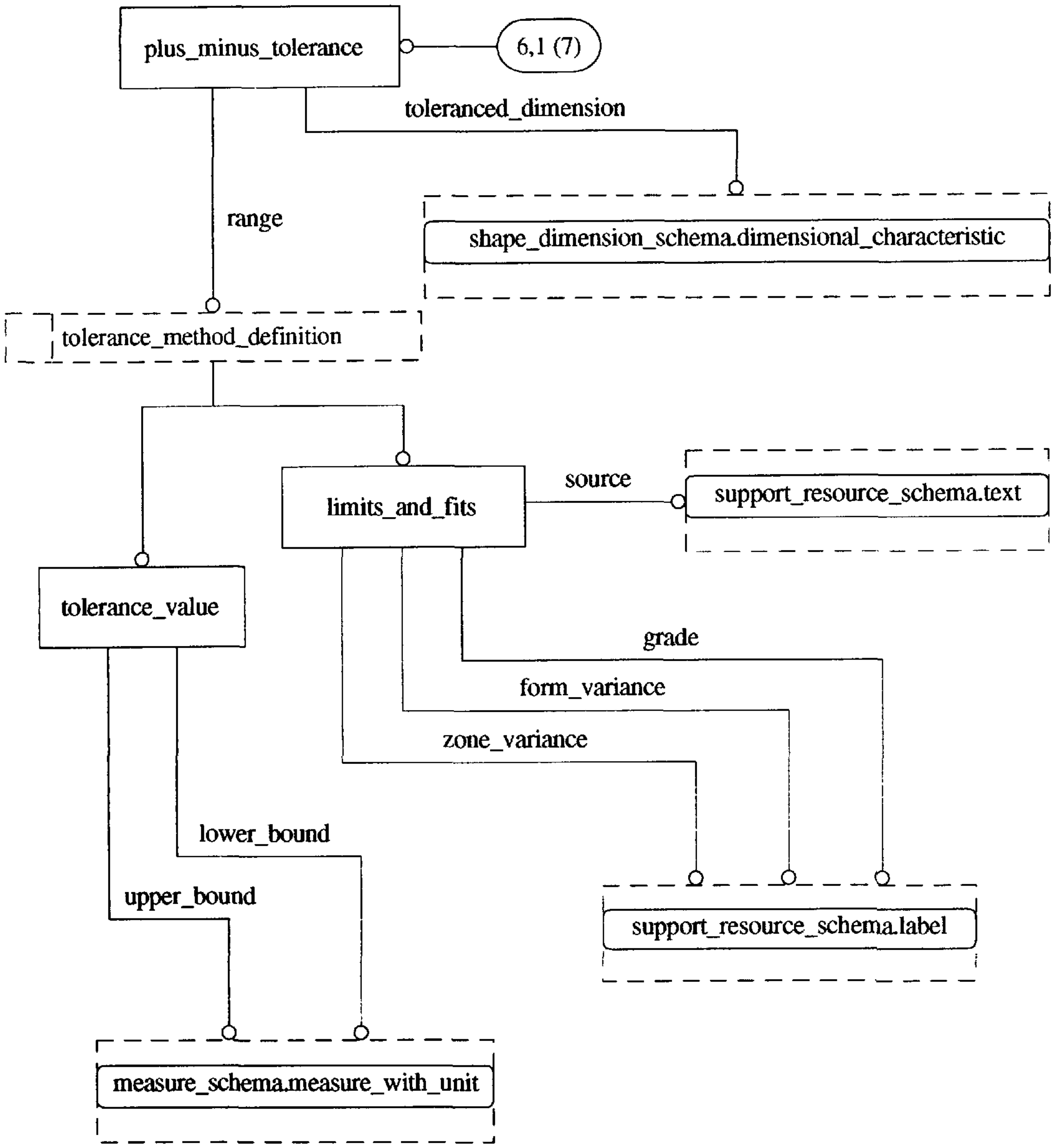


Figure D.6 - Shape_tolerance schema (see also figure D.4)

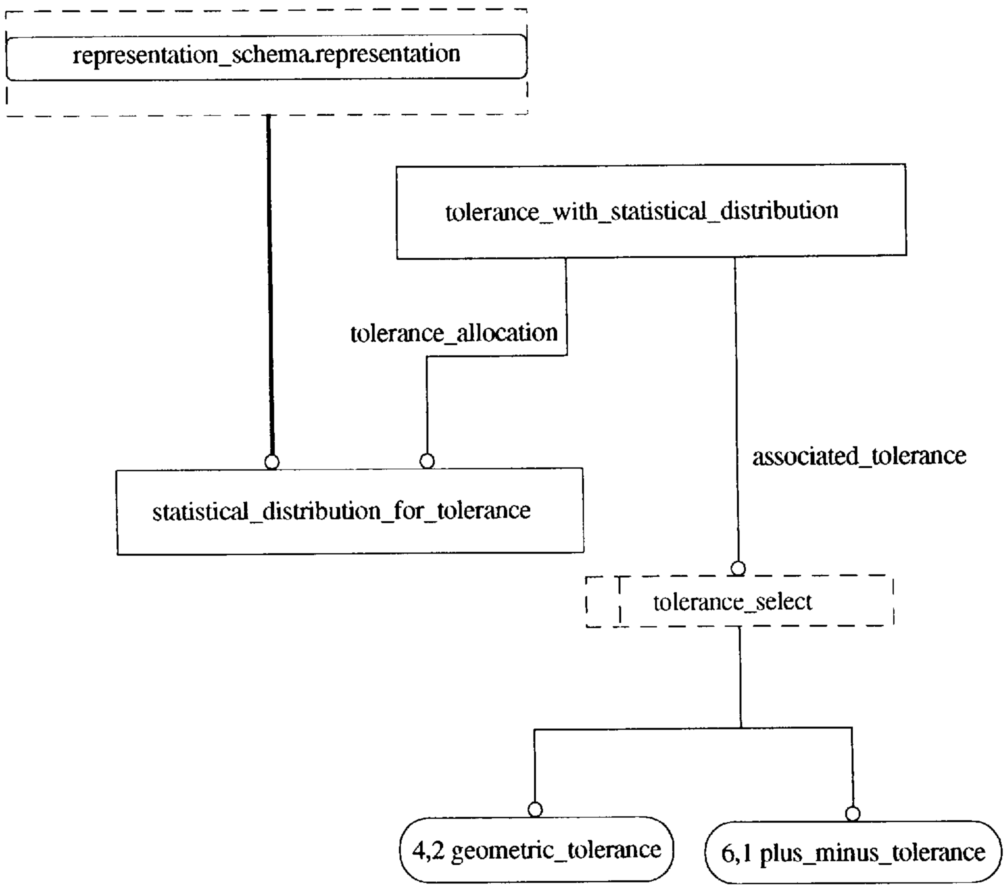


Figure D.7 - Shape_tolerance schema (see also figure D.5)

Annex E
(informative)

Bibliography

[1] *Dimensioning and Tolerancing*; The American Society of Mechanical Engineers, New York, N.Y.; ANSI Y14.5M, 1982.

[2] *Technical drawings - Dimensioning and tolerancing of profiles*; International Organization for Standardization, ISO 1660, 1987.

[3] *Technical drawings - Geometrical tolerancing - Positional tolerancing*; International Organization for Standardization, ISO 5458, 1987.

[4] *Technical drawings - Geometrical tolerancing - Tolerancing of form, orientation, location and run-out - Verification principles and methods - Guidelines*; International Organization for Standardization, ISO/TR 5460, 1985.

[5] *Technical drawings - Fundamental tolerancing principle*, ISO 8015, 1985.

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