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

Part 45:
Integrated generic resource: Materials

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

Partie 45: Ressource générique intégrée: Matériaux



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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 the 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 10303-45 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC4, *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 interface;
- Part 31, Conformance testing methodology and framework: General concepts;
- Part 32, Conformance testing methodology and framework: Requirements on testing laboratories and clients;
- Part 33, Conformance testing methodology and framework: Structure and use of abstract test suites;
- 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, interconnect, 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;
- 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 220, Application protocol: Process planning, manufacture, and assembly of layered electronic products;
- 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 228, Application protocol: Building services: Heating, ventilation, and air conditioning;
- 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;
- 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 320, Abstract test suite: Process planning, manufacture, and assembly of layered electronic products;
- 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 328, Abstract test suite: Building services: Heating, ventilation, and air conditioning;
- 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 this International Standard reflects its structure:

- Parts 11 to 13 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.

Should further parts of ISO 10303 be published, they will follow the same numbering pattern.

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

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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 databases 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 International Standard are:

- material property definition;
- material property representation;
- qualified measure.

Products are made from materials, the properties of which are important to many aspects of the life cycle of a product such as:

- product design;
- product manufacture;
- product disposal;
- material selection;
- material testing;
- product performance analysis;
- process planning;
- process control;
- product maintenance;
- failure analysis;
- component replacement.

This part of ISO 10303 is applicable to integrated resources and application protocols that need to reference a product and its material properties.

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Industrial automation systems and integration — Product data representation and exchange — Part 45 : Integrated generic resource: Materials

1 Scope

This part of ISO 10303 specifies the resource constructs for the material properties of a product and for the characterization of a numerical data value as to its uncertainty and reliability.

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

- association of a material property with a product;
- specification of the composition of a product in terms of the amount and type of its constituents;
- specification of the set of qualitative and quantitative conditions under which a material property is valid;
- characterization of a numerical data value as to its uncertainty and reliability;
- specification of the representation of a material property, including properties that are measured or assigned;
- the material properties of the surface of a product, including coatings.

NOTE – This part of ISO 10303 may be used to describe the material properties of a first stage product, such as cast ingot; an intermediate product, such as a tube or sheet; or a final stage product requiring no further processing, such as a part pressed from a sheet.

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

- the combination and transformation of material property values;

EXAMPLE 1 – A design value is determined by statistical analysis of a large number of test results whose values have been combined together. This part of ISO 10303 provides for the representation of the test results and for the representation of their combination but does not address the process of combination.

- the use of material properties in the analysis of product behaviour;

EXAMPLE 2 – Individual property values may be combined into matrices of coefficients for use in analysis models.

- the detailed geometry of the surface modification or surface finish of a product.

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 indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO, 1993, *Guide to the Expression of Uncertainty in Measurement*. (ISBN 92-67-10188-9).

3 Definitions

3.1 Terms defined in ISO 10303-1

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

- application protocol;
- data;
- information;
- integrated resource;
- product;
- resource construct.

3.2 Terms defined in Guide to the Expression of Uncertainty in Measurement

This part of ISO 10303 makes use of the following terms defined in Guide to Expression of Uncertainty in Measurement:

- uncertainty;
- standard uncertainty;
- combined standard uncertainty;
- expanded uncertainty;
- coverage factor.

3.3 Other definitions

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

3.3.1 material: the substance or substances of which a product is composed or made.

3.3.2 material property: a product characteristic which depends upon the material or materials comprising the product.

EXAMPLE 3 – Electrical resistance is a material property whose value is influenced by the shape and dimensions of the product and the electrical resistivity of the material.

3.3.3 material designation: an identifier of a material which is assigned by agreement.

EXAMPLE 4 – “3105” is the material designation for a class of aluminium alloys containing specific ranges of amounts of copper, magnesium, and manganese.

3.3.4 qualifier: an item of additional information associated with a value.

3.3.5 reliability: The characteristic associated with either a quantitative or qualitative value that describes the confidence or assurance with which the value can be depended upon.

4 material_property_definition_schema

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

EXPRESS specification:

```

*)
SCHEMA material_property_definition_schema;

REFERENCE FROM product_definition_schema
    (product_definition_relationship);
REFERENCE FROM product_property_definition_schema
    (characterized_definition,
    property_definition);
REFERENCE FROM support_resource_schema
    (label,
    text,
    bag_to_set);
REFERENCE FROM measure_schema
    (measure_with_unit);
REFERENCE FROM material_property_representation_schema
    (material_property_representation);
(*)

```

NOTES

- 1 – See annex D for a graphical representation of this schema using the EXPRESS-G notation.
- 2 – The schemas referenced above can be found in the following parts of ISO 10303:

product_definition_schema	ISO 10303-41
product_property_definition_schema	ISO 10303-41
support_resource_schema	ISO 10303-41
measure_schema	ISO 10303-41
material_property_representation_schema	clause 5 of this part of ISO 10303

4.1 Introduction

The subjects of the **material_property_definition_schema** are associations of a product with a material property, descriptions of material composition, and material identification.

4.2 Fundamental concepts and assumptions

The following are the fundamental concepts and assumptions related to material properties:

- a material property characterizes some aspects of the behaviour of a product;
- the composition of a product is described by the specification of the type, amounts, and arrangement of its constituents.

The material properties may be determined from measurements on the product as a whole, on a sample taken from the product in some way such as cutting, or on an entirely separate test piece prepared by processing in the same way as the product. The application of the results derived from the test piece to the whole product is dependent on the relationship of the sample to the product because, as a result of the manufacturing process, the product may not be homogeneous.

Values for a material property may also be assigned to a product by reference to a specification, by calculation, or by assumption.

The values of most material properties are influenced by the effect that the manufacturing process has had on the product. The manufacturing process may affect the type and amounts of the units that make up the product and their form and arrangement. These units may be atoms, molecules, or other aggregations of these into discrete forms such as crystals, fibres, or volumes of semicrystalline or glassy solids. The arrangement of the units is the material structure of the product.

EXAMPLES

5 – A manufacturer may make a product to a specification and, instead of reporting actual measurement results for a specific batch of the product, may report the nominal value indicated in the specification.

6 – A chemist might perform calculations using assumed values of bond strengths to predict the strength of a polymer that has never been synthesized.

7 – An analyst performing a finite element analysis on a part might assign property values to predict potential product performance as a function of the property.

The material structure of a solid product may be either homogenous or heterogeneous, or a mixture of solids, as is found in a composite structure. A complete specification of the structure includes the relationship of any preferentially aligned elements of the structure to each other and to the product.

4.3 material_property_definition_schema type definition: characterized_material_property

A **characterized_material_property** provides the mechanism by which a material designation can be associated with either a material property value or the material composition of a product.

EXPRESS specification:

```
*)
TYPE characterized_material_property = SELECT
  (material_property_representation,
   product_material_composition_relationship);
END_TYPE;
(*
```

4.4 material_property_definition_schema entity definitions

4.4.1 material_property

A **material_property** is a **property_definition** which shall have conditions that determine its validity when it specifies a property of a **product_definition**, **product_definition**, **shape_aspect**, or **shape_aspect_relationship**.

EXPRESS specification:

```

*)
ENTITY material_property
SUBTYPE OF (property_definition);
UNIQUE
  UR1 : SELF\property_definition.name, SELF\property_definition.definition;
WHERE
  WR1 : ('PRODUCT_PROPERTY_DEFINITION_SCHEMA.CHARACTERIZED_OBJECT' IN
        TYPEOF(SELF\property_definition.definition)) OR
        (SIZEOF(bag_to_set(USEDIN(SELF ,
        'PRODUCT_PROPERTY_REPRESENTATION_SCHEMA' +
        'PROPERTY_DEFINITION_REPRESENTATION_DEFINITION')) -
        QUERY(temp <* bag_to_set(USEDIN(SELF ,
        'PRODUCT_PROPERTY_REPRESENTATION_SCHEMA.' +
        'PROPERTY_DEFINITION_REPRESENTATION_DEFINITION')) |
        ('MATERIAL_PROPERTY_REPRESENTATION_SCHEMA.' +
        'MATERIAL_PROPERTY_REPRESENTATION' IN
        TYPEOF(temp)))) = 0);
END_ENTITY;
(*)

```

Formal propositions:

UR1: the name of each **material_property** that is related to a single **product_definition** or **shape_aspect** (through their **definition** attribute) shall be unique within the collection of **material_property** entities which are related to that **product_definition** or **shape_aspect**.

WR1: if a **material_property** is not to be assigned to a **characterized_object** through its **definition** attribute, all the **property_definition_representations** that reference it shall also be **material_property_representations** and will therefore have associated **data_environments**.

4.4.2 property_definition_relationship

A **property_definition_relationship** is an association between two **property_definitions**. The meaning of the relationship for a particular context is defined in specializations of this resource construct.

NOTES

1 – Relationships captured using this entity may be parent child relationships. Specializations of this entity state this fact if it is true for the particular specialization.

2 – This entity, in conjunction with the **property_definition** entity, is based on the relationship template that is described in annex D of ISO 10303-41.

EXPRESS specification:

```
*)
ENTITY property_definition_relationship;
    name                : label;
    description          : text;
    relating_property_definition : property_definition;
    related_property_definition  : property_definition;
END_ENTITY;
(*)
```

Attribute definitions:

name: the word or group of words by which the **property_definition_relationship** is referred to.

description: text that relates the nature of the **property_definition_relationship**.

relating_property_definition: one of the **property_definitions** which is a part of the relationship.

related_property_definition: the other **property_definition_relationship** which is part of the relationship. If one element of the relationship is dependent upon the other, this attribute shall be the dependent one.

NOTE 3 – The role of the **related_property_definition** and **relating_property_definition** attributes is defined in the part of ISO 10303 that uses or specializes this entity.

4.4.3 material_designation

A **material_designation** is the association of a material designation with a product or parts of a product.

EXPRESS specification:

```
*)
ENTITY material_designation;
    name                : label;
    definitions          : SET [1:?] OF characterized_definition;
END_ENTITY;
(*)
```

Attribute definitions:

name: the word or group of words by which the **material_designation** is referred to.

definitions: the definition of the product or parts of the product for which the **material_designation** is specified.

NOTE – A **characterized_definition** is a SELECT of many possibilities. The intention is to select either a product or parts of a product.

4.4.4 material_designation_characterization

A **material_designation_characterization** defines the characterization of a material designation through its association with either a **material_property_representation** or a **product_material_composition_relationship**.

EXPRESS specification:

```
*)
ENTITY material_designation_characterization;
  name      : label;
  description : text;
  designation : material_designation;
  property   : characterized_material_property;
END_ENTITY;
(*
```

Attribute definitions:

name: the word or group of words by which the **material_designation_characterization** is referred to.

description: a narrative description of the **material_designation_characterization**.

designation: the definition of the **material_designation** for which the **material_designation_characterization** is specified.

property: the definition of the property for which the **material_designation_characterization** is specified.

4.4.5 product_material_composition_relationship

The **product_material_composition_relationship** associates a material constituent with a **product**. The **product** participates in a **product_definition_relationship** as a **relating-product_definition**. The constituent participates in a **product_definition_relationship** as a **related_product_definition**.

NOTE 1 – The spatial location and orientation of the material constituents in the product are specified by their **product_definition_shape**. By this means, the material structure of the product is described.

EXPRESS specification:

```

*)
ENTITY product_material_composition_relationship
SUBTYPE OF (product_definition_relationship);
    class                : label;
    constituent_amount    : SET [1:?] OF measure_with_unit;
    composition_basis     : label;
    determination_method : text;
END_ENTITY;
(*)

```

Attribute definitions:

class: the name or identifier for the kind of relationship between a constituent and a product.

EXAMPLE 8 – Possible values for class include “mixture”, “chemically bonded”, and “alloyed”.

constituent_amount: the quantity of the material constituent in a product and the units in which the quantity is expressed.

NOTE 2 – Examples of elements of the set could be: the minimum value, the maximum value, the typical value. The description of the values as maximum, minimum, or typical may be achieved by using the constructs in the **qualified_measure_schema**.

composition_basis: the basis on which a product is decomposed into its constituents.

EXAMPLE 9 – Expected values for **composition_basis** include “volume”, “weight”, “moles” and “atoms”.

determination_method: a description of the procedure by which **constituent_amount** is determined.

4.5 material_property_definition_schema function definition: acyclic_property_definition_relationship

The **acyclic_property_definition_relationship** function determines whether or not the given **property_definitions** have been self-defined by the associations made in the specified **property_definition_relationship**. This function may be used to evaluate either a **property_definition_relationship** or any of its subtypes.

NOTE 1 – A specified type of the **property_definition_relationship** entity is either a **property_definition_relationship** or one of its subtypes.

The function returns a value of TRUE if none of the elements of the **relatives** argument occur in the **relation** argument which is given in the **specific_relation** argument. Otherwise it returns a value of FALSE.

NOTE 2 – This function is not used in this schema. It is defined here because other parts of ISO 10303 that use the **product_definition_relationship** entity define rules that use this function.

EXPRESS specification:

```

*)
FUNCTION acyclic_property_definition_relationship
  (relation          : property_definition_relationship;
   relatives         : SET OF property_definition;
   specific_relation : STRING) : LOGICAL;

  LOCAL
    x          : SET OF property_definition_relationship;
    i          : INTEGER;
    local_relatives : SET OF property_definition;
  END_LOCAL;

  REPEAT i := 1 TO HIINDEX(relatives);
    IF relation.relying_property_definition := relatives[i] THEN
      RETURN(FALSE);
    END_IF;
  END_REPEAT;
  x := bag_to_set(USEDIN (relation.relying_property_definition, specific_relation));
  local_relatives := relatives + relation.relying_property_definition;
  IF SIZEOF(x) > 0 THEN
    REPEAT i := 1 TO HIINDEX(x);
      IF NOT acyclic_property_definition_relationship
        (x[i], local_relatives, specific_relation) THEN
        RETURN(FALSE);
      END_IF;
    END_REPEAT;
  END_IF;
  RETURN(TRUE);
END_FUNCTION;
(*)

```

Argument definitions:

relation: (input) the candidate **property_definition_relationship** to be checked.

relatives: (input) the set of **property_definitions** which the function is searching for in the **relying_property_definition** parameter of the **relation** argument.

specific_relation: (input) the fully qualified name of a subtype of the **property_definition_-relationship** entity.

```

*)
END_SCHEMA;    -- material_property_definition_schema
(*)

```

5 material_property_representation_schema

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

EXPRESS specification:

```
*)
SCHEMA material_property_representation_schema;

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

NOTES

1 – See annex D for a graphical representation of this schema using the EXPRESS-G notation.

2 – The schemas referenced above can be found in the following parts of ISO 10303:

product_property_representation_schema	ISO 10303-41
support_resource_schema	ISO 10303-41

5.1 Introduction

The subjects of the **material_property_representation_schema** are the representations of material properties and of the conditions under which those property representations are valid.

5.2 Fundamental concepts and assumptions

The following are the fundamental concepts and assumptions related to the representation of material properties:

- multiple representations of a material property are possible including the use of numeric values, parametric or fundamental equations, graphical representations, and non-numeric values;

NOTE – The distinction between a concept and the representation of a concept is described in ISO 10303-43;

- the value of a material property may be either assigned or measured;
- if the value is measured, the resulting value will depend upon the method of measurement and on the conditions used in applying the method;

- if the value is assigned, the conditions under which that assignment is valid may be specified;
- in the case of either assignment or measurement, the conditions under which the value is valid are expressed as a set of quantitative and qualitative data which form the data environment.

EXAMPLE 10 – The ambient condition may be expressed as “room air” (a qualitative condition) or air at “standard temperature and pressure” (quantitative conditions specifying 25°C and 1 atmosphere).

The conditions of the measurement method may be maintained as constant throughout the measurement. Alternatively some conditions may be varied independently of other conditions to provide a set of related properties.

Not all values of material properties need be expressed quantitatively, i.e., by numerical values. Values may also be expressed qualitatively, i.e., by comparison.

EXAMPLE 11 – Colour, though expressible quantitatively, is most often described qualitatively by words such as “red”, “Aegean blue”, “metallic grey”, etc.

5.3 material_property_representation_schema entity definitions

5.3.1 material_property_representation

A **material_property_representation** specializes a **property_definition_representation** to associate it with a **data_environment**.

NOTE – The association with a **product** is through reference to a **material_property** entity which has a **characterized_definition**.

EXPRESS specification:

```
*)
ENTITY material_property_representation
  SUBTYPE OF (property_definition_representation);
  dependent_environment : data_environment;
END_ENTITY;
(*
```

Attribute definitions:

dependent_environment: the conditions under which a **property_representation** is valid.

5.3.2 data_environment

The **data_environment** entity is a set of **property_definition_representations** which allows the conditions which relate to one or more properties to be grouped together.

EXPRESS specification:

```

*)
ENTITY data_environment;
    name      : label;
    description : text;
    elements  : SET [1:?] OF property_definition_representation;
END_ENTITY;
(*)

```

Attribute definitions:

name: the word or group of words by which the **data_environment** is referred to.

description: a narrative description of the **data_environment**.

elements: the set of conditions under which a **data_environment** is valid.

5.3.3 data_environment_relationship

A **data_environment_relationship** is an association between two **data_environments**.

NOTE – An association may exist between **data_environments** that relate to different **material_property** entities or between different representations of the same **material_property**.

EXPRESS specification:

```

*)
ENTITY data_environment_relationship;
    name      : label;
    description : text;
    relating_data_environment : data_environment;
    related_data_environment  : data_environment;
END_ENTITY;
(*)

```

Attribute definitions:

name: the word or group of words by which the **data_environment_relationship** is referred to.

description: a narrative description of the **data_environment_relationship**.

relating_data_environment: the **data_environment** that acts as the parent of the **related_data_environment**.

related_data_environment: the **data_environment** that acts as the child of the **relating_data_environment**.

NOTE 1 – The role of the **relating_data_environment** and the **related_data_environment** attributes are defined in the part of ISO 10303 that uses or specializes this entity.

```
*)  
END_SCHEMA;    -- material_property_representation_schema  
(*
```

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6 qualified_measure_schema

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

EXPRESS specification:

```
*)
SCHEMA qualified_measure_schema;

REFERENCE FROM support_resource_schema
    (label,
     text);
REFERENCE FROM measure_schema
    (measure_with_unit);
REFERENCE FROM representation_schema
    (representation_item);
(*
```

NOTES

1 – See annex D for a graphical representation of this schema using the EXPRESS-G notation.

2 – The schemas referenced above can be found in the following parts of ISO 10303:

support_resource_schema	ISO 10303-41
measure_schema	ISO 10303-41
representation_schema	ISO 10303-43

6.1 Introduction

The **qualified_measure_schema** specializes the resource constructs from the **measure_schema** to allow quantities to be qualified, i.e., further characterized as to their uncertainty and reliability.

6.2 Fundamental concepts and assumptions

A physical quantity may have several aspects other than its value and units. The value may be uncertain because of the variability inherent in the measurement procedure, leading to a lack of reproducibility. The value of a datum may be labelled as being approved for design, for example, or otherwise characterized as to its type or status. This schema supports the addition of these concepts.

The concept of uncertainty on a measured value used in this part of ISO 10303 is taken from clause 2 of Expression of Uncertainty. In general, the result of a measurement, y , is only an approximation or estimate of the value of the specific quantity subject to measurement (the measurand), Y . The uncertainty of the result of a measurement reflects the lack of exact knowledge of the value of the measurand and thus the result is complete only when accompanied

by a quantitative statement of its uncertainty. The uncertainty generally consists of several components which may be grouped into two categories according to the method used to estimate the numerical values of the components:

- those which are evaluated by statistical methods;
- those which are evaluated by other means.

Each component of uncertainty that contributes to the uncertainty of a measurement result is represented by an estimated standard deviation, termed *standard uncertainty*, u_i , and equal to the positive square root of the estimated variance. The procedures for evaluating the standard uncertainty for both categories are described in clause 4 of Expression of Uncertainty.

The standard uncertainty of the result of a measurement, when that result is obtained from the values of a number of other quantities, is termed the *combined standard uncertainty*, u_c . It is the estimated standard deviation associated with the result and is equal to the positive square root of the combined variance, obtained by summing all variance and covariance components, however evaluated. The procedure for combining the variance and covariance components is described in clause 5 of Expression of Uncertainty. This schema provides the means for representing either the standard uncertainty or the combined standard uncertainty.

Although the combined standard uncertainty is used to express the uncertainty of many measurement results, what is often required is a measure of uncertainty that defines an interval about the measurement result within which the value of the measurand can be confidently asserted to lie. The measure of uncertainty intended to meet this requirement is termed the *expanded uncertainty*, U , and is obtained by multiplying $u_c(y)$ by a coverage factor, k . Thus $U = k u_c(y)$ and it can be confidently asserted that: $y - U \leq Y \leq y + U$, which is usually written as $Y = y \pm U$. In general, the value of k is chosen on the basis of the desired level of confidence to be associated with the interval defined by $U = k u_c$. Typically, k is in the range 2 to 3. When the normal distribution applies to the results and u_c has a negligible uncertainty, then $k = 2$ defines an interval having a level of confidence of approximately 95 percent and $k = 3$ defines an interval having a level of confidence greater than 99 percent.

6.3 qualified_measure_schema type definition: value_qualifier

A **value_qualifier** provides the mechanism by which a selection of a qualifier of a value can be made.

EXPRESS specification:

```
*)
TYPE value_qualifier = SELECT
    (precision_qualifier,
     type_qualifier,
     uncertainty_qualifier);
END_TYPE;
(*)
```

6.4 qualified_measure_schema entity definitions

6.4.1 type_qualifier

A **type_qualifier** specifies the type of a datum.

NOTE – Legal values and constraints for the attribute are specified in application protocols. Typical values for the attribute may include “measured”, “calculated”, “nominal”, “maximum”, “minimum”, “theoretical”, “remainder”, “design allowable”, “combined”, “A-basis statistical”, “B-basis statistical” and “arithmetic mean”.

EXPRESS specification:

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

Attribute definitions:

name: the word or group of words by which the type or reliability of the value is referred to.

6.4.2 precision_qualifier

A **precision_qualifier** specifies the number of significant figures in the representation of a value.

EXPRESS specification:

```
*)
ENTITY precision_qualifier;
    precision_value : INTEGER;
END_ENTITY;
(*
```

Attribute definitions:

precision_value: the number of significant figures of the value.

6.4.3 uncertainty_qualifier

An **uncertainty_qualifier** specifies the uncertainty of a value.

EXPRESS specification:

```
*)
ENTITY uncertainty_qualifier
```

```

    SUPERTYPE OF (ONEOF (standard_uncertainty,
                          qualitative_uncertainty));
    measure_name : label;
    description  : text;
END_ENTITY;
(*)

```

Attribute definitions:

measure_name: specifies the kind of measure that the entity defines the uncertainty of.

EXAMPLE 12 – Expected values for **measure_name** include “distance uncertainty”, “angular uncertainty”, “curvature uncertainty”.

description: the description of the uncertainty of the value.

6.4.4 qualitative_uncertainty

A **qualitative_uncertainty** specifies the uncertainty of a value by comparison.

EXPRESS specification:

```

*)
ENTITY qualitative_uncertainty
    SUBTYPE OF (uncertainty_qualifier);
    uncertainty_value : text;
END_ENTITY;
(*)

```

Attribute definitions:

uncertainty_value: the qualitative uncertainty of the value.

EXAMPLE 13 – Expected values for **uncertainty_value** include “low”, “medium”, and “high”.

6.4.5 standard_uncertainty

A **standard_uncertainty** specifies either the standard uncertainty or the combined standard uncertainty of a value.

EXPRESS specification:

```

*)
ENTITY standard_uncertainty
    SUPERTYPE OF (expanded_uncertainty)
    SUBTYPE OF (uncertainty_qualifier);
    uncertainty_value : REAL;
END_ENTITY;
(*)

```

Attribute definitions:

uncertainty_value: the quantitative uncertainty of the value.

6.4.6 expanded_uncertainty

An **expanded_uncertainty** specifies the coverage factor of an uncertainty.

EXPRESS specification:

```
*)
ENTITY expanded_uncertainty
  SUBTYPE OF (standard_uncertainty);
  coverage_factor : REAL;
END_ENTITY;
(*
```

Attribute definitions:

coverage_factor: the multiplier of the uncertainty of the value.

6.4.7 measure_representation_item

A **measure_representation_item** is a **representation_item** where a particular value is represented.

EXPRESS specification:

```
*)
ENTITY measure_representation_item
  SUBTYPE OF (representation_item, measure_with_unit);
END_ENTITY;
(*
```

6.4.8 descriptive_representation_item

A **descriptive_representation_item** is a text element of product data that participates in one or more **representations** or contributes to the definition of another **representation_item**.

A **descriptive_representation_item** contributes to the definition of another **representation_item** when it is either paired with another **representation_item** in a **representation** that has only two **representation_items** or when the **representation** that contains a **descriptive_representation_item** is related to another **representation** through a **representation_relationship**.

EXPRESS specification:

```

*)
ENTITY descriptive_representation_item
  SUBTYPE OF (representation_item);
  description : text;
END_ENTITY;
(*

```

Attribute definitions:

description: the value of the **representation** in textual form.

6.4.9 qualified_representation_item

A **qualified_representation_item** is a **representation_item** for which qualifiers are defined to describe its reliability and/or uncertainty.

EXPRESS specification:

```

*)
ENTITY qualified_representation_item
  SUBTYPE OF (representation_item);
  qualifiers : SET [1:?] OF value_qualifier;
WHERE
  WR1: SIZEOF(QUERY(temp <* qualifiers |
    'QUALIFIED_MEASURE_SCHEMA.PRECISION_QUALIFIER'
    IN TYPEOF(temp))) < 2;
END_ENTITY;
(*

```

Attribute definitions:

qualifiers: the qualifiers of the **representation_item**.

Formal propositions:

WR1: at most one of the elements of the qualifiers attribute can be a **precision_qualifier**.

6.4.10 measure_qualification

A **measure_qualification** associates one or more qualifiers with a **measure_with_unit**.

EXPRESS specification:

```

*)
ENTITY measure_qualification;

```

```

    name : label;
    description : text;
    qualified_measure : measure_with_unit;
    qualifiers : SET [1:?] OF value_qualifier;
WHERE
    WR1: SIZEOF(QUERY(temp <* qualifiers |
                      'QUALIFIED_MEASURE_SCHEMA.PRECISION_QUALIFIER'
                      IN TYPEOF(temp))) < 2;
END_ENTITY;
(*)

```

Attribute definitions:

name: the word or group of words by which the **measure_qualification** is referred to.

description: a narrative description of the **measure_qualification**.

qualified_measure: the **measure_with_unit** that is to be qualified.

qualifiers: the qualifiers of the **measure_with_unit**.

Formal propositions:

WR1: at most one of the elements of the qualifiers attribute can be a **precision_qualifier**.

```

*)
END_SCHEMA;  -- qualified_measure_schema
(*)

```

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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 short names are found in the implementation methods included in ISO 10303.

Table A.1 – Short names of entities

Entity name	Short name
DESCRIPTIVE_REPRESENTATION_ITEM	DSRPIT
DATA_ENVIRONMENT_RELATIONSHIP	DTENRL
DATA_ENVIRONMENT	DTENV
EXPANDED_UNCERTAINTY	EXPUNC
MEASURE_REPRESENTATION_ITEM	MSRPIT
MEASURE_QUALIFICATION	MSRQLF
MATERIAL_DESIGNATION	MTRDSG
MATERIAL_DESIGNATION_CHARACTERIZATION	MTDSCH
MATERIAL_PROPERTY	MTRPRP
MATERIAL_PROPERTY_REPRESENTATION	MTPRRP
PRODUCT_MATERIAL_COMPOSITION_RELATIONSHIP	PMCR
PRECISION_QUALIFIER	PRCQLF
PROPERTY_DEFINITION_RELATIONSHIP	PRDFR
QUALIFIED_REPRESENTATION_ITEM	QLRPIT
QUALITATIVE_UNCERTAINTY	QLTUNC
STANDARD_UNCERTAINTY	STNUNC
TYPE_QUALIFIER	TYPQLF
UNCERTAINTY_QUALIFIER	UNCQLF

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(45) version(1) }

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

B.2 Schema identification

B.2.1 material_property_definition_schema identification

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

{ iso standard 10303 part(45) version(1) object(1) material-property-definition-schema(1) }

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

B.2.2 material_property_representation_schema identification

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

{ iso standard 10303 part(45) version(1) object(1)
material-property-representation-schema(2) }

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

B.2.3 qualified_measure_schema identification

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

{ iso standard 10303 part(45) version(1) object(1) qualified-measure-schema(3) }

is assigned to the qualified_measure_schema schema (see clause 6). The meaning of this value is defined in ISO/IEC 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.

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

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Annex D

(informative)

EXPRESS-G diagrams

Figures D.1 through D.3 correspond to the EXPRESS listing given in annex C. The diagrams use the EXPRESS-G graphical notation for the EXPRESS language. EXPRESS-G is defined in annex D of ISO 10303-11.

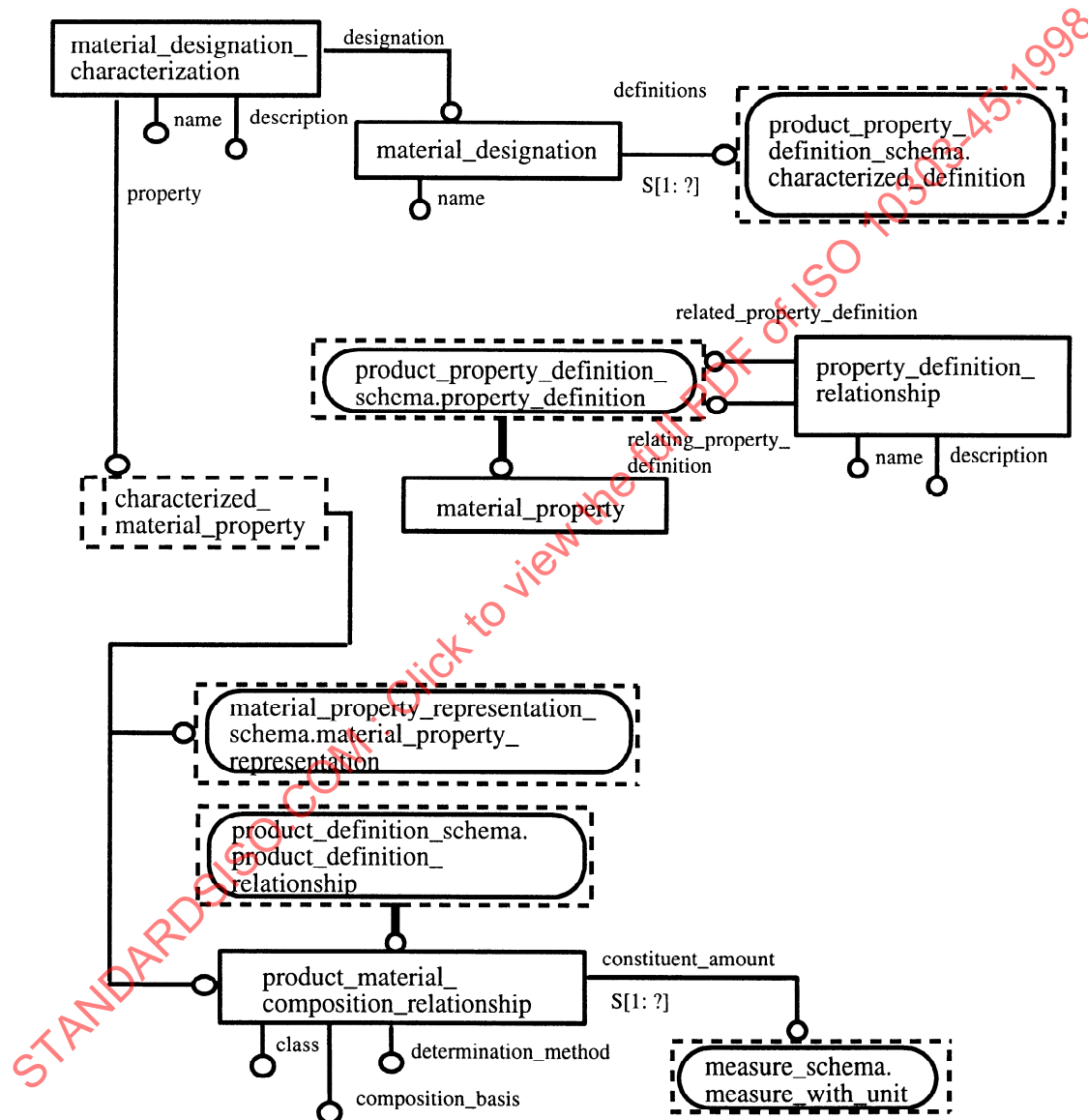


Figure D.1 – material_property_definition_schema - EXPRESS-G diagram 1 of 1

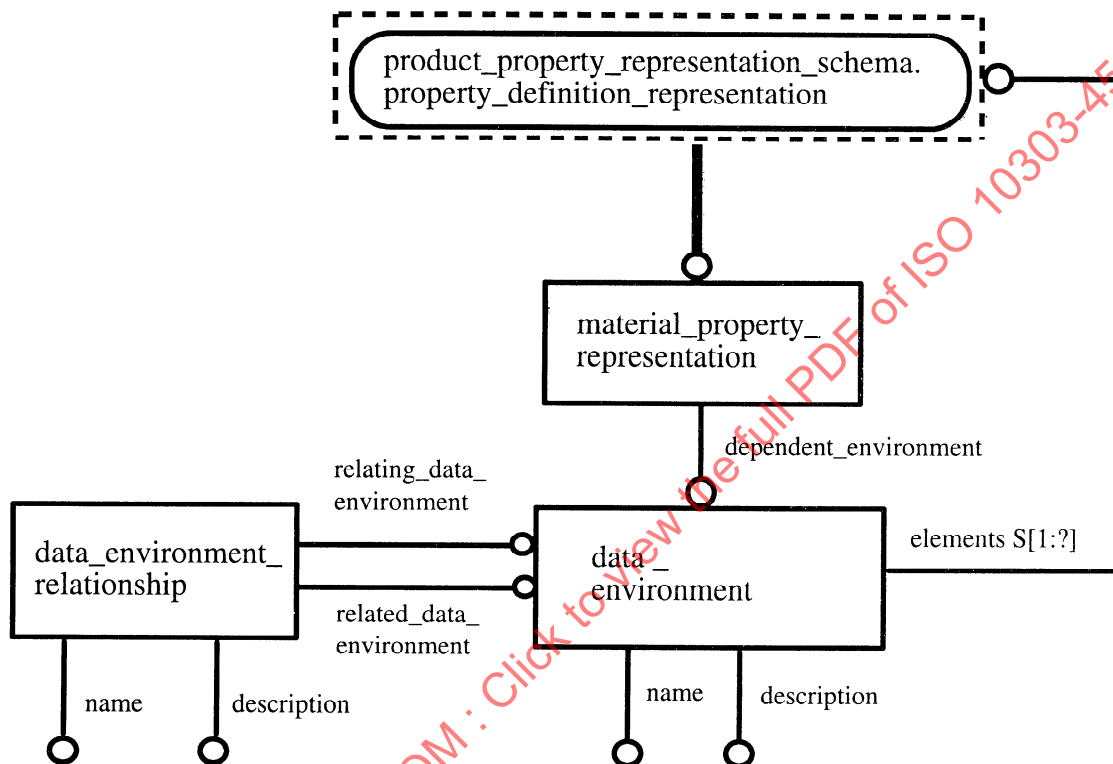


Figure D.2 – material_property_representation_schema - EXPRESS-G diagram 1 of 1

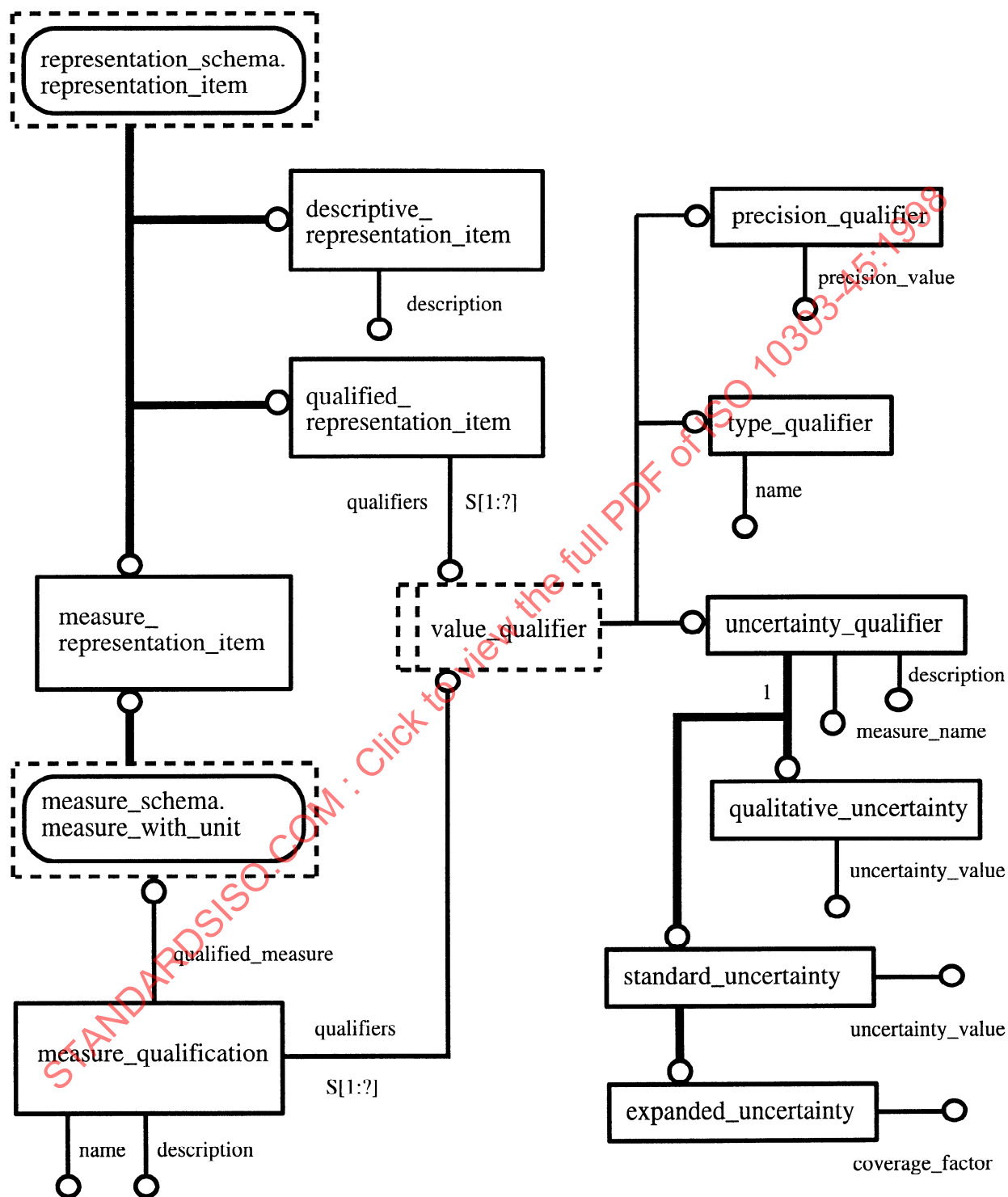


Figure D.3 – qualified_measure_schema - EXPRESS-G diagram 1 of 1

Annex E

(informative)

Model scope

E.1 Introduction

All manufactured products are made of substances whose properties contribute to the behaviour of the product during its production and in service. This part of ISO 10303 enables those properties which are closely associated with the substance of the product to be described. It follows that what are commonly called: “materials”, “engineering materials”, “raw materials” or “starting materials” are all products, resulting from a production process. Properties of such products can be described by using the resources in this part of ISO 10303.

Since the focus is on the properties of a product, the constructs in this part of ISO 10303 can be used for the products of the materials industry, as well as the products of other manufacturing sectors. In this annex the manner in which this description is achieved is explained and examples of the use of the constructs are given.

The properties of a product which are the subject of this part of ISO 10303 are those which are either determined by a measurement procedure or are assigned by agreement, such as standardized properties or values approved for design. The value of a property of a product has to be associated with the conditions under which it is valid. Some properties of materials may be related to the fundamental nature of the substance. These are referred to as *intrinsic* properties. This part of ISO 10303 does not attempt to provide separate resources for this category of properties.

The names of specific properties are not included in this part of ISO 10303. The naming of properties is the responsibility of the compilers of those application protocols which use the generic resources provided in this part of ISO 10303. There are also several other concepts commonly used in the description of engineering materials which are provided for in other parts of ISO 10303. An example is the, so-called, “class” of a material (e.g., ceramic, polymer, metallic alloy, etc.).

E.2 Example of a product

In this section, a hypothetical product called the “part 45 example product” is described by both diagrams and words. This product provides the basis for explaining how different properties are associated with the product. See figure E.1 for a diagram of this product.

The product is a regular, rectangular block. An orthogonal coordinate system corresponds to the principal dimensions of the block. This shape has been chosen to highlight the concept that a simple exterior shape can have a complex internal arrangement. The internal arrangement is called the material structure of the product. There are four possible alternative situations. The interior of the product could be:

- homogeneous in composition and isotropic in properties;

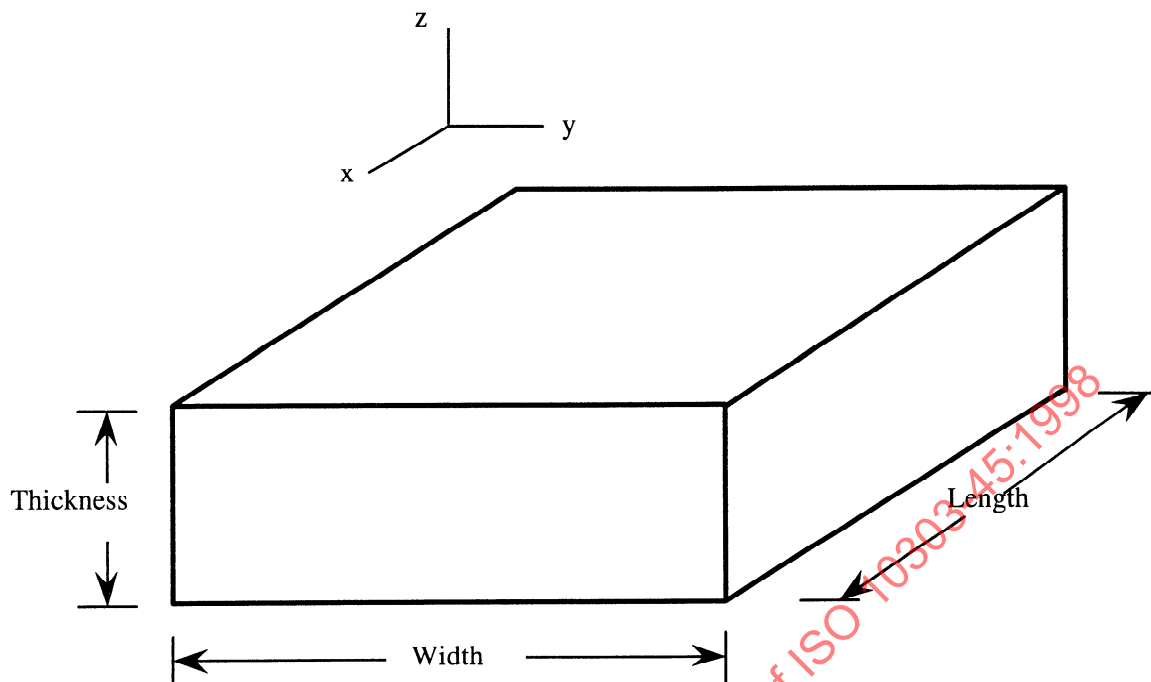


Figure E.1 – Part 45 example product

- inhomogeneous in composition and isotropic in properties;
- homogeneous in composition and anisotropic in properties;
- inhomogeneous in composition and anisotropic in properties.

An example of the first situation would be a sintered compact of either a uniform metallic or ceramic powder. An example of the second category would be a compression moulding of a thermosetting polymer with an inorganic particulate filler. An example of the third would be a sheet rolled from a metal alloy. An example of the fourth would be a plate manufactured as a fibre-reinforced, polymer resin composite.

There are, therefore, several different materials and processes which could be used to manufacture this product. Each of them would result in a characteristic set of material properties for the product. The descriptions of the process of manufacture and the conditions during the manufacture of a product are achieved by using the resources in ISO 10303-49.¹⁾

A real example of the part 45 example product could be aluminium alloy sheet, manufactured by rolling to the specification of British Standard BS1470:1987 and intended for use as a cladding for buildings.

Some of the details of the product would be described by using the entities in ISO 10303-41. The entities: **product_context**, **product_definition_context** and **product_related_product_category** from ISO 10303-41 can contain information about the intended use of the prod-

¹⁾to be published