TECHNICAL SPECIFICATION

ISO/TS 15926-12

First edition
2018-07

Industrial automation systems and integration — Integration of life-cycle data for process plants including oil and gas production facilities —

Part 12: Life-cycle integration ontology represented in Web Ontology Language (OWL)

Systèmes d'automatisation industrielle et intégration — Intégration de données de cycle de vie pour les industries de "process", y compris les usines de production de pétrole et de gaz —

Partie 12: Ontologie d'intégration de cycle de vie représentée dans le langage d'ontologie du Web (OWL)

Reference number
ISO/TS 15926-12:2018(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

A list of all parts in the ISO 15926 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 15926 is an International Standard for the representation of process industries facility life-cycle information. This representation is specified by a generic, conceptual data model that is suitable as the basis for implementation in a shared database or data warehouse. The data model is designed to be used in conjunction with reference data, i.e. standard instances that represent information common to a number of users, production facilities, or both. The support for a specific life-cycle activity depends on the use of appropriate reference data in conjunction with the data model.

This document specifies an ontology for the integration of industrial data throughout its life-cycle. The ontology implements capabilities defined by the life-cycle integration schema of ISO 15926-2, and is represented in Web Ontology Language (OWL).

This document is complementary to ISO/TS 15926-8, as follows:

— ISO/TS 15926-8 is a direct transposition of ISO 15926-2 into OWL, in which all relationships are reified. ISO/TS 15926-8 is intended an OWL implementation for the template methodology defined in ISO/TS 15926-7.

— This document is an implementation of ISO 15926-2 in OWL in which relationships are object properties, datatype properties or annotation properties. This document defines an ontology that is intended to be used with standard Resource Description Framework (RDF) and OWL tools. The ontology has a partition that is OWL DL and that can support reasoning.

Some of the content of ISO 15926-2 has not been included in this document, as follows:

— shape, which is within the scope of ISO/TS 15926-3;

— approval and status, which are covered by other ontologies and developments within W3C.

Industrial automation systems and integration — Integration of life-cycle data for process plants including oil and gas production facilities —

Part 12: Life-cycle integration ontology represented in Web Ontology Language (OWL)

1 Scope

This document specifies an ontology for the integration of industrial data throughout its life-cycle. The ontology is represented in Web Ontology Language (OWL).

NOTE 1 The ontology implements capabilities of the life-cycle integration schema of ISO 15926-2.

NOTE 2 OWL has a representation in RDF. Therefore, this document provides an ability to query life-cycle integration data using Simple Protocol and RDF Query Language (SPARQL).

The following are within the scope of this document:

— fundamental subclasses of an individual that exists in an actual or possible world, including physical object, activity and event;

— relationships between physical objects, activities and events, including the creation and destruction of physical objects;

— whole-part relationships between physical objects, including temporal part relationships that implement a 4-dimensional (4D) approach to change over time;

— points and periods in time;

— points and regions in space;

— the identification of points in time by text strings in the format defined by ISO 8601.

The following are outside the scope of this document:

— definitions of physical quantities and measurement scales;

— knowledge organization and document metadata specifications;

— approval and status;

— geometry and topology, including shape.

NOTE 3 Geometry and topology are covered by ISO/TS 15926-3.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1.1
activity
individual (3.1.5) that is something happening or changing

3.1.2
event
individual (3.1.5) that has zero extent in time

3.1.3
ontology
formal statement of an understanding of the world

Note 1 to entry: An ontology can be represented in any language. It need not be represented in a language specifically designed for ontologies, such as OWL. An ontology can have different representations.

Note 2 to entry: An ontology does not specify what data need to be recorded about the world.

Note 3 to entry: The ontology defined by this document is principally concerned with the world outside a computer system.

3.1.4
physical object
individual (3.1.5) that is a distribution of energy, matter or both

3.1.5
individual
thing that exists in space and time

Note 1 to entry: An individual can exist in the actual world or in a possible world that is a prediction, plan or scenario.

3.1.6
punning
assigning the same name to objects that are treated as different in OWL Direct Semantics

3.1.7
temporal part relationship
whole-part relationship (3.1.8) such that the part is all of the whole for a period of time

3.1.8
whole-part relationship
relationship between two *individuals* (3.1.5) such that 4D extent of one is part of the 4D extent of the other

3.2 Abbreviated terms

4D	4-dimensional
FPSO	Floating Production Storage and Offloading
IRI	Internationalized Resource Identifier
lci	Life-Cycle Integration
	NOTE This initialization is used in lower case as the TURTLE prefix for things in the life cycle integration ontology.
NORSOK	Norsk Sokkels Konkuranseposisjon
OWL	Web Ontology Language
PED	Pressurized Equipment Directive
RDF	Resource Description Framework
RDL	Reference Data Library
SPARQL	Simple Protocol and RDF Query Language
TURTLE	Terse RDF Triple Language

3.3 Symbols

This document contains examples with diagrams which show instantiations of ISO 15926. The concise notation is used for these diagrams as defined in Figure 1.

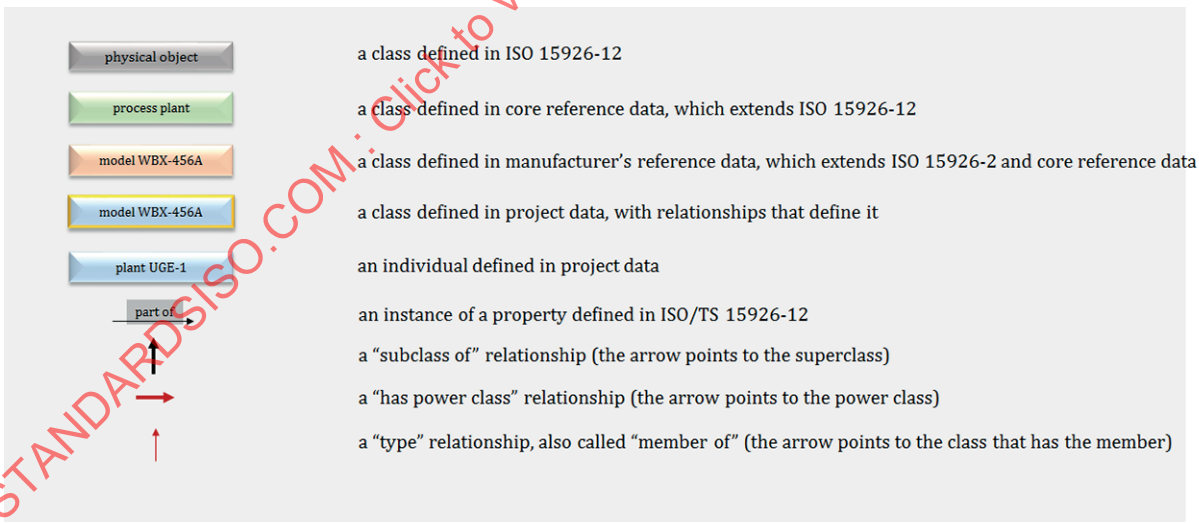


Figure 1 — Notation for the ISO 15926 instantiation examples

3.4 Identification of classes and properties and reference in text

The classes and properties defined by this document have natural language identifiers which are in lower case and which contain spaces where appropriate.

The classes and properties defined by this document have Internationalized Resource Identifiers (IRIs) with suffices derived from their natural language identifiers as follows:

— spaces are removed and encoded by camel-case;

— classes have an initial upper case letter;

— properties have an initial lower case letter.

The normative text of this document refers to a class or property in the following ways:

— if the class or property is defined by this document, then the text has the identifier of the class or property in bold font;

— otherwise, the text has the identifier of the class or property in normal font and in quotes and states the source.

The text of an example in this document has the identifier of an example class or property in normal font and in quotes.

4 Implementation of the life-cycle integration ontology

4.1 Data that conforms to the ontology

Implementation of the life-cycle ontology represented in OWL shall use the representation of the ontology in Annex A. Various examples are presented in Annex D, Annex F and Annex G.

Data that conforms to the life-cycle integration ontology shall consist of members of **thing** and statements that are relationships between them. A **thing** is either:

— **individual**: something that exists in space and time, and that has variation defined in 4D;

— **abstract object**: something that does not exist in space and time.

NOTE 1 An owl:Thing can be something other than an **individual** or **abstract object**. Therefore, **thing** is a subclass of owl:Thing.

NOTE 2 An **abstract object** can be:

— **class of individual**: class that has **individuals** as members;

— **class of class of individual**: class that has **classes of individual** as members;

or a higher order power class of **individual**.

There are very few things that are members of **abstract object** but not members of **class of individual** or **class of class of individual**. Most of these are:

— classes that have a mixture of individuals, classes of individual, and classes of class of individual as members;

An example is the class that consists of all classes defined by this document.

— relationships that are recorded as **mappings**.

An example is the **mapping** "identification by UK vehicle registration number", which is shown in Annex D. The **mapping** "identification by UK vehicle registration number" has a **representation space assigned by** relationship with the "UK Driver and Vehicle Licencing Authority". Using OWL punning, the mapping is also an owl:ObjectProperty, an owl:FunctionalProperty and an owl:InverseFunctionalProperty.

A statement of the relationship between **things** shall not be qualified in any way. If a statement is true for a particular **period in time**, then temporal parts of the related **individuals** shall be defined. If a

statement is true for a particular scenario, or "possible world", then **individuals** that exist only within that possible world shall be defined.

4.2 Extensions to the ontology

The life-cycle integration ontology may be extended by creating new classes that are subclasses of **individual**, **abstract object**, **class of individual**, and **class of class of individual**.

NOTE There are likely to be few subclasses of **abstract object** that are not subclasses of **class of individual** or **class of class of individual**, outside the realm of mathematics.

4.3 Choice of OWL version

This document defines an ontology that is represented using the W3C OWL 2 Web Ontology Language. The approach of the OWL implementation is described in Annex B, while a representation of the ontology as diagrams is presented in Annex E. The relationship between the life-cycle integration ontology and the EXPRESS entities in ISO 15926-2 is described in Annex C.

The ontology complies with the Direct Semantics of OWL 2. However, compliance has been achieved by using punning and by implementing relationships between classes as OWL annotation properties. Industrial experience using an OWL Direct Semantics representation that enables efficient support for automated reasoning is described in Annex H. The ontology has been partitioned into:

— a part concerned with individuals and their relationships — this part supports OWL DL reasoners;

— an extension containing subclasses of class and of class of class and their relationships — this part supports the full capability of ISO 15926-2; use of this part results in data that complies with OWL 2 RDF-based semantics.

NOTE An objective of this document is to enable the recording of all engineering data as precisely as possible, and to support direct querying using languages such as SPARQL.

4.4 Punning

ISO 15926-2 makes statements about relationships between classes and classification of classes. These statements are implemented by making the classes **class of individual** and **class of class of individual** subclasses of the OWL class "Thing", instead of the OWL class "Class".

This is an implementation of punning as defined in W3C, OWL 2 Web Ontology Language New Features and Rationale.

4.5 Thing and class

ISO 15926-2 contains the classes **thing** and **class**. These classes are not identical to the classes "Thing" and "Class" in OWL. The differences are as follows:

thing: In ISO 15926-2, the class **thing** is defined as the disjoint union of **individual**, which has a 4D spatio-temporal extent, and **abstract object** which does not have a spatio-temporal extent. All classes in ISO 15926-2 are subclasses of either **individual** or **abstract object**. Members of **thing** are defined with respect to the 4D paradigm or are independent of space and time.

In other ontologies, the OWL class "Thing" has members that are not within the 4D paradigm.

class: In ISO 15926-2, the class **class** has all sets as members. The members of **class** are not necessarily regarded as classes by an OWL implementation. There is also a difference in approach. An ISO 15926 class is the set of members, but an OWL class "Class" is a definition of a class that has an extension. Two members of OWL "Class" are equivalent if they have the same extension. Two members of an ISO 15926 **class** are either the same or different.

5 Time and time duration

5.1 Time duration

The class **time duration** is a measure of how long an individual lasts. It is a subclass of **quantity** and a member of **quantity kind**.

NOTE **Time duration** is important for many practical implementations of ISO 15926. This document extends ISO 15926-2 by including this class within the ontology.

5.2 ISO 8601 identification of point in time

ISO 8601 identification of point in time is a sub-property of **identified by litera**l, where the domain is **point in time** and the range is a text string defined by ISO 8601.

NOTE The representation of a **point in time** according to ISO 8601 is useful for many practical implementations of ISO 15926. This document extends ISO 15926-2 by providing an identification of a **point in time** using a text string defined in ISO 8601.

EXAMPLE The text string "2007-04-05T12:30-02:00" is an ISO 8601 identifier of the **point in time** that is 12:30 in a time zone 2 h ahead of UTC on 2007-04-05.

5.3 ISO 8601 identification of period in time

ISO 8601 identification of period in time is a sub-property of **identified by litera**l, where the domain is **period in time** and the range is a text string defined by ISO 8601.

NOTE The representation of a **period in time** according to ISO 8601 is useful for many practical implementations of ISO 15926. This document extends to capabilities in ISO 15926-2 by providing an identification of a **period in time** using a text string defined in ISO 8601.

EXAMPLE The text string "2007-04-05T12:30-02:00/2007-04-05T13:30-02:00" is an ISO 8601 identifier of the **period in time** that is 12:30 to 13:30 in a time zone 2 h ahead of UTC on 2007-04-05.

5.4 ISO 8601 identification of duration

ISO 8601 identification of duration is a sub-property of **identified by litera**l, where the domain is **point in time** and the range is a text string defined by ISO 8601.

NOTE 1 The representation of a **time duration** according to ISO 8601 is useful for many practical implementations of ISO 15926. This document extends to capabilities in ISO 15926-2 by providing an identification of a **duration** using a text string defined in ISO 8601.

NOTE 2 A time duration can also be represented using members of **scale,** such as second, minute, hour, day, which are defined in ISO/TS 15926-4.

EXAMPLE The text string "P1DT12H" is an ISO 8601 identifier of the **time duration** that is 1 day and 12 h, which is usually 36 h except when daylight saving time begins or ends during the period.

Annex A
(normative)

Ontology for life-cycle integration

A.1 Full ontology

This document defines an ontology for life-cycle integration.

NOTE 1 This ontology is intended for OWL 2 RDF-based semantics.

The following copyright statement applies to the ontology and is included within the representation of the ontology.

The life-cycle integration ontology defined by this document has the IRI:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology

The version of the ontology that is defined by this edition of this document is represented by the TURTLE files listed in Table A.1. The files can be obtained by dereferencing the IRIs with the prefix:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/<file>.ttl

NOTE 2 TURTLE is a W3C recommendation and is much more readable than the XML serialization of RDF.

Table A.1 — Representation of the ontology for life-cycle integration

File	File content
abstract-object-v-1.0	**abstract object**, **mapping** and subclasses of **class of individual** and **class of class of individual**
annotation-lci-v-1.0	Annotation of the ontology using annotation properties defined in this document
annotation-skos-v-1.0	Annotation of the ontology using annotation properties defined in SKOS
arranged-individual-v-1.0	Subclasses of **physical object**
class-of-arranged-individual-v-1.0	Subclasses of **class of physical object**
collector-v-1.0	Collector of all the ontologies except the annotation and the inferred statements
document-v-1.0	Classes relevant to information and documents
individual-v-1.0	Subclasses of **individual**
inferred-domains-and-ranges-v-1.0	Domains, ranges, and inverse statements that could be inferred
inverse-occurrance-relationship-v-1.0	Inverses of relationships between **classes of individual**
inverse-relationship-v-1.0	Inverses of relationships between **individuals**
maths-v-1.0	Simple mathematical classes and relationships
occurrence-relationship-v-1.0	Relationships between **classes of individual**
quantity-v-1.0	Classes and relationships about quantities and properties
relationship-v-1.0	Relationships between **individuals**

The annotation files in the ontology are informative copies of the normative definitions contained in the following HTML file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/iso_ts_15926-12_definitions.htm

The import graph for the ontology files is shown in Figure A.1.

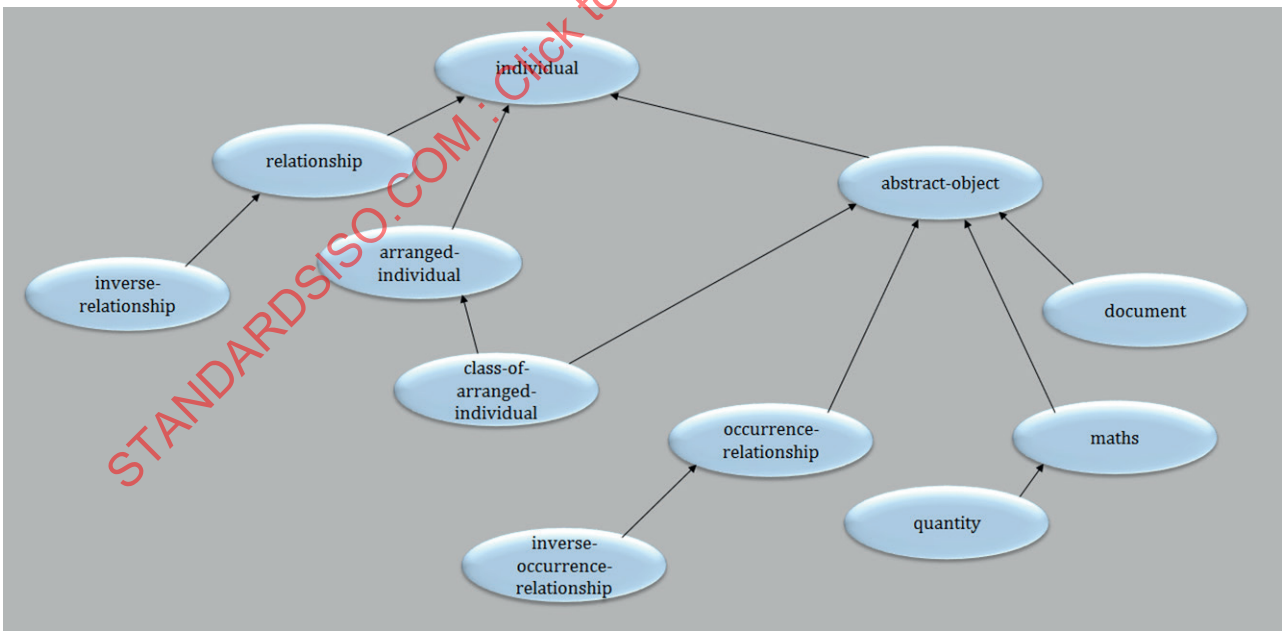


Figure A.1 — Import hierarchy

The annotation and the inferred domains, ranges and inverse statements can be added to the collector as shown in Figure A.2.

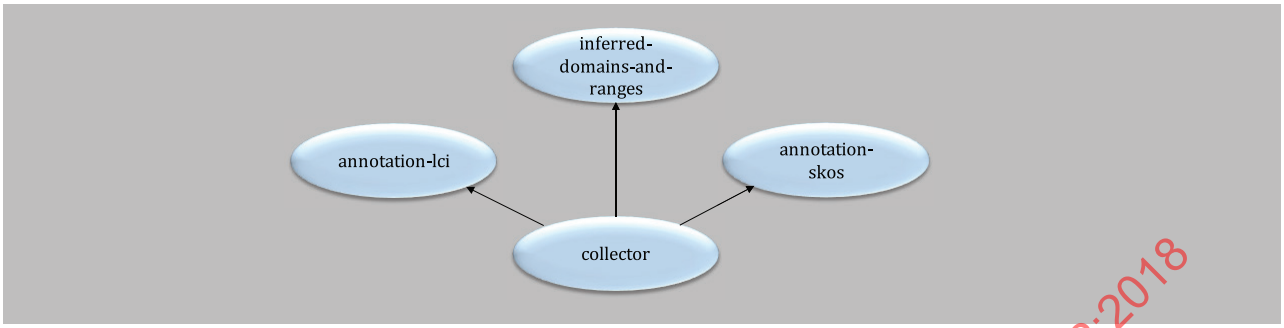


Figure A.2 — Annotation and inferred statements

The annotation in SKOS is provided by the SKOS vocabulary shown in Table A.2.

Table A.2 — SKOS annotation

SKOS term	Definition	Equivalent in this document
prefLabel	The preferred lexical label for a resource, in a given language	**identificationByLiteral**
definition	A statement or formal explanation of the meaning of a concept	**definitionByLiteral**
scopeNote	A note that helps to clarify the meaning and/or the use of a concept	**noteByLiteral**
example	An example of the use of a concept	**descriptionOfExampleByLiteral**

A.2 Individual subset ontology

A subset of the full ontology that is concerned only with individuals and their properties is defined.

NOTE 1 This ontology is intended for OWL 2 direct semantics.

The "individual subset" ontology imports the ontologies "individual", "relationship" and "inverse relationship". The ontology also contains the classes in "abstract object" and "quantity" that are useful for the representation of physical quantities.

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/individual-subset-v-1.0.ttl

NOTE 2 The ontology is also represented in the OWL Functional Syntax. This representation was used to check the validity of the OWL in the ontologies. This representation is informative. The files can be obtained by dereferencing the IRIs of the form:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/individual-subset-v-1.0.ofn

The imported ontologies "individual", "relationship" and "inverse relationship" are also available in the OWL Functional Syntax in the files:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/<file>.ofn

where the name <file> is as specified in Table A.1.

An informative extract of the normative definitions, which are appropriate for the individual subset, is contained in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/individual-subset-annotation-skos-v-1.0.ttl

Annex B
(informative)

Approach to the OWL implementation of ISO 15926-2

B.1 Class and class of class

The entity **class** in ISO 15926-2 is implemented by **lci:ClassOfIndividual**, and **class_of_class** in ISO 15926-2 is implemented by **lci:ClassOfClassOfIndividual**, where:

— **lci:ClassOfIndividual** is the power class of **lci:Individual**;

— **lci:ClassOfClassOfIndividual** is the power class of **lci:ClassOfIndividual**.

lci:ClassOfIndividual and **lci:ClassOfClassOfIndividual** are disjoint subclasses of **lci:AbstractObject**.

lci:Individual and **lci:AbstractObject** are disjoint classes of **lci:Thing**. This implements punning as defined in W3C, OWL 2 Web Ontology Language New Features and Rationale.

B.2 Classification, specialization and other relationships between classes

The entity **classification** in ISO 15926-2 is implemented by **rdf:type**.

The entity **specialization** in ISO 15926-2 is implemented by **rdfs:subClassOf** and **rdfs:subPropertyOf**.

The EXPRESS schema in ISO 15926-2 contains ONE OF constraints. These constraints are implemented by **owl:disjointWith**.

B.3 Power class

The power class of a class X consists of all subclass of X, including X itself and the empty set. A power class exists for any class.

In this document, the power class for a class "lci:X" is assigned the IRI "lci:ClassOfX". IRIs of this form are only used for power classes.

NOTE 1 Each class has a power class, whether or not it is recorded in the ontology. Hence, the class **activity** has the power class **class of activity**. The class **class of activity** also has the power class **class of class of activity**, and so on. The inclusion of these classes in an ontology is purely structural because they do not add any information. However, they are useful superclasses for other classes of class.

EXAMPLE The class "ISO 19008 activity breakdown class" has only subclasses of **activity** as members. This can be recorded by the statement that "ISO 19008 activity breakdown class" is a subclass of **class of activity**.

NOTE 2 Each power class in the life-cycle integration ontology has a **power class of** relationship with its defining class. The **power class of** relationship can be used to check the consistency of the life-cycle integration ontology and its extensions. The relationship is not used by OWL inferencing and is an OWL "annotation property".

B.4 Relationship and class of relationship

The entity **relationship** in ISO 15926-2 is implemented by **rdf:Statement**.

The entity **class_of_relationship** in ISO 15926-2 is implemented by **rdf:Property**.

In data that conforms to this document, a relationship is usually represented as an RDF triple. Only if it is necessary to refer to a relationship is it reified as an **rdf:Statement**.

In ISO 15926-2, a **class_of_relationship** is bi-directional. An **rdf:Property** has a forward direction. Therefore, in most cases, a **class_of_relationship** is implemented by two instances of **rdf:Property** with an **owl:inverseOf** relationship between them. The exception is where a **class_of_relationship** is implemented by an **owl:SymmetricProperty**, which is the inverse of itself.

In this document, properties are classified as **owl:TransitiveProperty**, **owl:SymmetricProperty**, **owl:FunctionalProperty**, and **owl:InverseFunctionalProperty** where appropriate. These classifications are not present in ISO 15926-2.

B.5 Class of class of relationship

ISO 15926-2 uses members of **class of class of relationship** to define relationships between classes rather than between members of classes.

NOTE 1 This capability cannot be completely implemented in OWL, but some of the capability is provided informally in the way defined by this clause.

In a design, there are many interrelated classes, where the definitions of the classes are mutually dependent. Consider the wiring diagram for a model of motor car. In such a diagram, there are many symbols representing wires, sensors, actuators, lights, etc., and the diagram shows their connectivity. However, each symbol represents a **class of physical object**, where there is a member in each motor car that is of the model.

A set of mutually dependent classes within a design can be expressed mathematically using a set builder notation, as follows:

$$D = \{ (a, b, ..., z) \mid P(a, b, ..., z)\}$$

where

D is the design;

(a, b, ..., z) are set builder bound variables corresponding to parts of the design;

P(a, b, ..., z) is the set of statements that define the design.

The classes in the design are defined as follows:

$$A = \{ a \mid \exists\ b, c, ..., z\ ;\ (a, b, ..., z) \in D \}$$

$$B = \{ b \mid \exists\ a, c, ..., z\ ;\ (a, b, ..., z) \in D \}$$

etc.

This document implements the ISO 15926-2 entity **composition of individual** by the OWL object properties **lci:hasPart** and **lci:partOf**. This document partially implements the ISO 15926-2 entity **class of composition of individual** by the OWL object properties shown in Figure B.1.

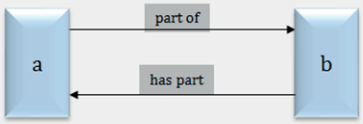
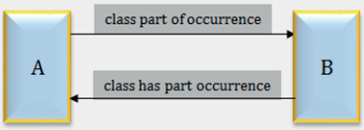
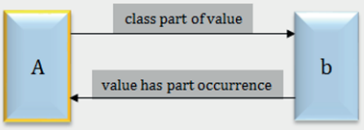
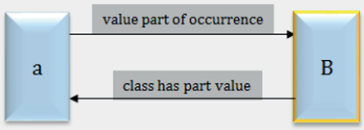
	**possible individual** 'a' is part of **possible individual** 'b'
	each member of **class of individual** 'A' is part of a member of **class of individual** 'B' and each member of **class of individual** 'B' has a member of **class of individual** 'A' as a part
	each member of **class of individual** 'A' is part of **possible individual** 'b'
	each member of **class of individual** 'B' has **possible individual** 'a' as a part

Figure B.1 — Naming convention for composition and class of composition

NOTE 2 The relationship:

A *occurrence part of value* b

is identical to the relationship:

A *occurrence part of* {b}

Similarly, the relationship:

a *value part of occurrence* B

is identical to the relationship:

{a} *occurrence part of* *B*

Shorthand forms of the relationships between a class and an individual are provided so that it is not necessary to define singleton classes.

The same approach is used for:

— **class of temporal whole part**;

— **class of beginning**;

— **class of ending**;

— **class of cause of beginning of class of individual**;

— **class of cause of ending of class of individual**.

EXAMPLE The implementation of **class of class of relationship** is used as follows:

— the **physical object** that is the pump with serial number "P-98/1234" has a **has part** relationship with the **physical object** that is the impeller with serial number "I-05/5678" during 2016;

— the **class of physical object** that is the pump design with model number "WBX-356A" has an **occurrence has part** relationship with the **class of physical object** that is the occurrence of the impeller type with part number "WI-57SS" within pump model "WBX-356A".

The occurrence of the impeller type with part number "WI-57SS" within pump model "WBX-356A" is a subclass of the impeller type with part number "WI-57SS". An impeller of this type need not be a part of a pump of model "WBX-356A".

The relationships are shown in Figure B.2 and Figure B.3.

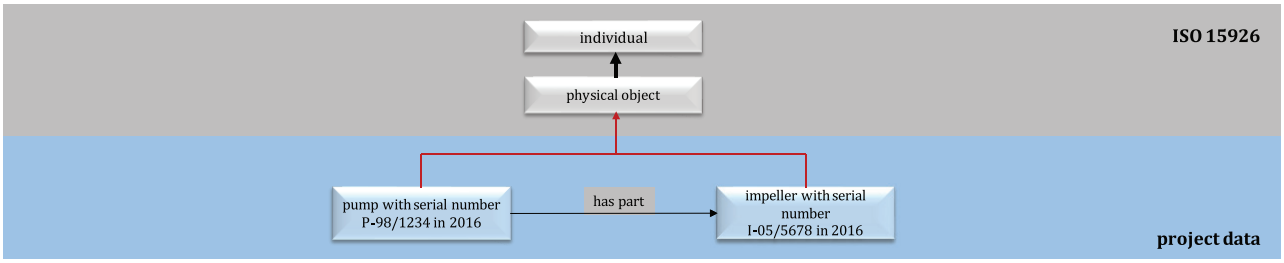


Figure B.2 — Composition of an individual

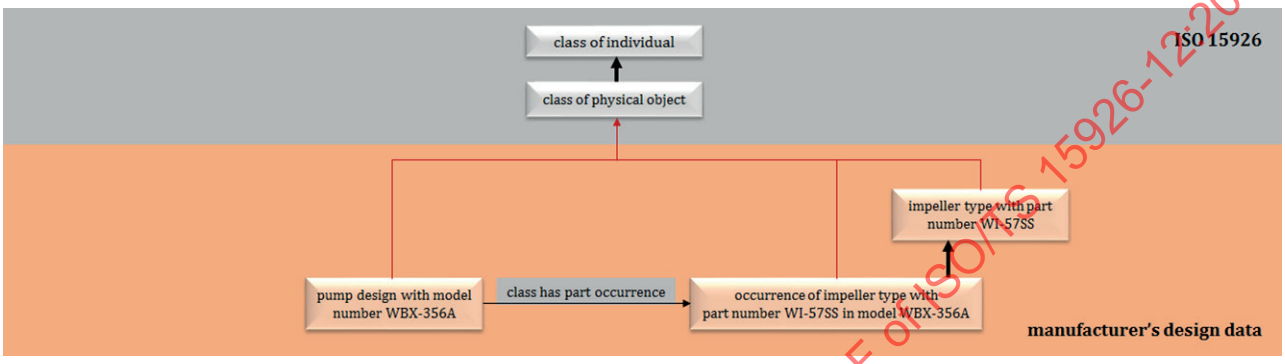


Figure B.3 — Specification of composition in a design

An individual can be related to the design as shown in Figure B.4.

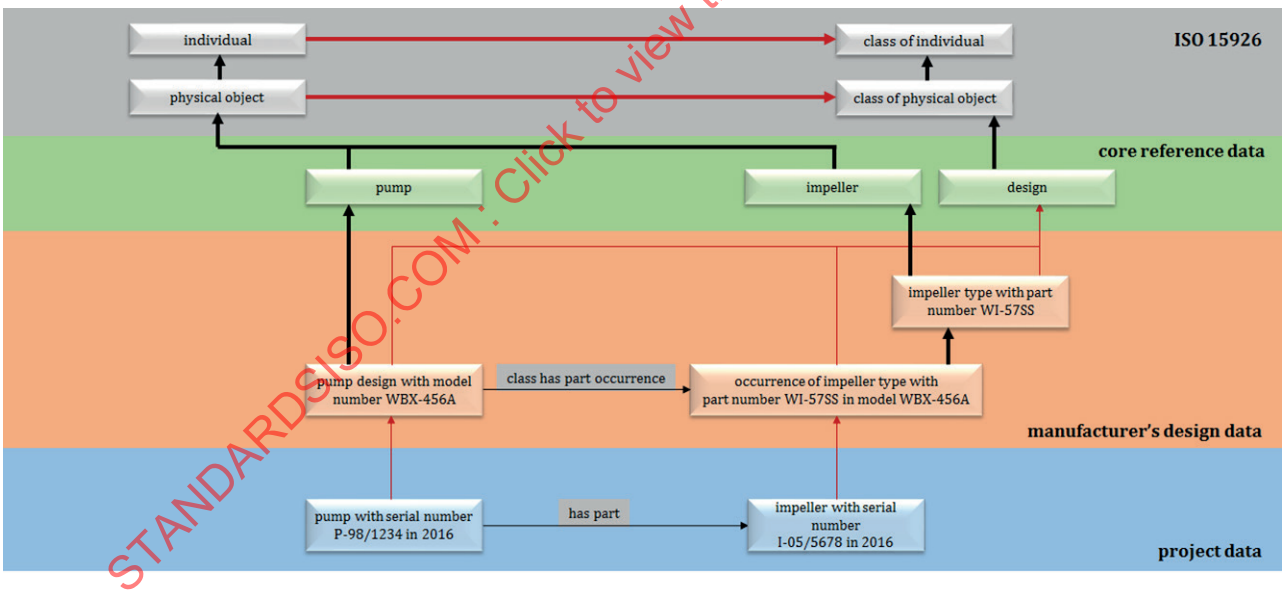


Figure B.4 — Individual and design

The object "pump with serial number P-98/1234 in 2016" is the temporal part of "pump with serial number P-98/1234" that exists during 2016. "Pump with serial number P-98/1234" is a **materialized physical object** because it has material continuity.

The object "impeller with serial number I-05/5678 in 2016" is the temporal part of "impeller with serial number I-05/5678" that exists during 2016. "Impeller with serial number I-05/5678" is a **materialized physical object** because it has material continuity.

The object “impeller with serial number I-05/5678 in 2016” is also the temporal part of “impeller of pump with serial number P-98/1234” that exists during 2016. “Impeller of pump with serial number P-98/1234” is a **functional physical object** because it has functional continuity. It does not have material continuity because different impellers can be installed at different times.

The object “occurrence of the impeller type with part number WI-57SS” within pump model “WBX-356A” is necessarily a subclass of **functional physical object** because all its members necessarily have functional continuity.

These objects and their relationships are shown in Figure B.5.

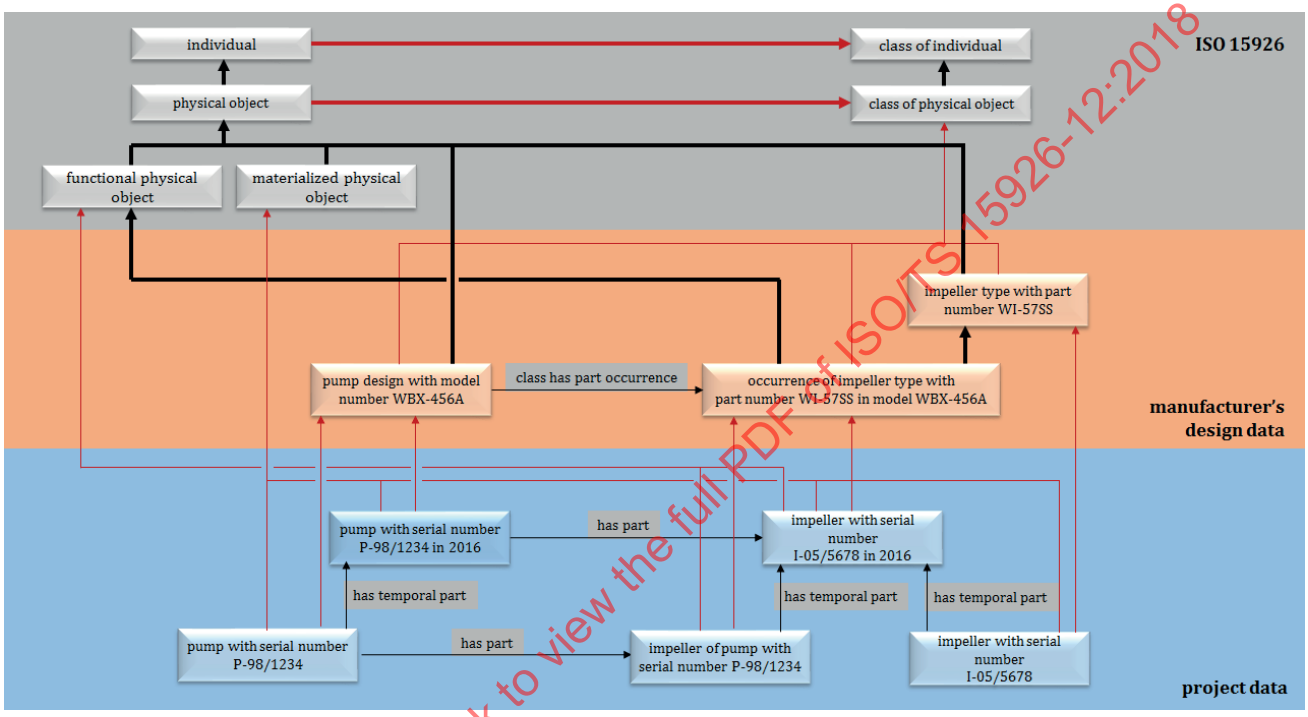


Figure B.5 — Materialized and functional physical objects and design

For simplicity, the core reference data classes are not shown in Figure B.5.

The example is represented in TURTLE in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Individual and design.ttl

In this simple example, which is concerned with a part of a design by itself, the class that is the impeller within pump model “WBX-356A” can be defined using an OWL Restriction as follows:

```
ex-des:ImpellerInWBX-456A
    owl:equivalentClass [
        owl:intersectionOf (
            ex-rdl:Impeller
            [ owl:onProperty lci:partOf ;
            owl:allValuesFrom ex-des:WBX-456A ]
        )
    ] ;
    rdfs:subClassOf ex-des:WI-57SS .
```

From this restriction, it can be inferred that an impeller that is part of a pump of type “WBX-456A” is of type “WI-57SS”.

The example is represented in TURTLE, using the “individuals subset” ontology in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Individual and design - individuals.ttl

Annex C
(informative)

Relationship between the life-cycle integration ontology and the EXPRESS entities in ISO 15926-2

The relationship between the ontology defined by this document and the EXPRESS entities defined in ISO 15926-2 is documented in the EXCEL workbook:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/mapping between ISO 15926-12 and ISO 15926-2.xlsx

This workbook shows the entities that have been addressed in this edition of ontology and the way that they have been implemented in OWL.

The workbook contains two spreadsheets with columns as defined in Table C.1 and Table C.2.

Table C.1 — Columns of spreadsheet ISO/TS 15926-12 source and changes

Column	Content
ISO/TS 15926-12 class or property	The class or property identifier in this document
source	The clause in ISO 15926-2 from which the definition of the class or property is derived. This is "ISO/TS 15926-12" where the class or property has been introduced in this document.
ISO 15926-2 entity	The entity name in ISO 15926-2
history note	The reason for a change of name in this document, or for the introduction of a new class or property

Table C.2 — Columns of ISO 15926-2 disposition

Column	Content
ISO 15926-2 entity	The class or property identifier in this document
category	A broad classification of ISO 15926-2 entities
ISO/TS 15926-12 class or property label	The label of the class or property in ISO 15926-2
reason for non-implementation in ISO/TS 15926-12	The reason for a change of name in this document, or for the introduction of a new class or property
history note	Copied from Table C.1

The categories of ISO 15926-2 entities are shown in Table C.3.

Table C.3 — Categories of ISO 15926-2 entities

Category	Content
4D core	The entities that implement the ISO 15926 "4D" approach to modelling change
definition and description	Entities concerned with the definition and description of things
document	Entities concerned with documents and their content
geometry and topology	Entities concerned with geometry and topology. This is out of scope for this document.
identification	Entities concerned with identification
intention and possibility	Entities concerned with intents and possibilities
maths	Entities concerned with maths
methodology	Entities concerned with set theory methodology and the representation of statements
possibly incorrect	Entities which may not be correct in ISO 15926-2
power class	Entities that are power classes of other entities
provenance and trust	Entities concerned with provenance and trust
quantities and units	Entities concerned with quantities and units
serialization methodology	Entities concerned with the EXPRESS serialization methodology

Annex D
(informative)

Examples

D.1 Assembly, installation and classification of individuals

D.1.1 Composition of an individual assembly and classification of components

The Floating Production Storage and Offloading (FPSO) "UGE-1" has a separation and stabilization system. There is a deaerator that is part of train A within this system, with tag "20-VH-001A". This can be recorded using this document as shown in Figure D.1.

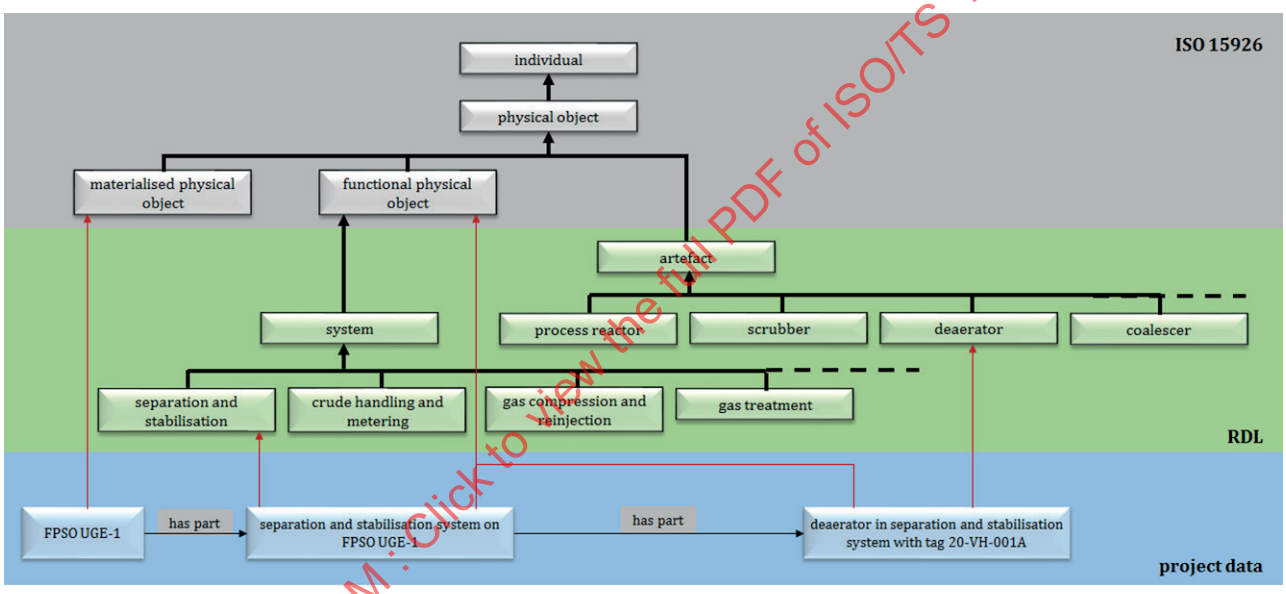


Figure D.1 — Deaerator in a separation and stabilization system

Both the separation and stabilization system and the deaerator are defined by their function with FPSO "UGE-1". Hence, they are both classified as **functional physical objects**.

"UGE-1" is classified as an FPSO (not shown in Figure D.1) and a **materialized physical object**.

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Composition of an assembly.ttl

The SPARQL query that returns all deaerators in the separation and stabilization system in "UGE-1" is as follows:

```
SELECT ?separationAndStabilizationDeaerator
WHERE {
   ex-ind:UGE-1 lci:hasPart ?separationAndStabilizationSystem .
   ?separationAndStabilizationSystem a ex-norsok:SeparationAndStabilization .
   ?separationAndStabilizationSystem lci:hasPart ?separationAndStabilizationDeaerator .
   ?separationAndStabilizationDeaerator a ex-rdl:Deaerator .
}
```

The class "separation and stabilization" is defined by Norsk Sokkels Konkuranseposisjon (NORSOK) and is shown in the SPARQL example with the "ex-norsok" namespace. The class "deaerator" is defined in a core Reference Data Library (RDL) and is shown in the SPARQL example with the "ex-rdl" namespace. The property **hasPart** is defined within the life-cycle integration schema of this document and is shown in the SPARQL with the "lci" namespace.

D.1.2 Multiple classification of an individual

An individual can be classified in many ways. The deaerator with tag "20-VH-001A" is also classified as being within risk category 4 according to the EU Pressurized Equipment Directive 97/23/EC. This is shown in Figure D.2.

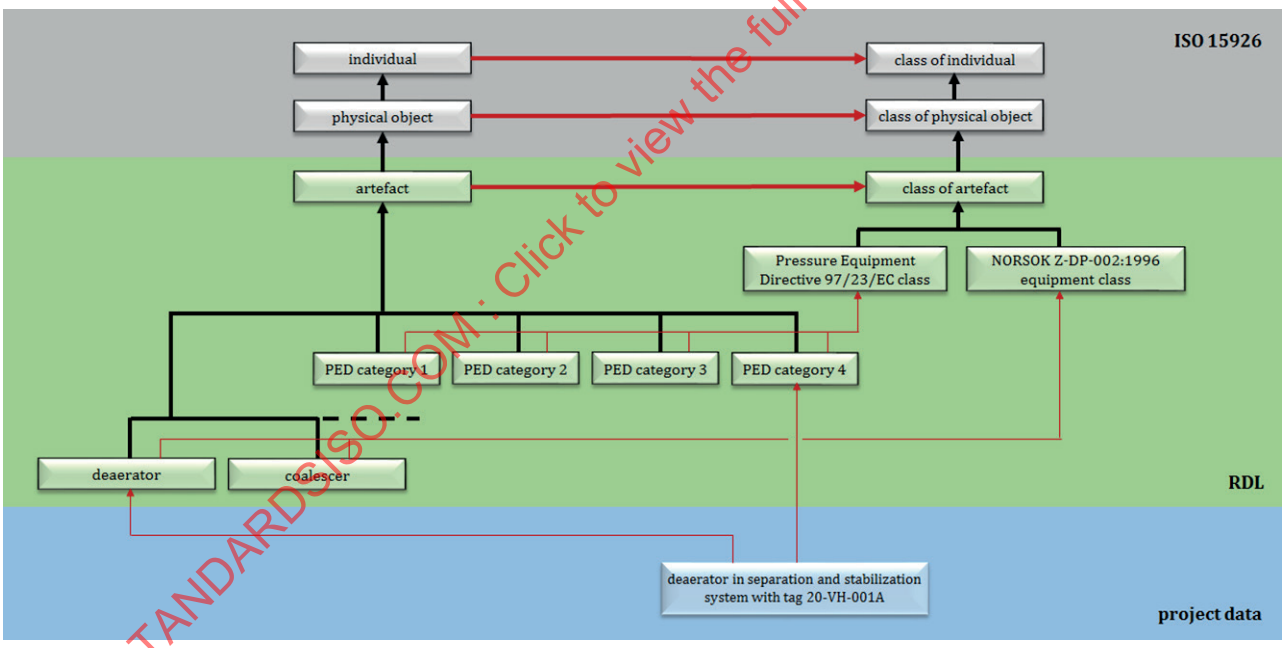


Figure D.2 — Multiple classifications of an individual

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Multiple classification of an individual.ttl

The SPARQL query that returns the classification of "20-VH-001A" that is also a NORSOK class is as follows:

```
SELECT ?norsokClass
WHERE {
  ex-ind:UGE-1–20-VH-001A a ?norsokClass .
  ?norsokClass a ex-norsok:Z-DP-002–1996 .
}
```

The SPARQL query that returns the Pressurized Equipment Directive (PED) risk category of "20-VH-001A" is as follows:

```
SELECT ?pedCategory
WHERE {
  ex-ind:UGE-1–20-VH-001A a ?pedCategory .
  ?pedCategory a ex-ped:PED-97–23-EC .
}
```

D.1.3 Installation of an individual part within an assembly

The deaerator vessel with serial number "05/1234-8" is installed as the **functional physical object** with tag "20-VH-001A". The vessel with serial number "05/1234-8" is a **materialized physical object** that is also classified as a deaerator. This is shown in Figure D.3.

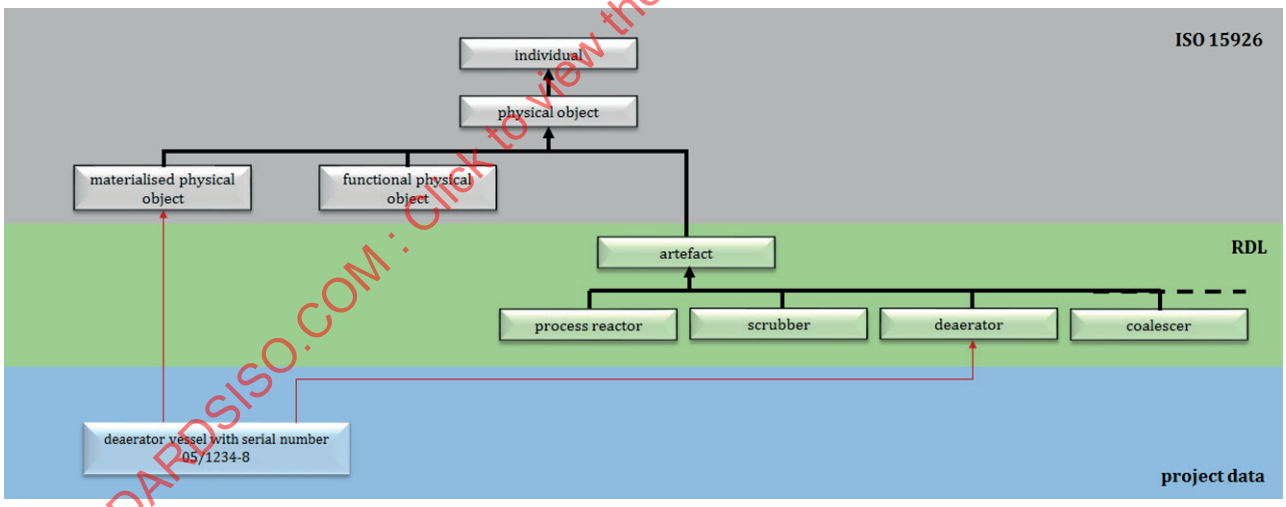


Figure D.3 — Deaerator as a materialized physical object

The installation begins on 2016-07-08. After this date, and until a future de-installation, the deaerator vessel with serial number "05/1234-8" is also the deaerator vessel with tag "20-VH-001A". The is one object that is both a temporal part of the vessel with serial number "05/1234-8" and a temporal part of the vessel with tag "20-VH-001A". This is shown by the space-time diagram in Figure D.4.

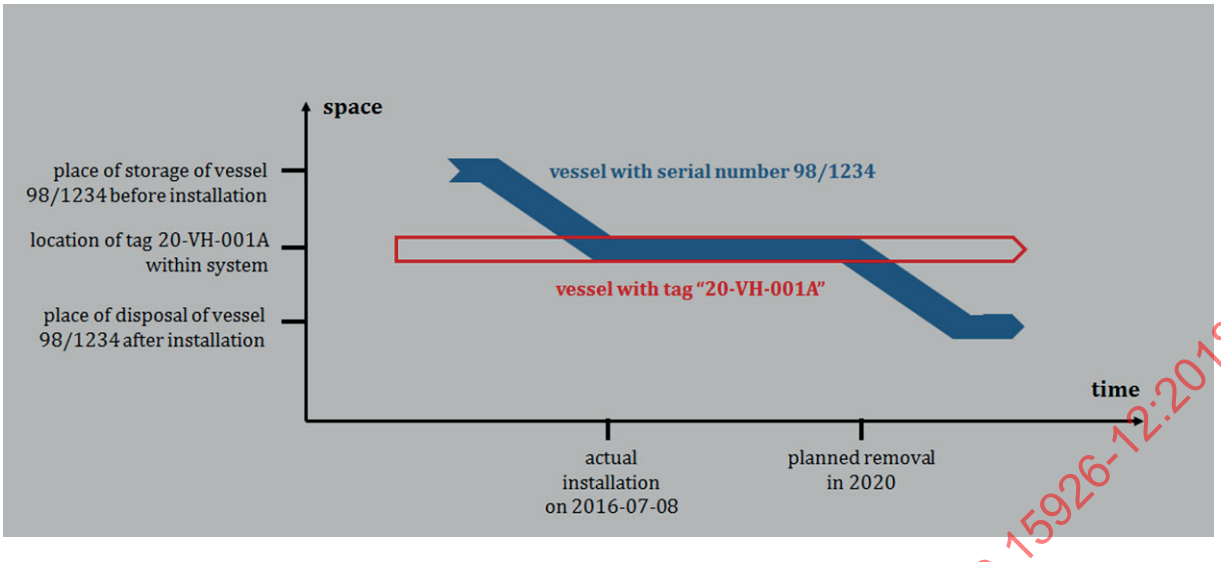


Figure D.4 — Space-time diagram for an installation

The classifications of the temporal part and its relationships are shown in Figure D.5.

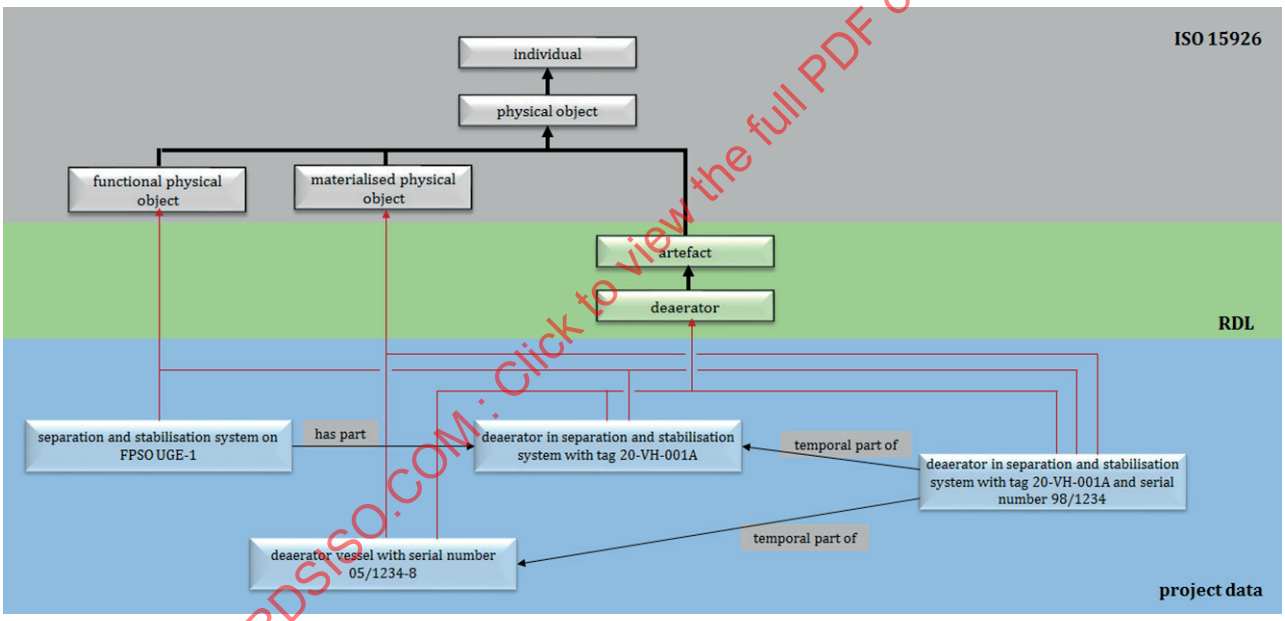


Figure D.5 — Installation within a system

The **materialized physical object** that is the deaerator vessel with serial number "05/1234-8" and **functional physical object** that is the deaerator vessel with tag "20-VH-001A" are both members of the class "deaerator". All their temporal parts are also members of this class.

The temporal parts of the **materialized physical object** that is the deaerator vessel with serial number "05/1234-8" are also members of **materialized physical object**. The temporal parts of the **functional physical object** that is the deaerator vessel with tag "20-VH-001A" are also members of **functional physical object**.

The object "deaerator in separation and stabilization system with tag 20-VH-001A and serial number 98/1234" has both a material and a functional definition for its identity and is therefore both a **materialized physical object** and a **functional physical object**.

The object "deaerator in separation and stabilization system with tag 20-VH-001A and serial number 98/1234" has a starting event that takes place on 2016-07-08. This **event** is caused by an installation **activity**. Information about the **activity**, such as who performed it and the resources used, can be recorded if required. This is shown in Figure D.6.

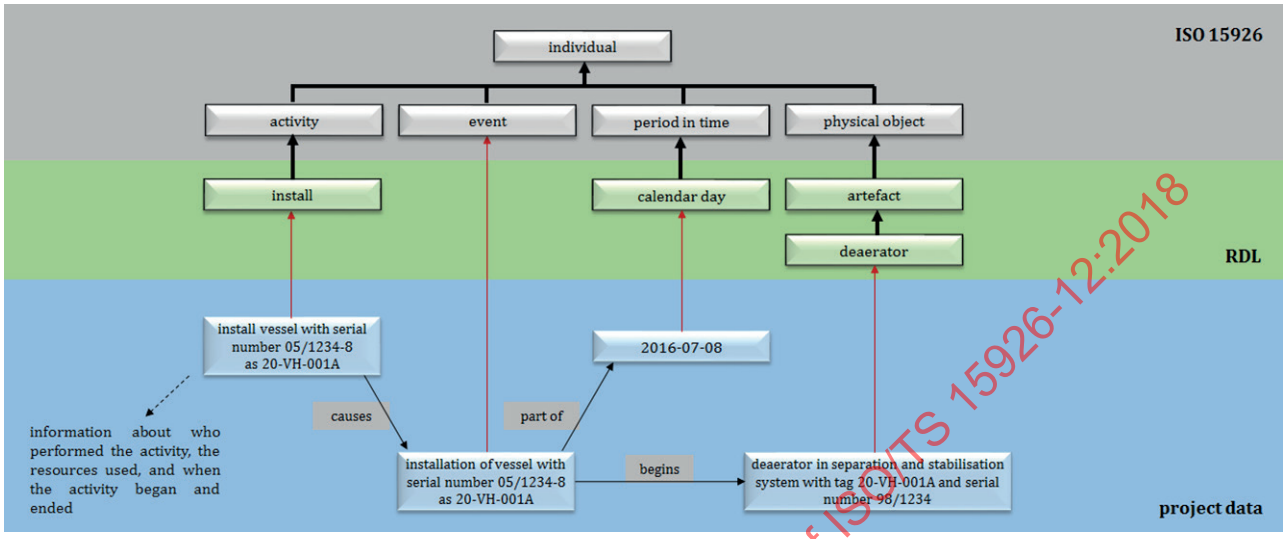


Figure D.6 — Installation event and activity

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Installation of an individual part within an assembly.ttl

The SPARQL query that returns the date of the installation of the deaerator vessel with serial number "05/1234-8" is as follows:

```
SELECT ?date
WHERE {
  ?vesselWhenInstalled lci:temporalPartOf ex-ind:DV-05-1234-8 .
  ?installationEvent lci:begins ?vesselWhenInstalled ; lci:partOf ?installationDay .
  ?installationActivity a ex-rdl:Install ; lci:causes ?installationEvent .
  ?installationDay a ex-rdl:CalendarDay ; lci:iso8601IdentificationOfPeriodInTime ?date .
}
```

D.2 Role in an activity

This document enables statements to be made about the role played by a physical object that participates in an activity. The role is a classification of the temporal part of the physical object that is also part of the activity.

There is a lifting activity "lifting of container C-101". Fred Bloggs is the "slinger-signaller" for this activity. Hence, there are relationships as follows:

— "Fred Bloggs as slinger-signaller in the lifting of container C-101" is part of activity "lifting of container C-101";

— "Fred Bloggs as slinger-signaller in the lifting of container C-101" is a temporal part of "Fred Bloggs";

— "Fred Bloggs as slinger-signaller in the lifting of container C-101" is classified as a "slinger-signaller", where slinger-signaller is classified as a "role of a person in activity".

These relationships are shown in Figure D.7.

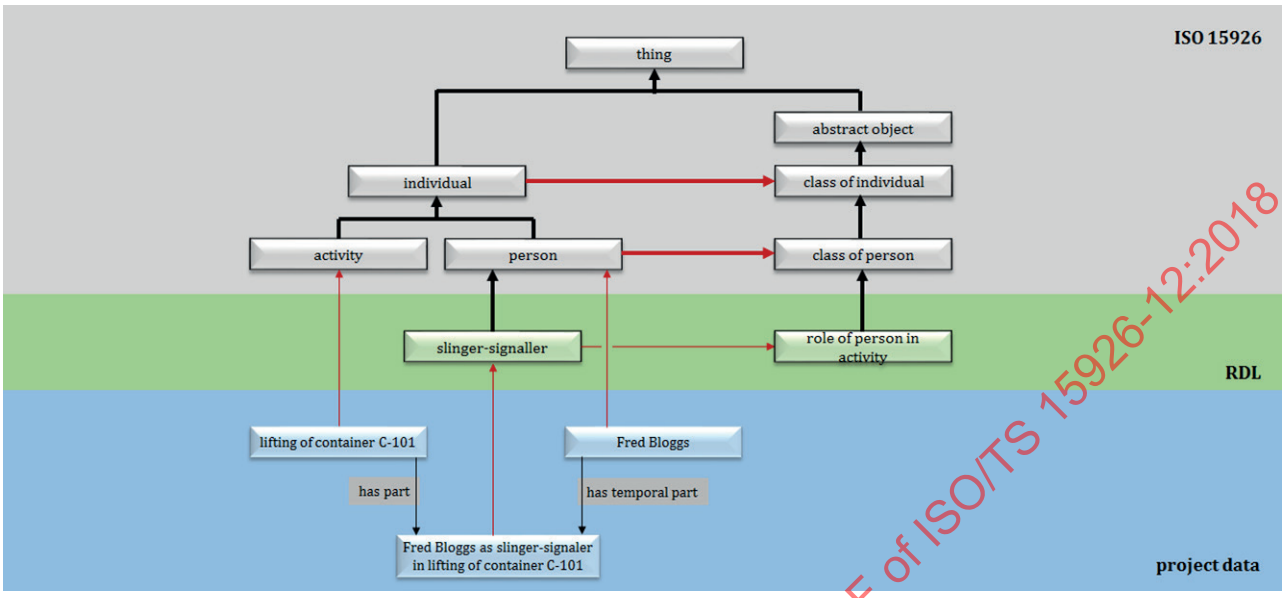


Figure D.7 — Role in an activity

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Role in an activity.ttl

A SPARQL query that returns the people participating in activities and their roles is as follows:

```
SELECT ?activity ?person ?role
WHERE {
  ?activity a lci:Activity .
  ?activity lci:hasPart ?personInRole .
  ?personInRole a ?role .
  ?role a ex-rdl:RoleOfPersonInActivity .
  ?person a lci:Person .
  ?person lci:hasTemporalPart ?personInRole .
}
```


D.3 Assignment and usage of representation spaces

This document enables statements to be made about the organization that assigns a representation and about the organizations that use it. A representation can be an identification, description or definition.

There is a vehicle that has the vehicle registration number "DV 58 HUK" assigned by the UK Driver and Vehicle Licensing Authority. Hence, there are relationships as follows:

— a vehicle that has an "identification by UK vehicle registration number" relationship with the text string "DV 58 HUK";

— a **representation space assigned by** relationship between "identification by UK vehicle registration number" and the UK Driver and Vehicle Licensing Authority.

These relationships are shown in Figure D.8.

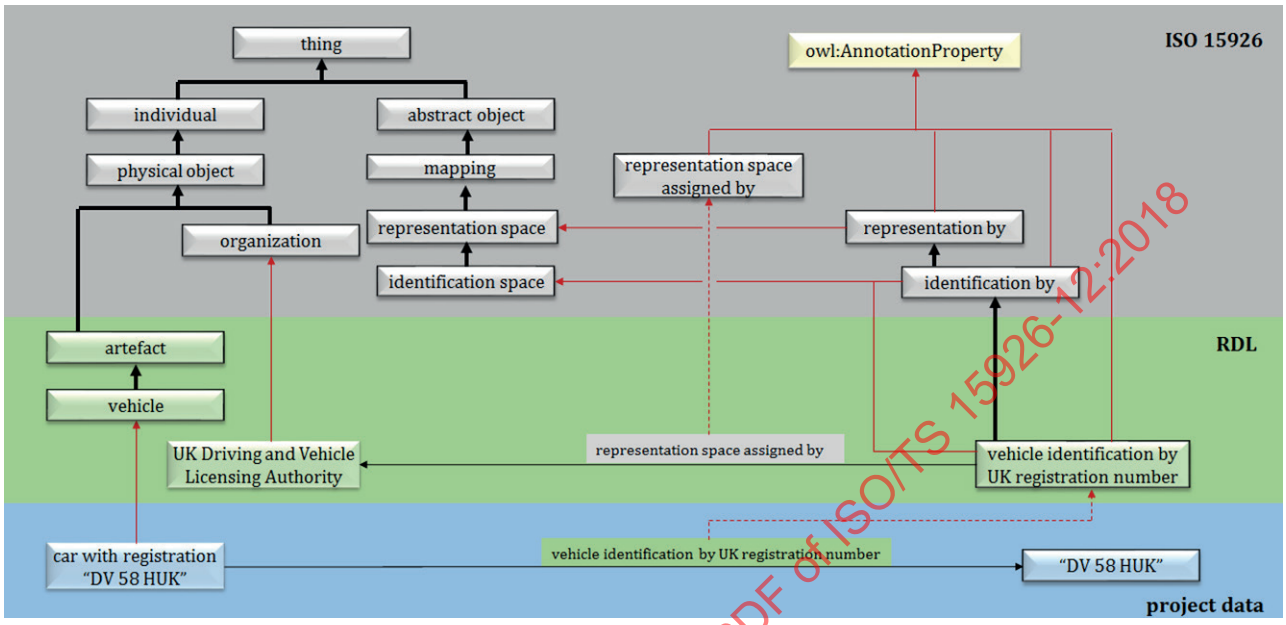


Figure D.8 — Assignment of a representation space

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Assignment of a representation space.ttl

A SPARQL query that returns the identifiers for vehicles and their assignment organizations is as follows:

```
SELECT ?vehicle ?vehicleIdentifier ?organization
WHERE {
  ?vehicle a ex-rdl:Vehicle .
  ?vehicle ?identification ?vehicleIdentifier .
  ?identification a lci:IdentificationSpace .
  OPTIONAL {
    ?identification lci:representationSpaceAssignedBy ?organization
  }
}
```

D.4 Material used in a connection

This document enables statements to be made about connections between physical objects at different levels of detail. If necessary, statements can be made about the physical objects that make a connection.

There is a connection between pipes P-101 and P-102. Looking in more detail, the connection is between flange 2 of pipe P-101 and flange 1 of pipe P-102. The connection is made by a bolted connection assembly which has a gasket. Hence, there are relationships as follows:

Level 1:

— “pipe P-101” is connected to pipe “P-102”.

Level 2:

— “pipe P-101” has arranged part “pipe P-101 flange 2”;

— “pipe P-102” has arranged part “pipe P-102 flange 1”;

— “pipe P-101 flange 2” is connected to “pipe P-102 flange 1”.

Level 3:

— “pipe P-101” has arranged part “pipe P-101 flange 2”;

— “pipe P-102” has arranged part “pipe P-102 flange 1”;

— “pipe P-101 flange 2” is part of “connection assembly P-101 to P-102”;

— “pipe P-101 flange 1” is part of “connection assembly P-101 to P-102”;

— “gasket in connection assembly P-101 to P-102” is part of “connection assembly P-101 to P-102”;

— “connection assembly P-101 to P-102” is classified as a bolted connection.

These relationships are shown in Figure D.9, Figure D.10 and Figure D.11.

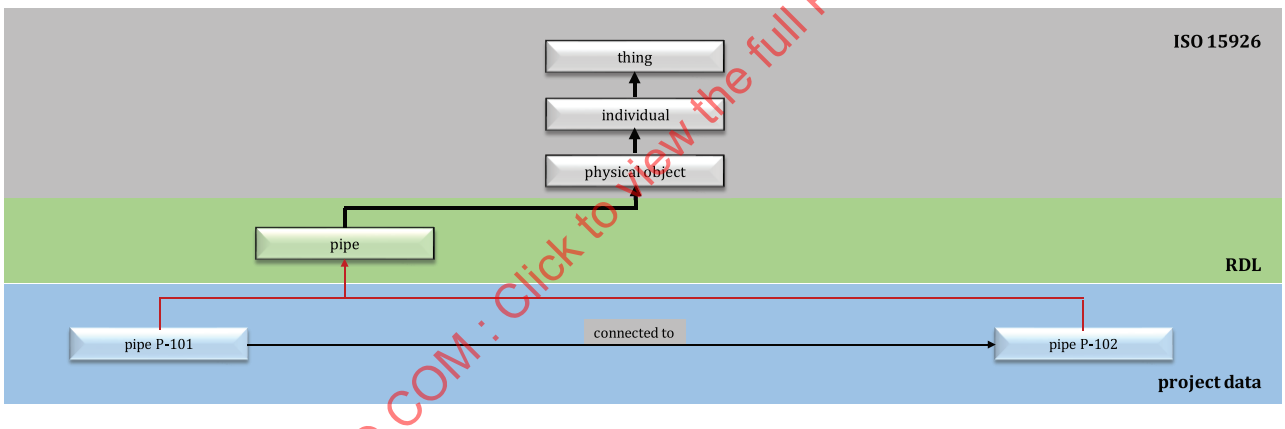


Figure D.9 — Connection level 1

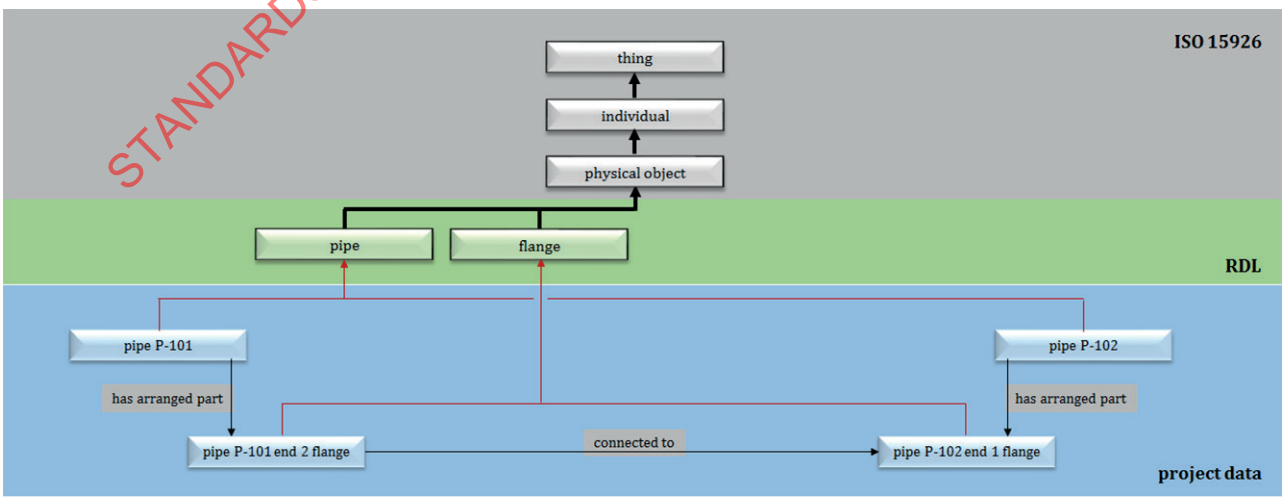


Figure D.10 — Connection level 2

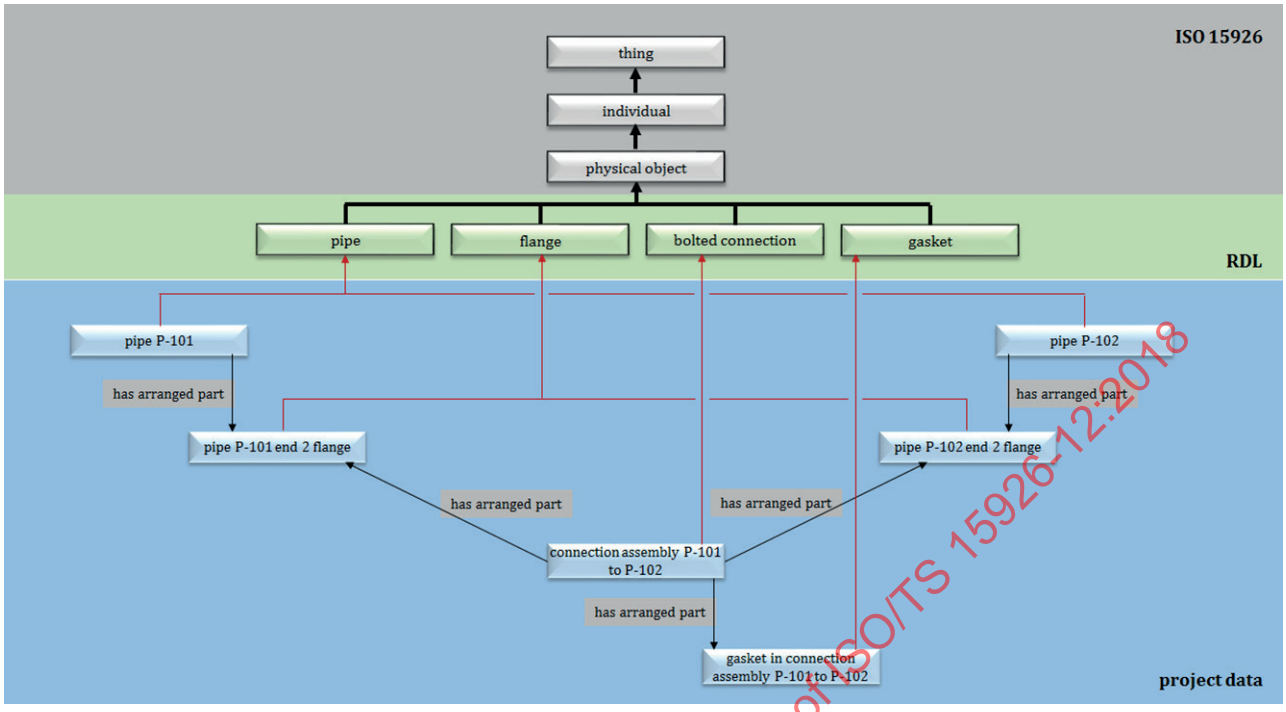


Figure D.11 — Connection level 3

All three levels of the example are in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Material used in a connection.ttl

A SPARQL query that returns information about the material used in an assembly at level 3 that implements a connection at level 2 is as follows:

```
SELECT ?side1 ?side2 ?materialUsedInAssembly ?typeOfMaterialUsedInAssembly
WHERE {
  ?side1 lci:connectedTo ?side2 .
  ?connectionAssembly lci:hasArrangedPart ?side1 .
  ?connectionAssembly lci:hasArrangedPart ?side2 .
  ?connectionAssembly a ?typeOfConnectionAssembly.
  ?connectionAssembly lci:hasArrangedPart ?materialUsedInAssembly .
  ?materialUsedInAssembly a ?typeOfMaterialUsedInAssembly .
  NOT EXISTS {?materialUsedInAssembly lci:connectedTo ?side2 }
  NOT EXISTS {?side1 lci:connectedTo ?materialUsedInAssembly }
}
```

D.5 Ratio

A ratio between two quantities can be recorded. A ratio can have a unitless representation as a fraction, percentage or parts per million, or a representation dependent upon units such metre per kilometre or foot per mile.

The class **ratio** is a subclass of **class of ordered pair**.

The property **percent** represents a **ratio** as a percentage represented as a decimal number.

The property **fraction** represents a **ratio** as a fraction represented as a decimal number.

EXAMPLE The staff time for activity A-101 in plan version 2 is 200 hours. The actual staff time used to 2015-04-20 is 50 hours. The percentage or fraction used can be recorded as follows:

— "actual staff time for activity A-101 to 2015-04-20": a member of **actual individual**, **staff time** and 50 hours;

— "staff time for activity A-101 in plan version 2": a member of **non-actual individual**, **staff time** and 200 hours;

— "50 hours": a member of **time duration** and a subclass of **period in time**;

— "200 hours": a member of **time duration** and a subclass of **period in time**;

— "50 hours, 200 hours": an **ordered pair**;

— "5:20"; a **ratio**.

These objects, with their classifications and relationships, are shown in Figure D.12.

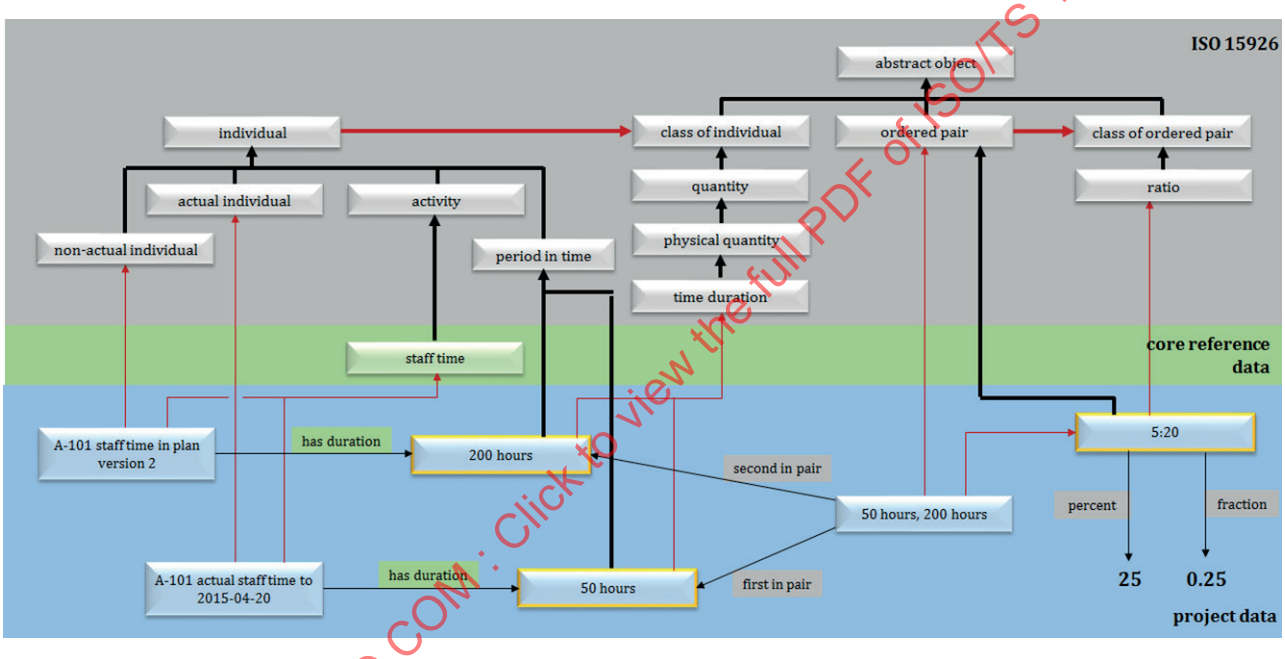


Figure D.12 — Ordered pair and ratio

The example is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Ratio.ttl

A SPARQL query that returns the percentage of staff time used and the baseline against which it is measured is as follows:

```
SELECT ?percent ?baseline
WHERE {
   ex-ind:A_101ActualStaffTimeTo2015–04–20 ex-rdl:hasDuration ?actualDuration .
   ?pair lci:hasFirstInPair ?actualDuration .
   ?pair lci:hasSecondInPair ?baselineDuration .
   ?pair a ?ratio .
   ?ratio lci:percent ?percent .
   ?baseline ex-rdl:hasDuration ?baselineDuration .
}
```

D.6 Physical properties and quantities

D.6.1 Physical properties and quantities example ontologies

The examples concerning physical properties and quantities rely upon a common set of ontologies with the import hierarchies shown in Figure D.13.

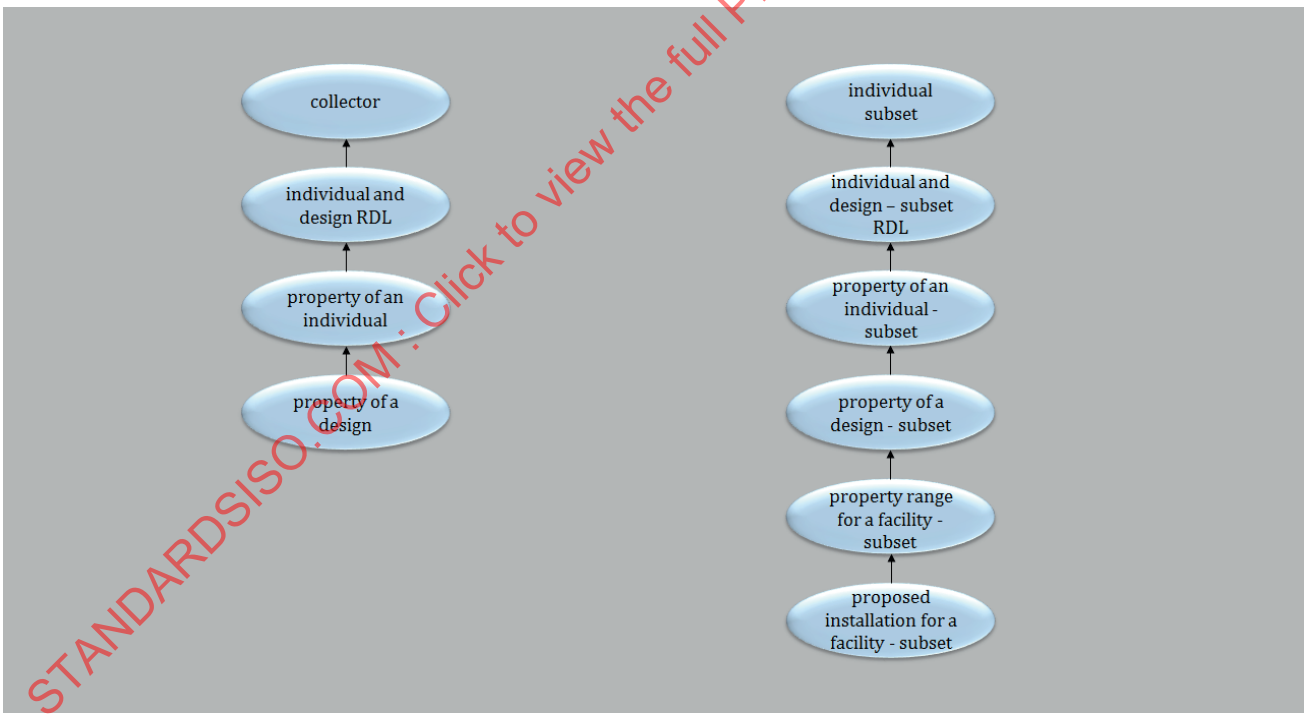


Figure D.13 — Import hierarchy for example ontologies

The ontologies in the hierarchy in Figure D.13 on the left are intended for OWL RDF semantics. The ontologies in the hierarchy on the right are intended for OWL direct semantics.

The example ontologies in TURTLE can be downloaded from an IRI of the form:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/<file>.ttl

where the <file> is as specified in Table D.1.

The example ontologies that are intended for OWL direct semantics can also be downloaded in OWL functional notation from an IRI of the form:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/<file>.ofn

Table D.1 — Property of an individual example files

File	File content
individual and design - rdl	The reference data for the example importing the full ontology
individual and design - subset - rdl	The reference data for the example importing the individual subset ontology
property of an individual	Property of an individual example, importing the full ontology
property of an individual - subset	Property of an individual example, importing the individual subset ontology
property of a design	Property of a design example, importing the full ontology
property of a design - subset	Property of a design example, importing the individual subset ontology
property range for a facility - subset	Property range for a facility example, importing the individual subset ontology
proposed installation for a facility - subset	Proposed installation for a facility example, importing the individual subset ontology

D.6.2 Property of an individual

The pump with serial number P-98/1234 has a rated driver power of 1,5 kW or 2,0 hp. This is shown in Figure D.14.

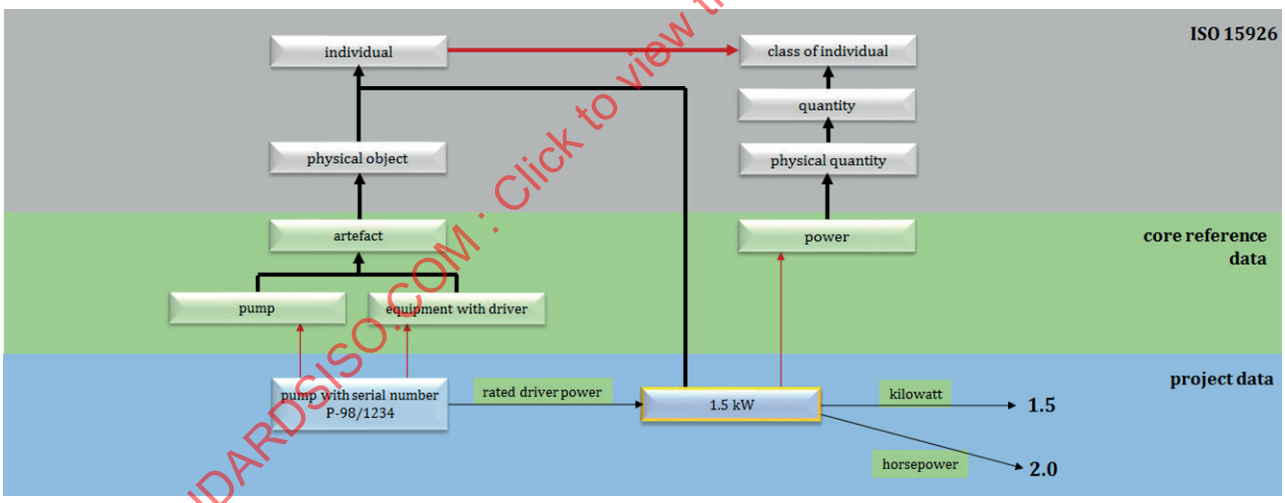


Figure D.14 — Rated driver power for an individual

The **physical quantity** "power" and the **scale** "kilowatt" are defined in the ISO 80000 and IEC 80000 series. For use within ISO 15926, it is necessary to interpret "power" as a member of the class **physical quantity** and to interpret "kilowatt" as **scale** that has its domain "power". This interpretation is carried out within ISO/TS 15926-4.

1,5 kW and 2,0 hp are representations of the same **physical quantity**, using different **scales**.

The example ontology is in the files:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of an individual.ttl

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of an individual - subset.ttl

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of an individual - subset.ofn

The SPARQL query that returns the rated driver power in kilowatts for each driven equipment item is as follows:

```
SELECT ?equipment ?ratedDriverPowerKW
WHERE {
  ?equipment ex-rdl:ratedDriverPower ?ratedDriverPower .
  ?ratedDriverPower ex-rdl:kilowatt ?ratedDriverPowerKW .
}
```

Usually, the object "1,5 kW" is anonymous, so that the representation of the rated driver power of pump P-98/1234 is:

ex-ind:P-98-1234 ex-rdl:ratedDriverPower [ex-rdl:kilowatt "1.5"^^xsd:float] .

A reference data library can define the composition of the functions "rated driver power" and "kilowatt" to give "rated driver power in kilowatt". This will give a simple representation of the rated diver power of pump P-98/1234 as:

ex-ind:P-98-1234 ex-rdl:ratedDriverPowerInKilowatt "1.5"^^xsd:float .

D.6.3 Property of a design

A design is a class of artefact. Each artefact that complies with a design is a member.

The pump design with model number WBX-356A has a rated driver power of 1,5 kW. This means that each individual pump that is a member of the design has a rated driver power of 1,5 kW.

Using the approach of ISO 15926-2, there is a relationship between WBX-356A and 1,5 kW, as shown in Figure D.15.

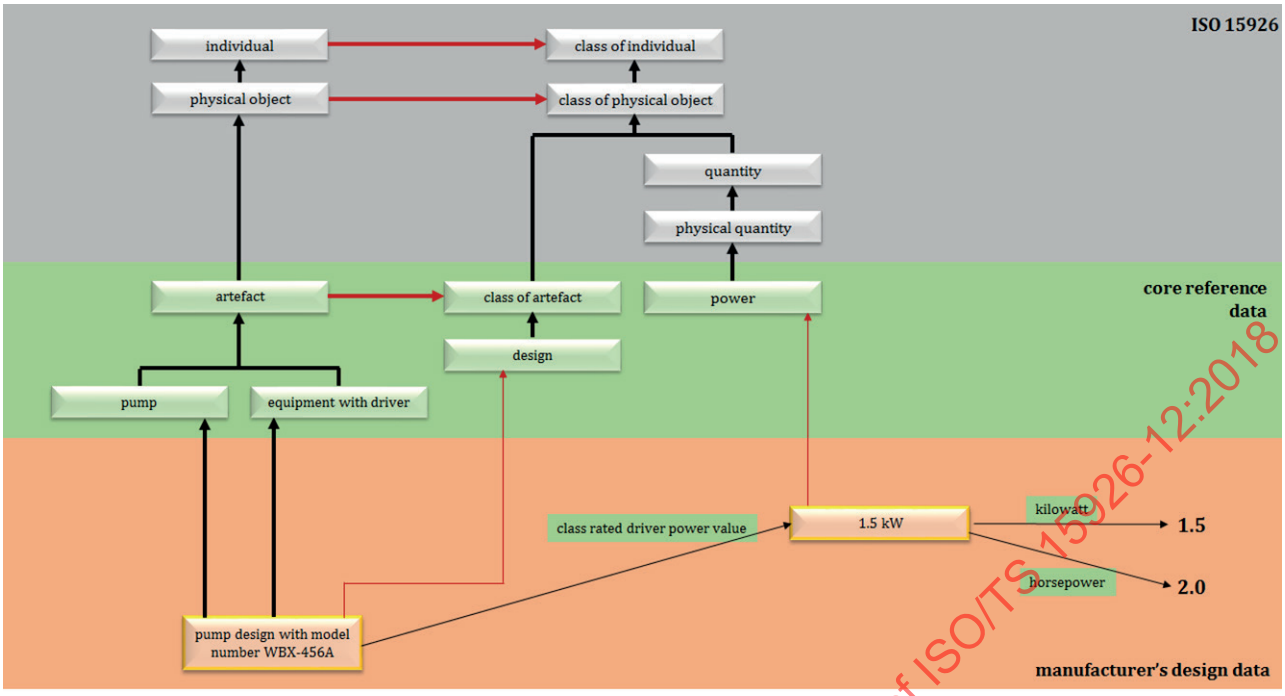


Figure D.15 — Rated driver power for a design

The example ontology is in the file:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of a design.ttl

The SPARQL query that returns the rated driver power in kilowatts for each design of a driven equipment item is as follows:

```
SELECT ?equipmentDesign ?ratedDriverPowerKW
WHERE {
  ?equipmentDesign a ex-rdl:Design .
  ?equipmentDesign ex-rdl:classRatedDriverPowerValue ?ratedDriverPower .
  ?ratedDriverPower ex-rdl:kilowatt ?ratedDriverPowerKW .
}
```

Where inferencing is the objective, the constraint upon individual members of a class is conveniently expressed using OWL using an owl:Restriction.

This is shown in Figure D.16.

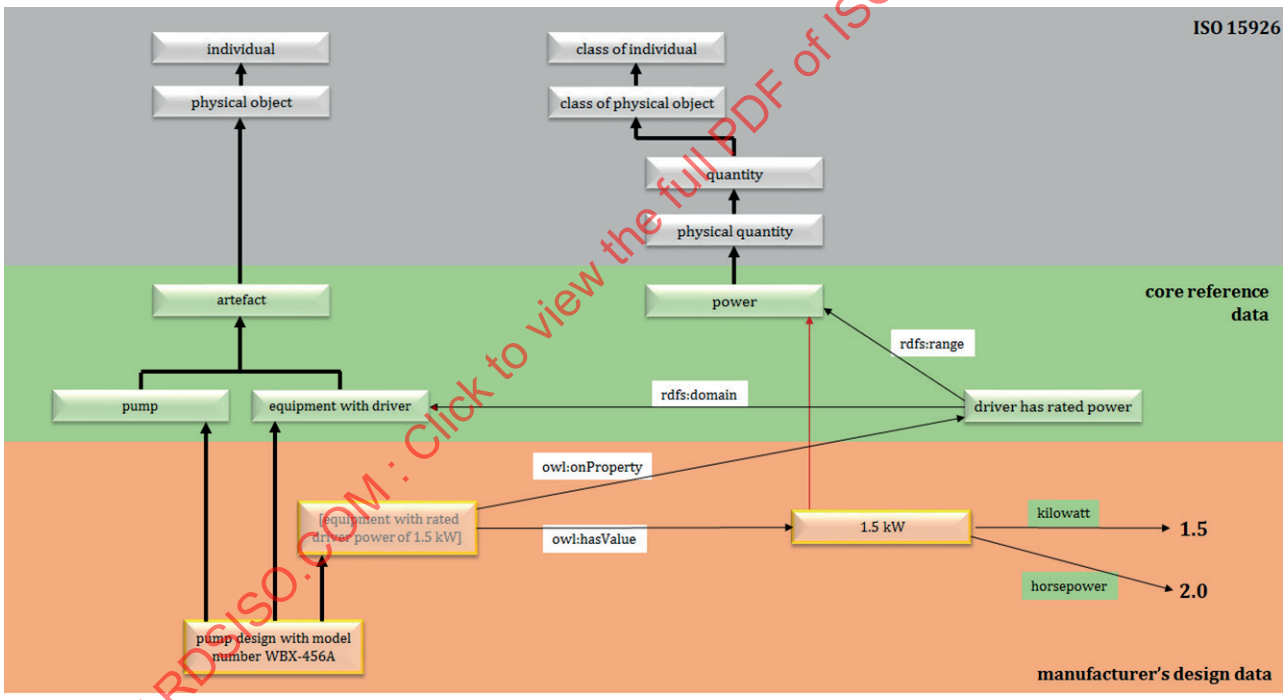


Figure D.16 — Rated driver power for a design — Restriction

The example ontology is in the files:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of a design - subset.ttl

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property of a design - subset.ofn

Inferencing can be applied to this ontology. Hence, from the statement that pump P-98-1235 is of design WBX-356A:

ex-ind:P-98-1235 rdf;type ex-eqt:WBX-456A .

it can be inferred that pump P-98-1235 has a rated driver power of 1,5 kW:

ex-ind:P-98-1235 ex-rdl:ratedDriverPower ex-ind:1-5kW .

D.6.4 Property range in the specification of a facility

A temporal part of pump facility 20-P-101 is classified as underpowered, if it has a rated driver power of less than 2 kW. This is shown in Figure D.17.

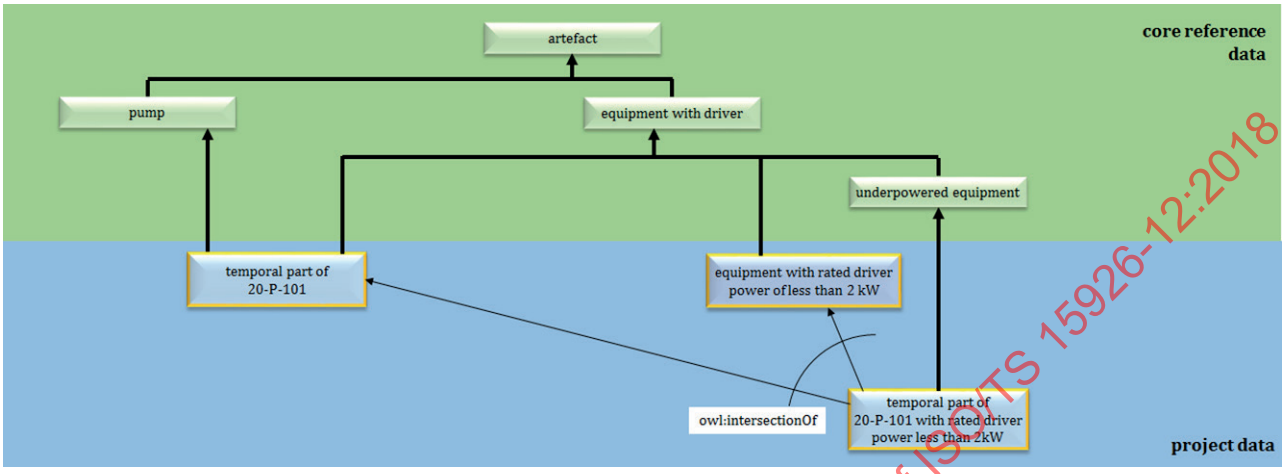


Figure D.17 — Property range in the specification of a facility

The classes “temporal part of 20-P-101” and “equipment with rated driver power of less than 2 kW” are defined by OWL restrictions. The example ontology is in the files:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property range for a facility - subset.ttl

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Property range for a facility - subset.ofn

It is proposed that a pump of model WBX-456A be installed as pump facility 20-P-101. Hence, it is proposed that a temporal part of 20-P-101 be a member of WBX-456A. This is shown in Figure D.18.

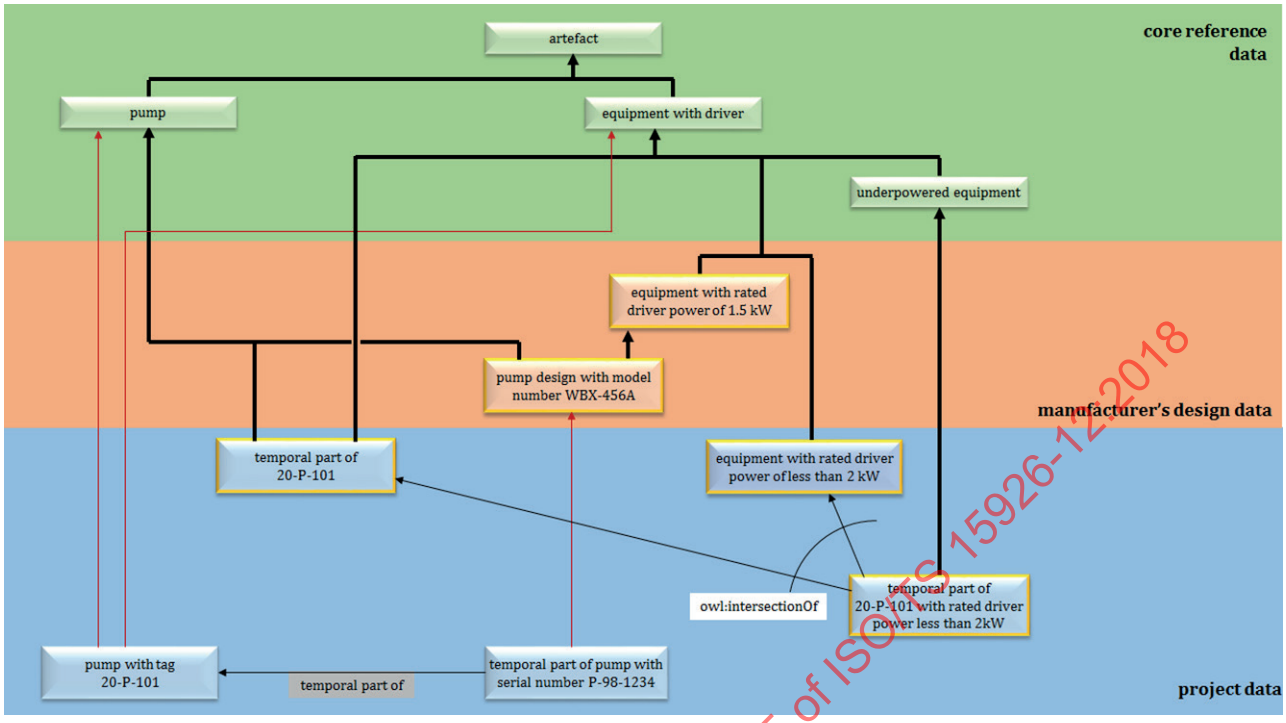


Figure D.18 — Proposed installation

Each pump of model WBX-456A has a rated driver power of 1,5 kW. Therefore, an inference engine can infer that the proposed installation is a member of the class “underpowered equipment”. The example ontology is in the files:

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Proposed installation for a facility - subset.ttl

http://standards.iso.org/iso/ts/15926/-12/ed-1/en/tech/ontology/examples/Proposed installation for a facility - subset.ofn

Annex E
(informative)

Representation of the ontology as diagrams

E.1 The 4D core

The principal subclasses of **individual** that define the 4D core of the ontology are shown in Figure E.1.

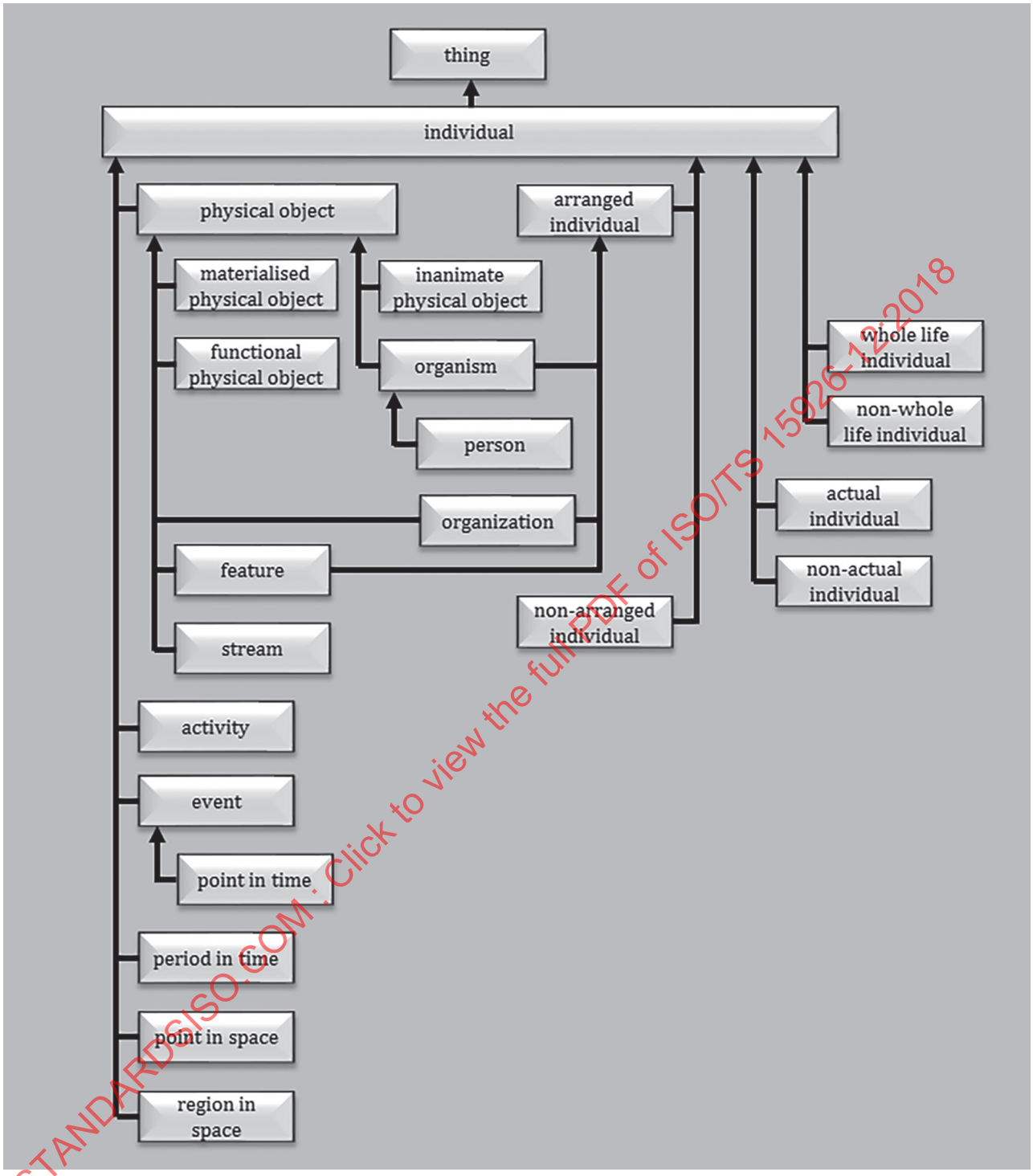


Figure E.1 — Principal subclasses of individual

The subclasses of **arranged individual** are shown in Figure E.2.

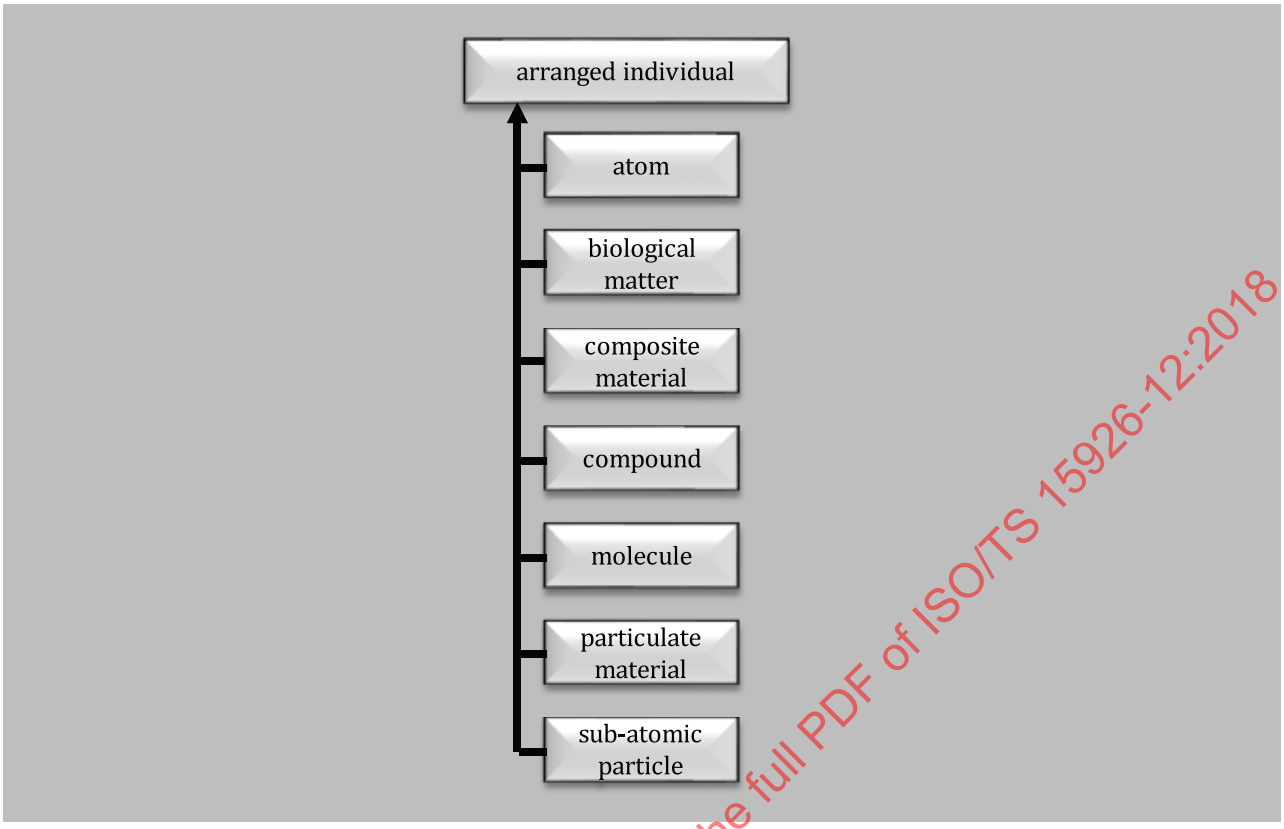


Figure E.2 — Subclasses of arranged individual

The relationships between **individuals** within the 4D core are shown in Figure E.3.

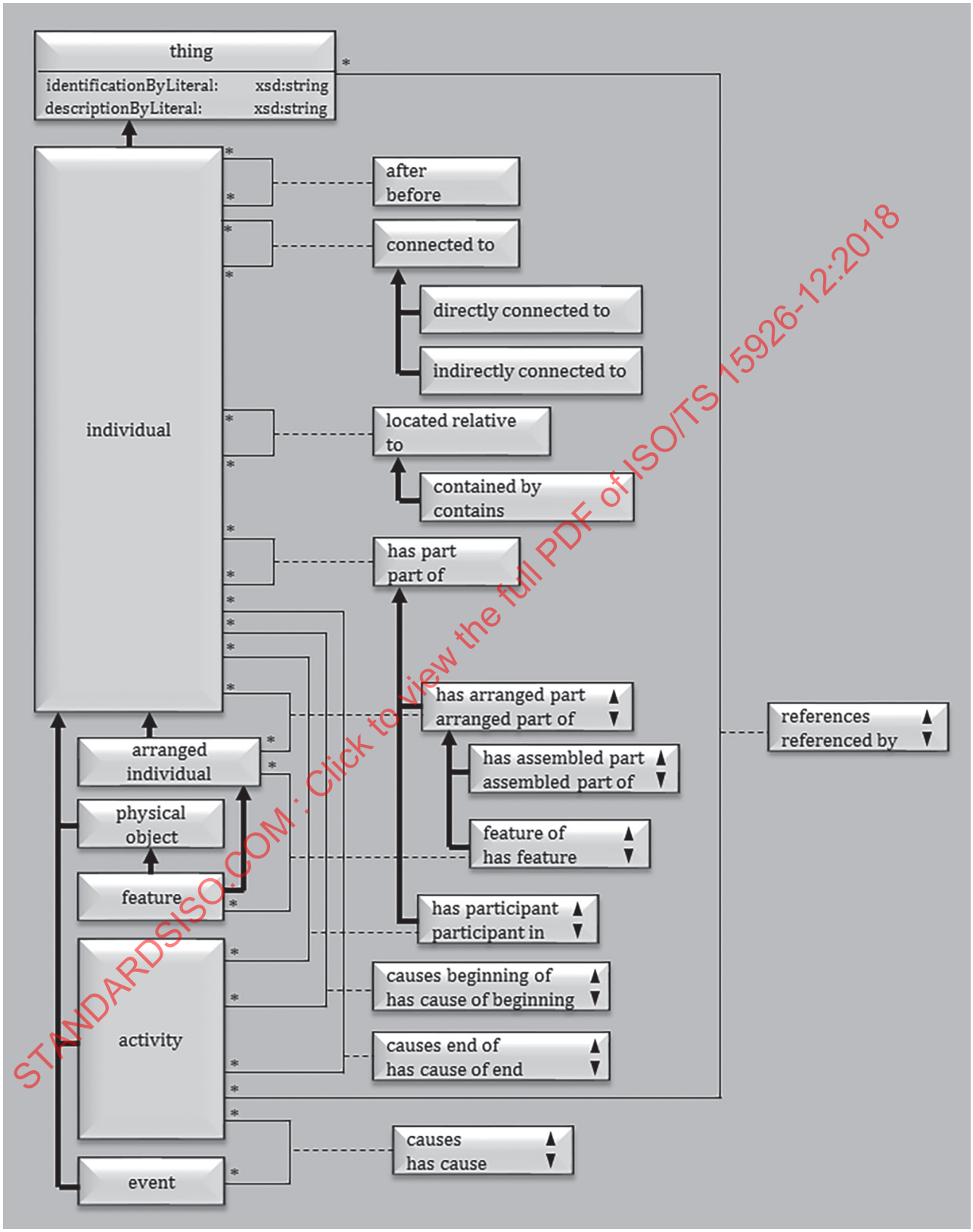


Figure E.3 — Relationships between individuals

The temporal bound relationships between **individuals** are shown in Figure E.4.

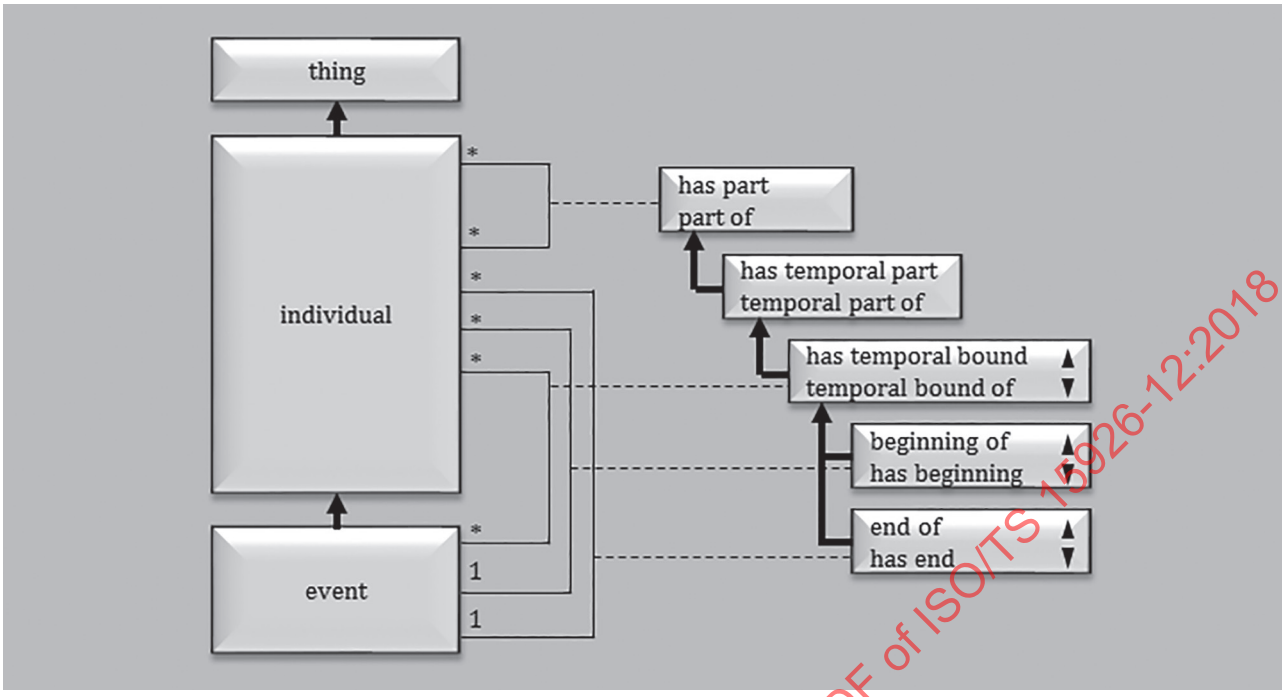


Figure E.4 — Temporal bound relationships

E.2 Classes of class in the 4D core

Principal subclasses of **class of individual** in the 4D core are shown in Figure E.5.

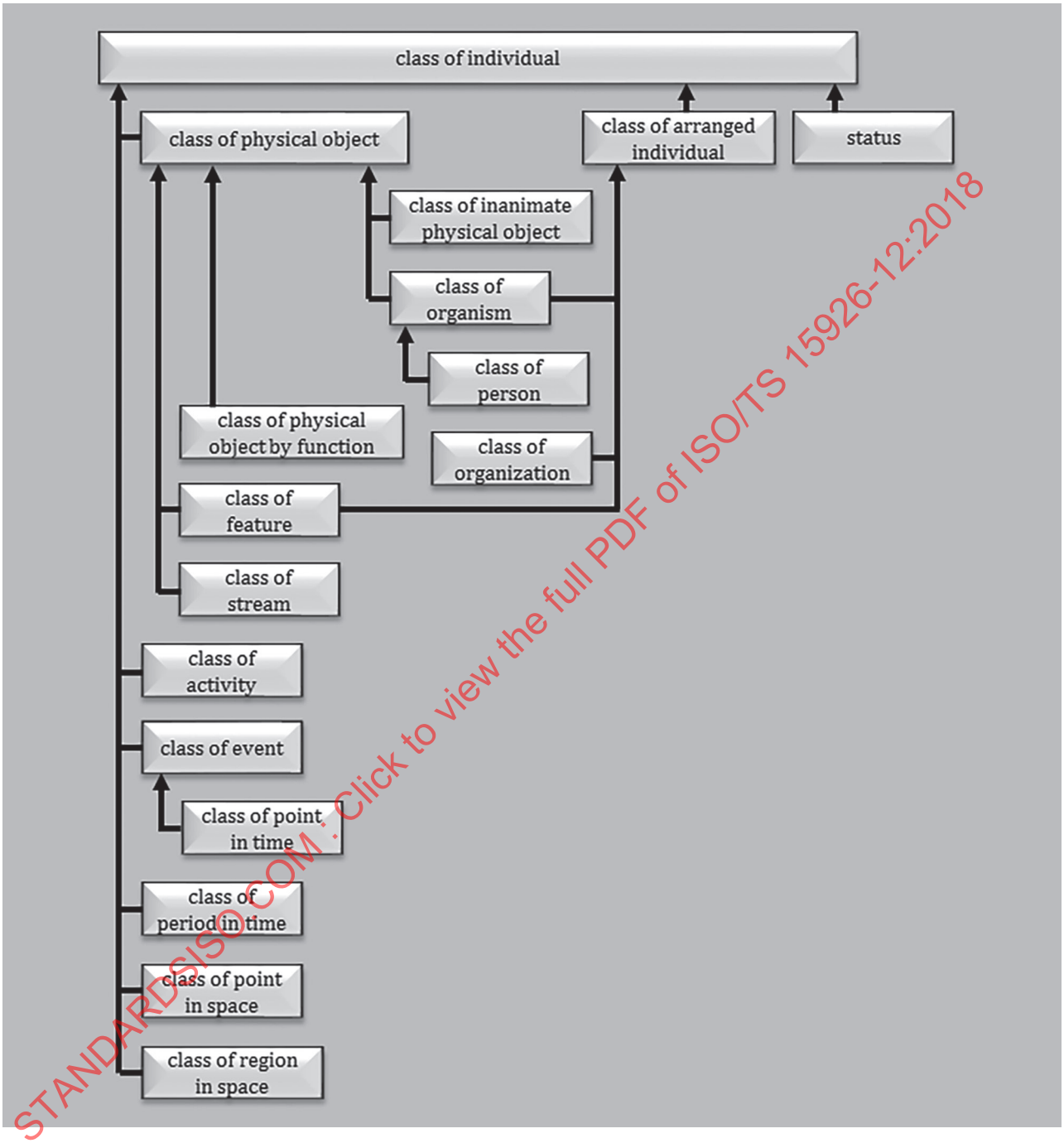


Figure E.5 — Principal subclasses of class of individual

Except for **status**, all the classes shown in Figure E.5 are power classes of classes shown in Figure E.1.

Subclasses of **class of arranged individual** are shown in Figure E.6.

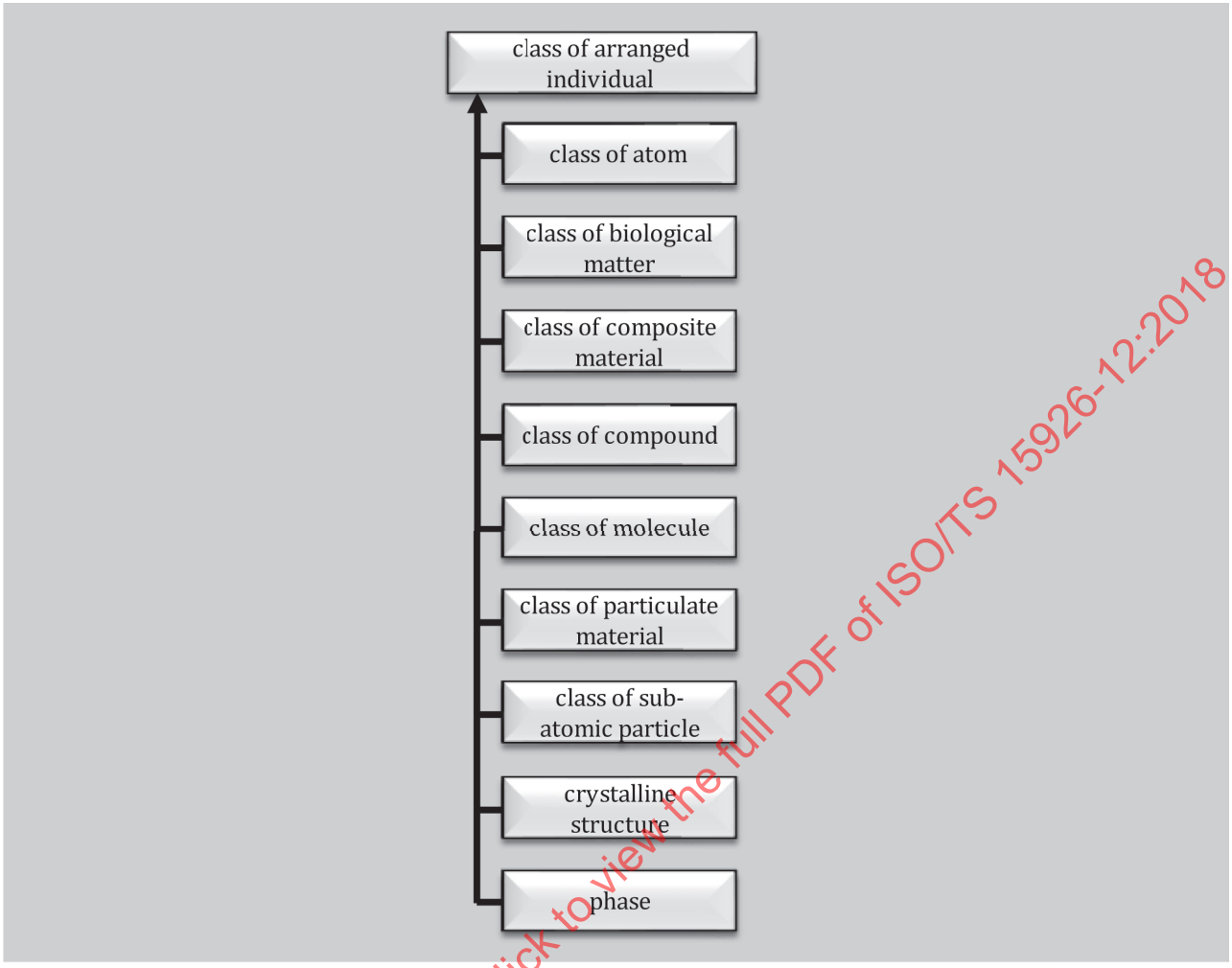


Figure E.6 — Subclasses of class of arranged individual

Except for **crystalline structure** and **phase**, all the classes shown in Figure E.6 are power classes of classes shown in Figure E.2.

Subclasses of **class of class of individual** are shown in Figure E.7.

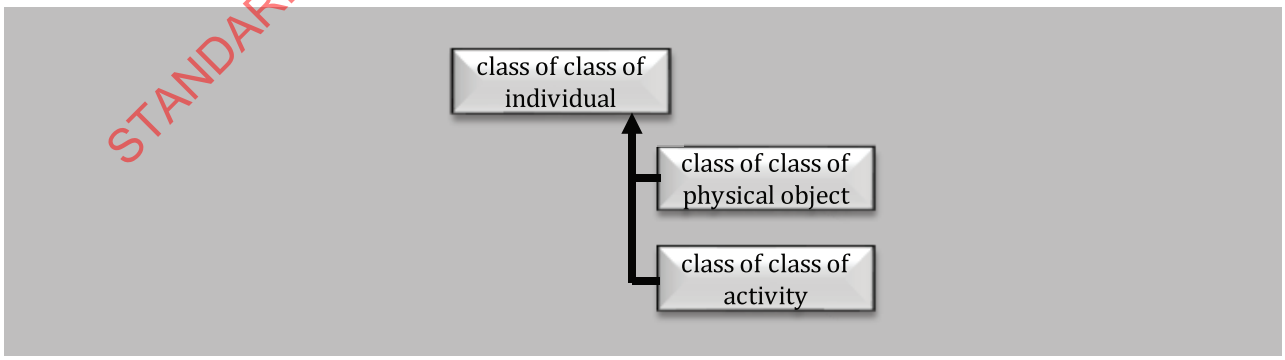


Figure E.7 — Subclasses of class of class of individual

All the classes shown in Figure E.7 are power classes of classes shown in Figure E.5.

E.3 Abstract object

The principal subclasses of **abstract object** are shown in Figure E.8.

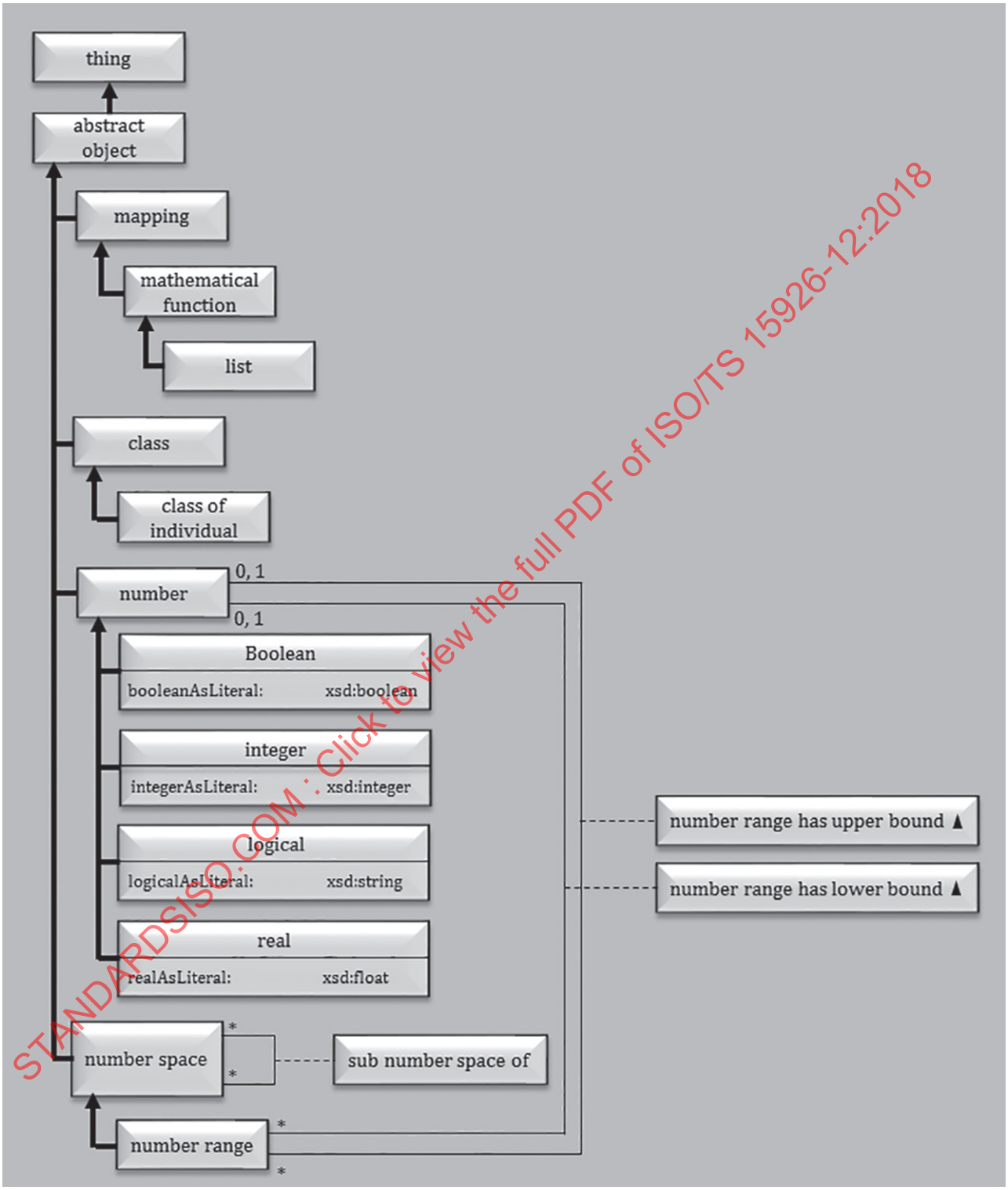


Figure E.8 — Principal subclasses of abstract object

E.4 Classes of abstract object

Principal subclasses of **class of abstract object** are shown in Figure E.9.

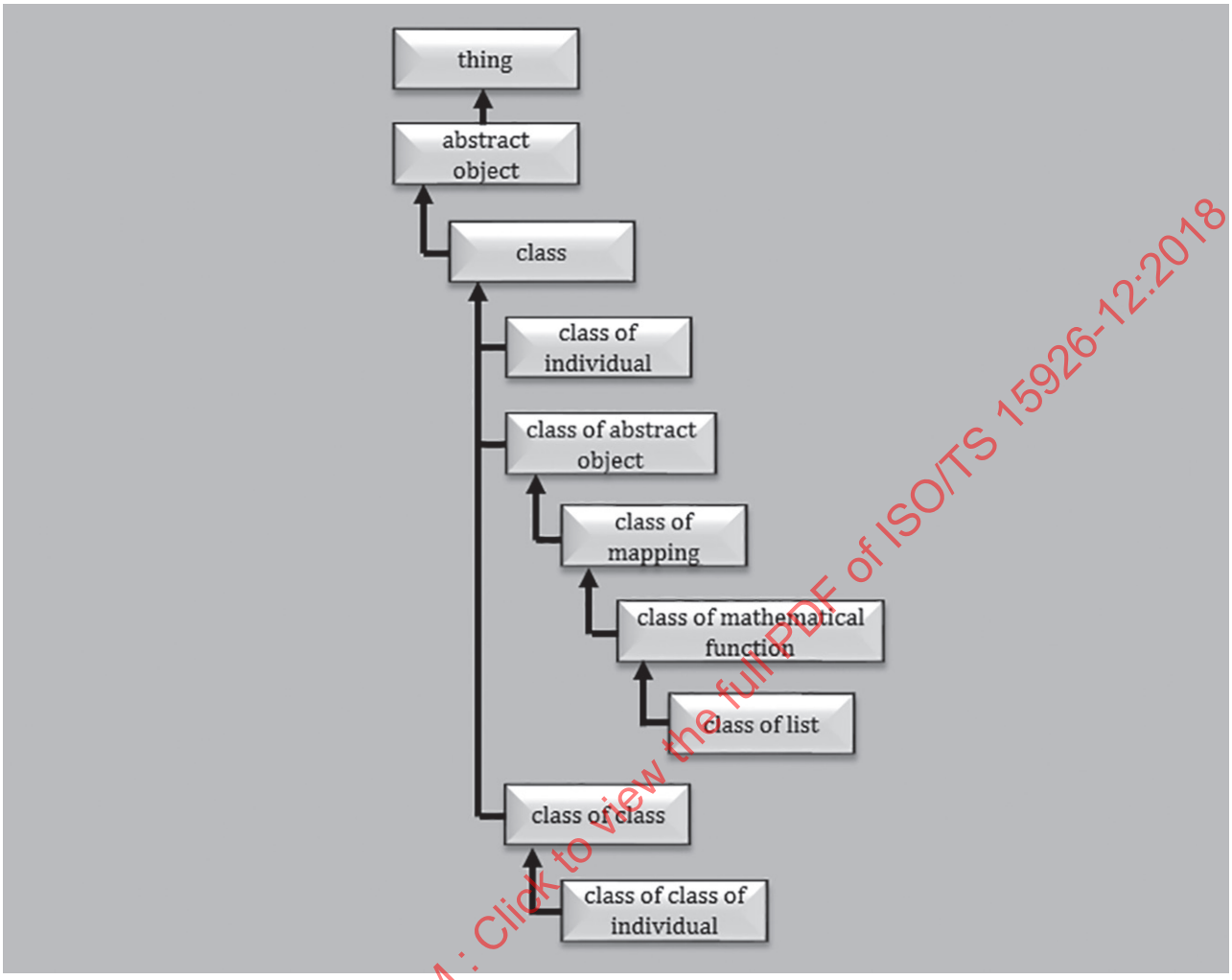


Figure E.9 — Principal subclasses of class of abstract object

All the classes shown in Figure E.9 are power classes of classes shown in Figure E.8.

E.5 Physical quantity and property

Classes for **physical quantities** and **physical properties** are shown in Figure E.10.

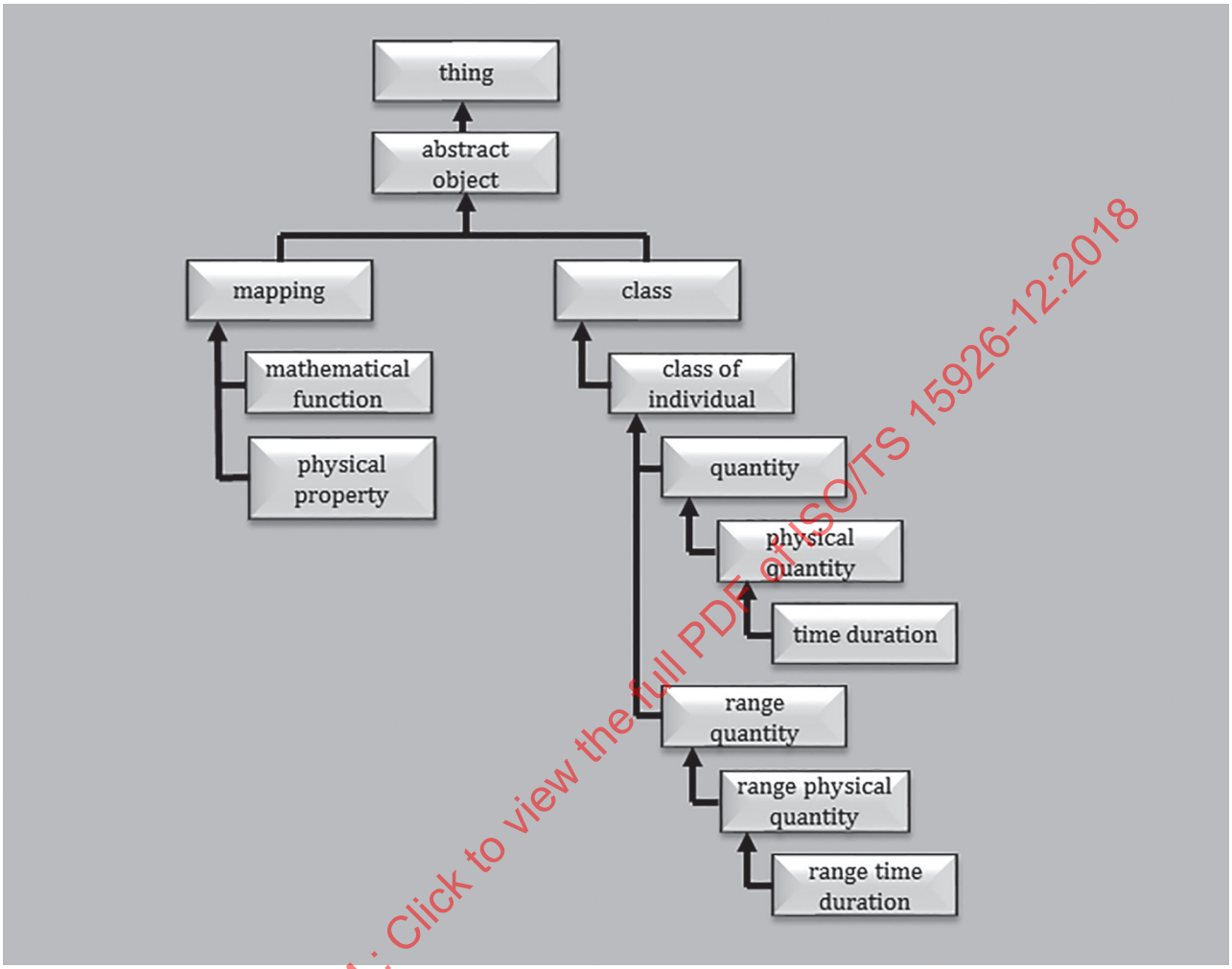


Figure E.10 — Classes for physical quantities and properties

Examples of **physical properties** and **physical quantities** are shown in D.6.1.

E.6 Subclasses of class of quantity

Subclasses of **class of quantity** are shown in Figure E.11.

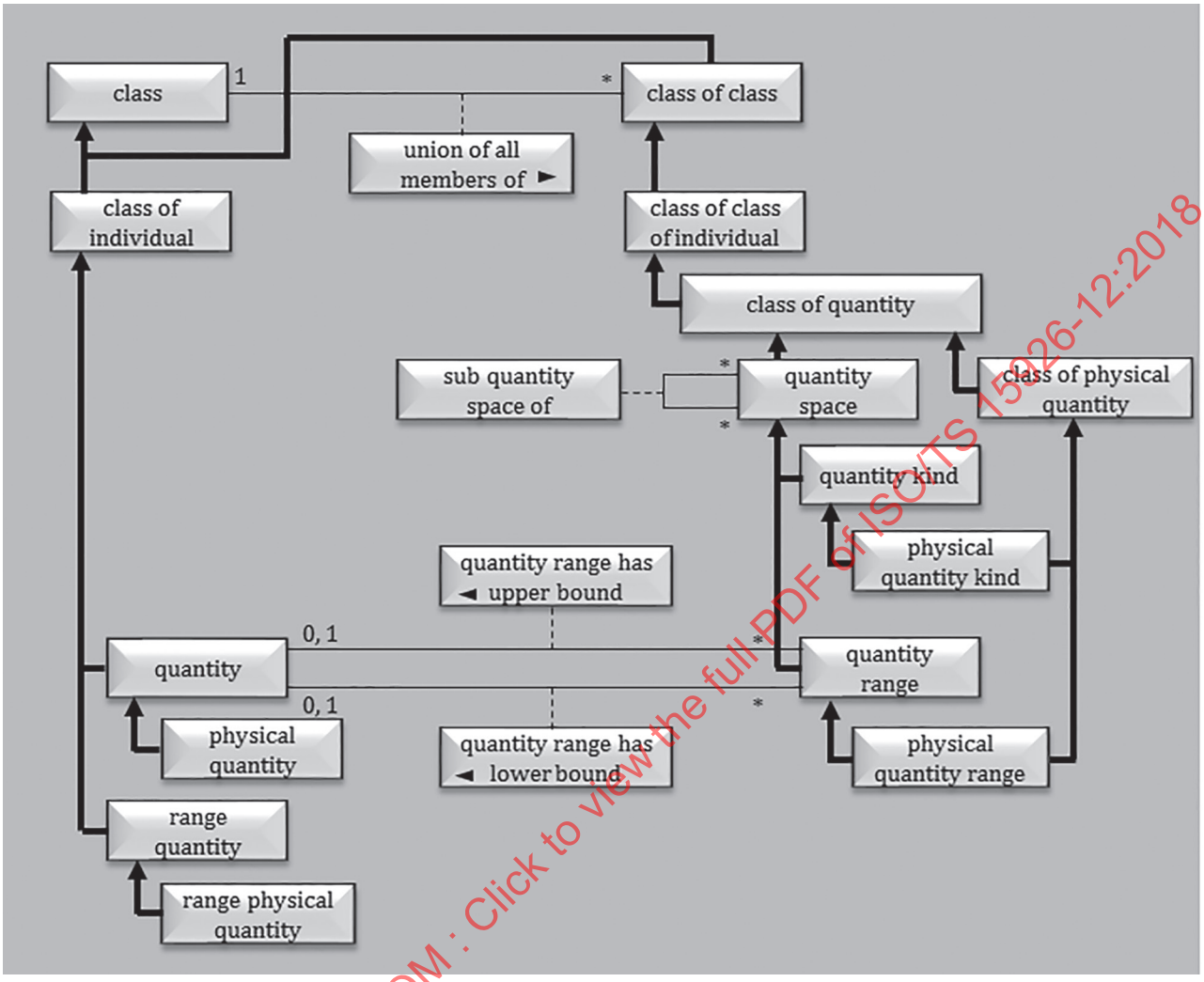


Figure E.11 — Subclasses of class of quantity

E.7 Ordered pair and ratio

Classes for **ordered pair** are shown in Figure E.12.

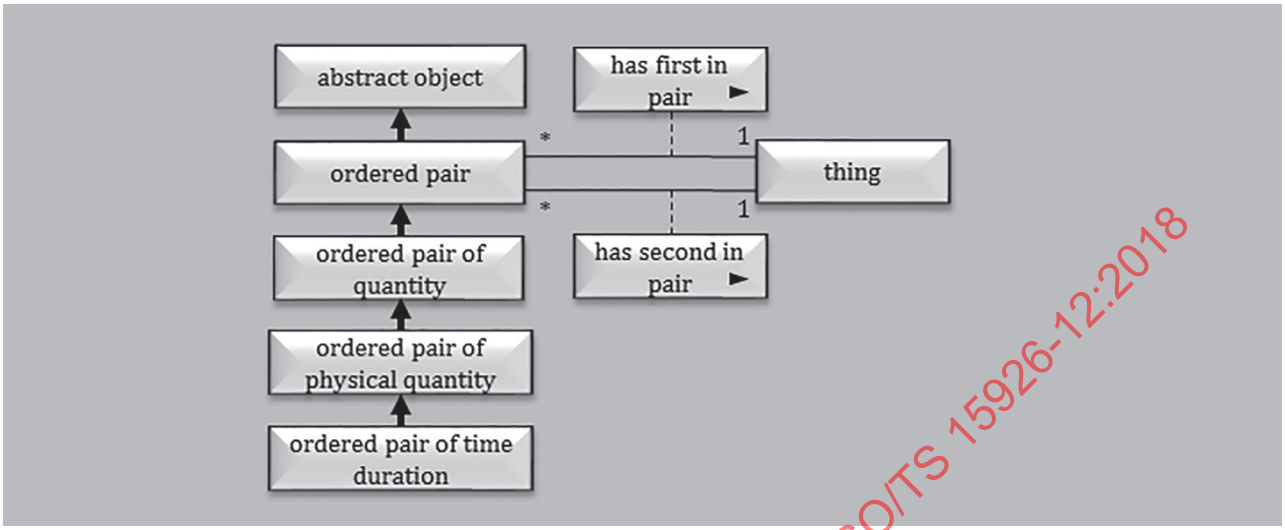


Figure E.12 — Ordered pair

Classes for **class of ordered pair** and **ratio** are shown in Figure E.13.

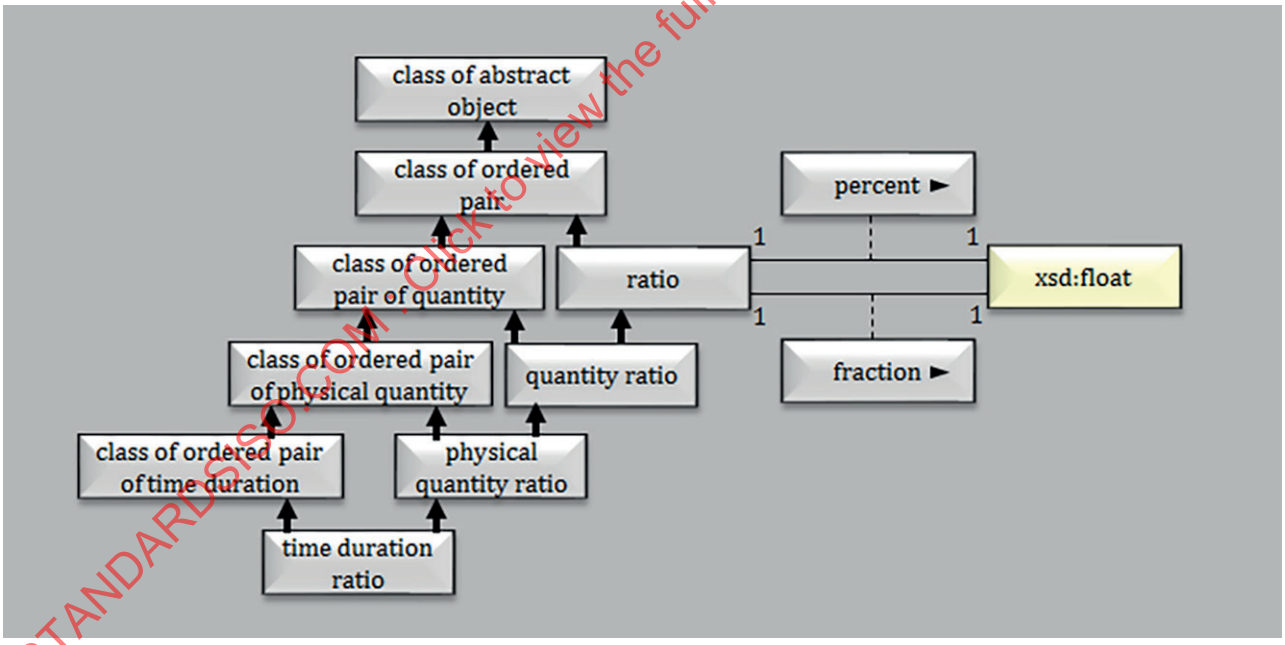


Figure E.13 — Class of ordered pair and ratio

Examples of **ordered pair** and **ratio** are shown in D.5.

E.8 Scale and class of scale

The classes **scale** and **class of scale** are shown in Figure E.14.

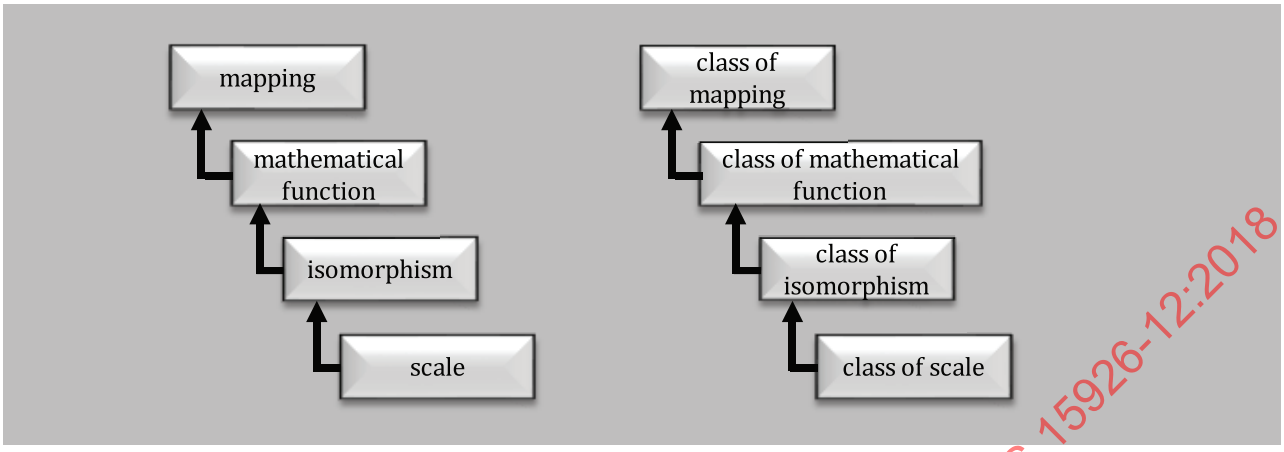


Figure E.14 — Scale and class of scale

E.9 Information object and information content

Classes for information objects and their content are shown in Figure E.15.

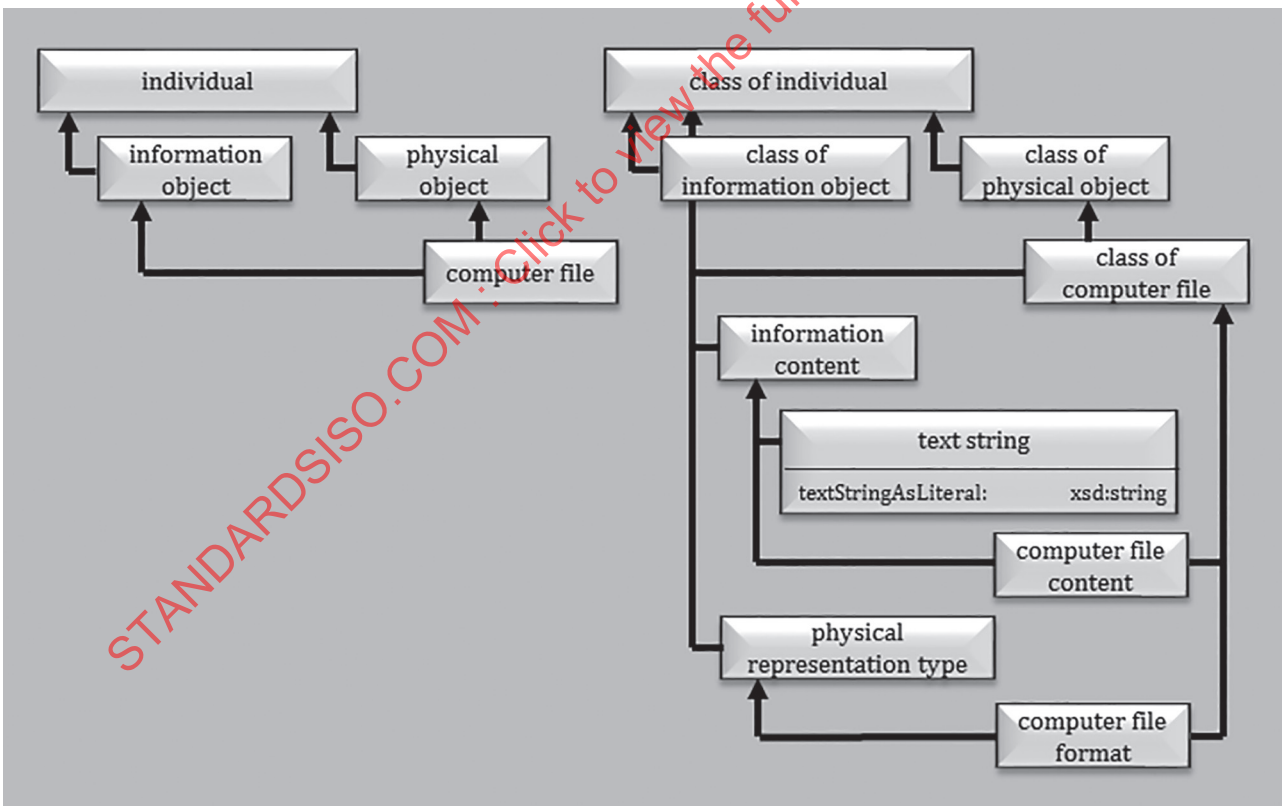


Figure E.15 — Classes for information objects and their content

E.10 Classes of information content

Subclasses of **class of information content** are shown in Figure E.16.

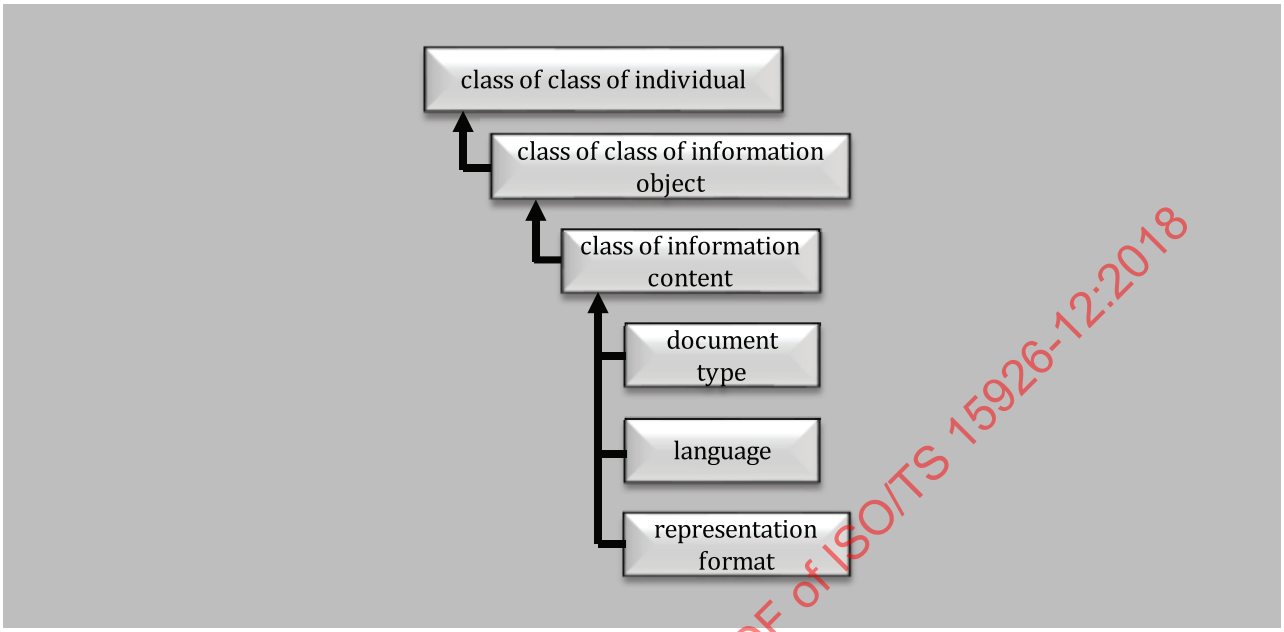


Figure E.16 — Subclasses of class of information content

E.11 Representation

Sub-properties of **representation by** for identification, description and definition are shown in Figure E.17.

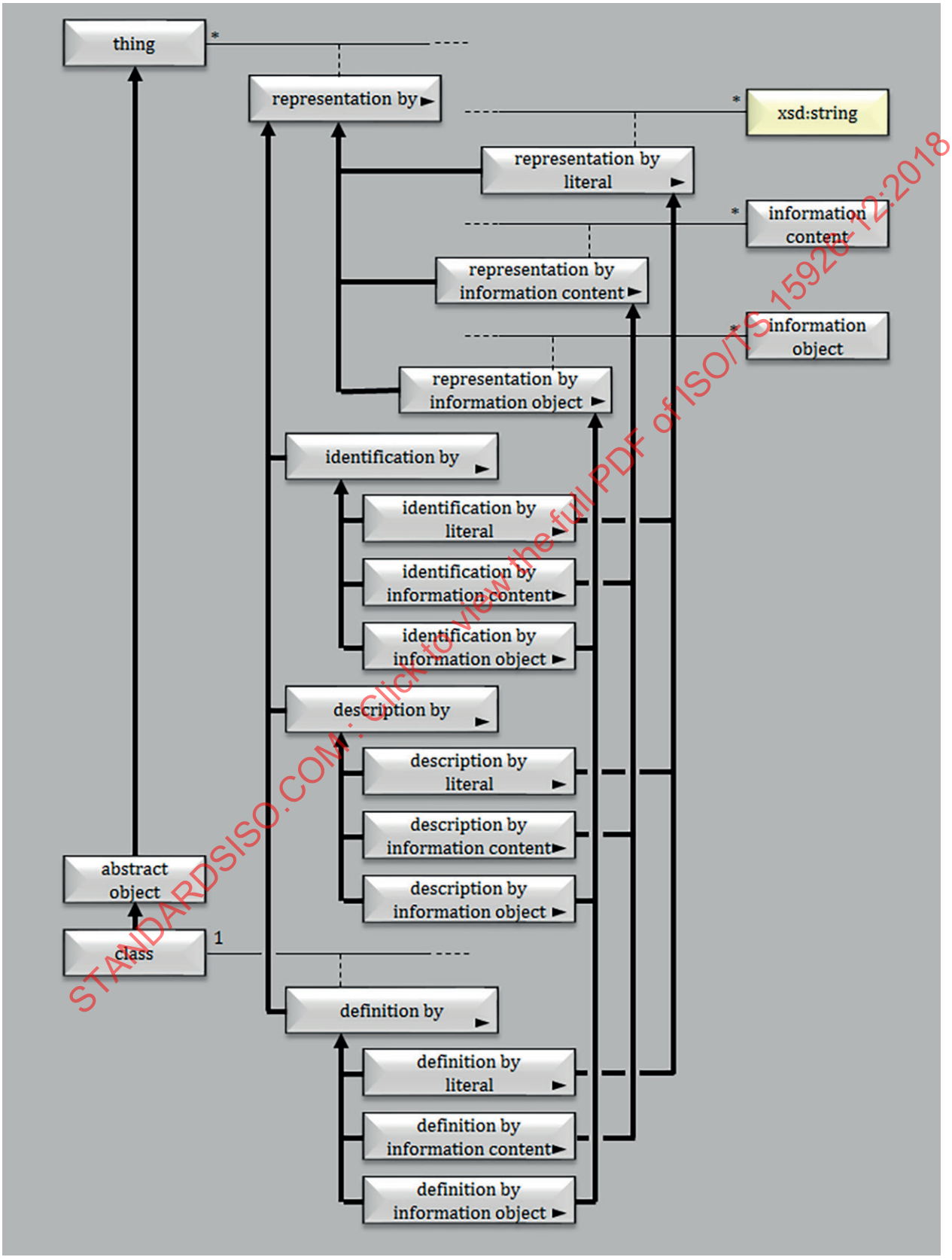


Figure E.17 — Sub-properties of representation by for identification, description and definition

Sub-properties of **representation by** for notes and examples are shown in Figure E.18.

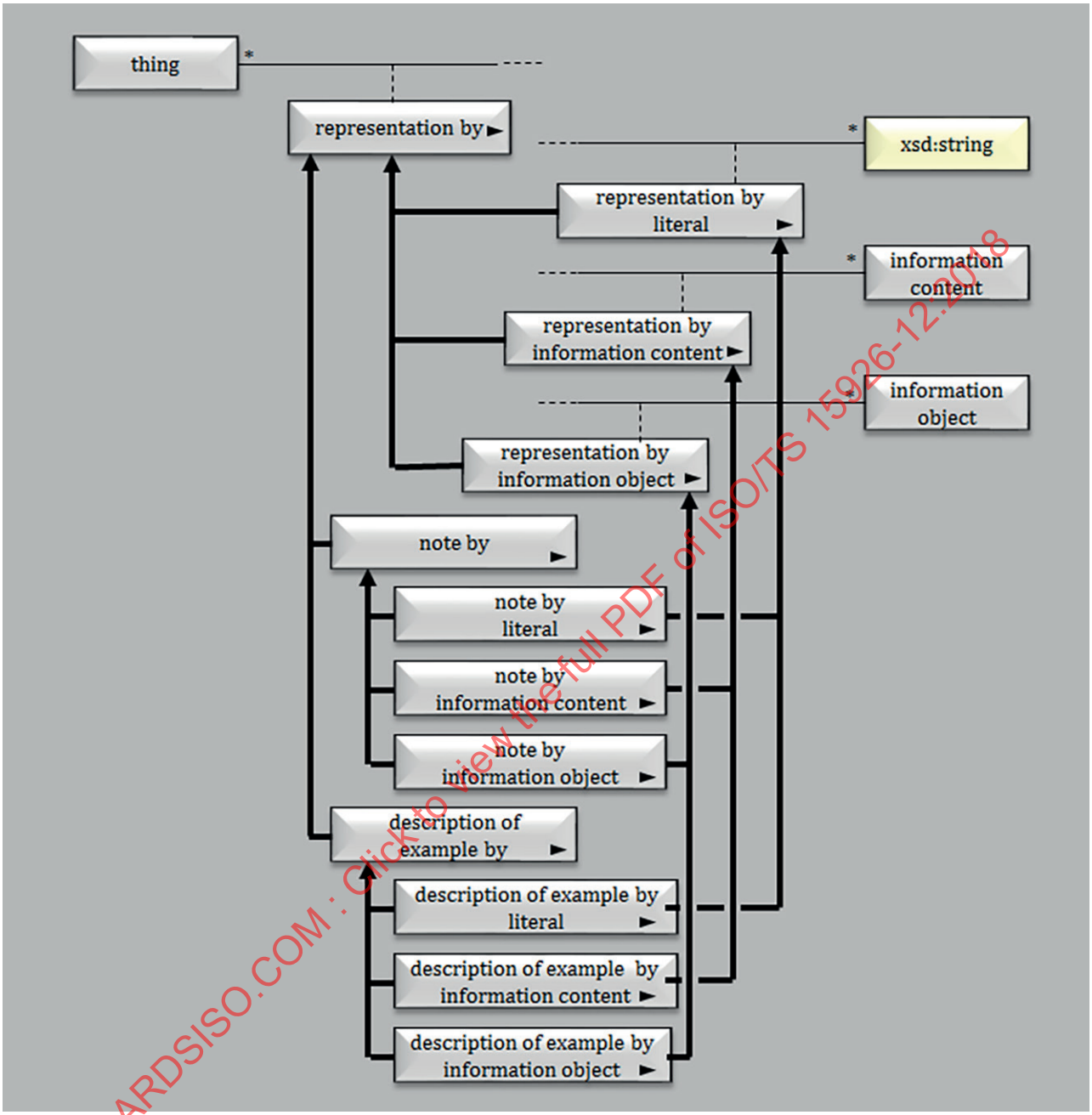


Figure E.18 — Sub-properties of representation by for notes and examples

Examples of **representation by** are shown in D.3.

E.12 Representation space

Subclasses of mapping for **representation space** are shown in Figure E.19.

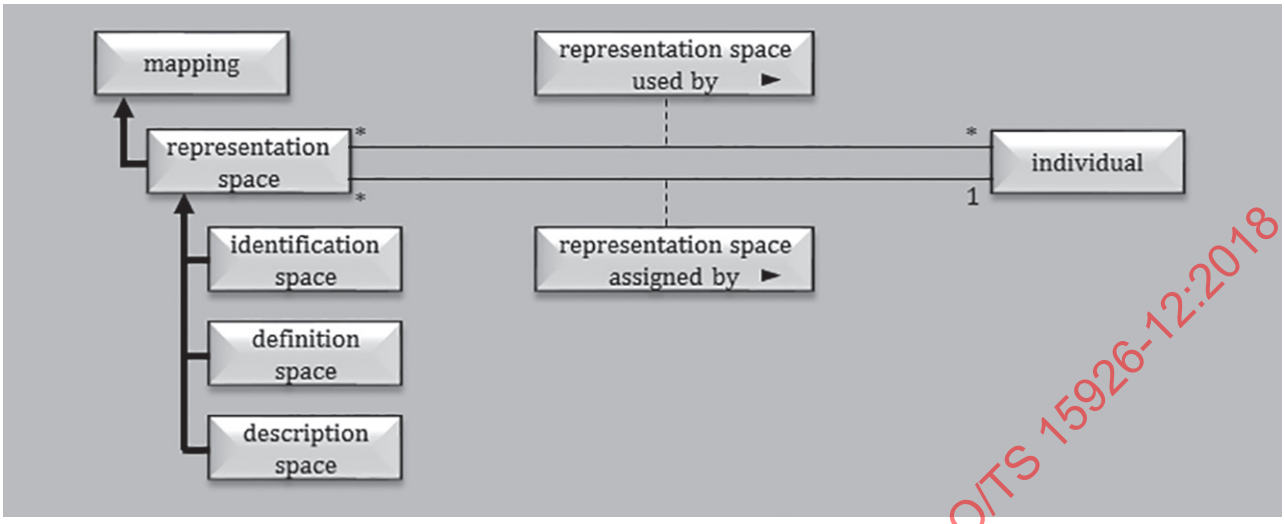


Figure E.19 — Subclasses of mapping for representation space

Examples of **representation space** are shown in D.3.

Annex F
(informative)

Requirements and designs

F.1 ISO 15926 in the design process

This annex contains an example scenario of the use of ISO 15926 in a design process.

The example considers a required bridge for which functional requirements are defined. These requirements are refined and changed during the design process.

A proposed technical solution for the bridge is defined by a design specification. This specification is refined and changed during the design process.

Ultimately, an actual bridge is constructed which fulfils the requirement and the proposed technical solution.

F.2 Functional specification

F.2.1 Initial specification

"Required bridge at P v1" is the initial required **physical object**. It is defined by "functional requirements" that are:

— it crossed river R at P;

— it begins on 2020-01-01.

This is shown in Figure F.1.

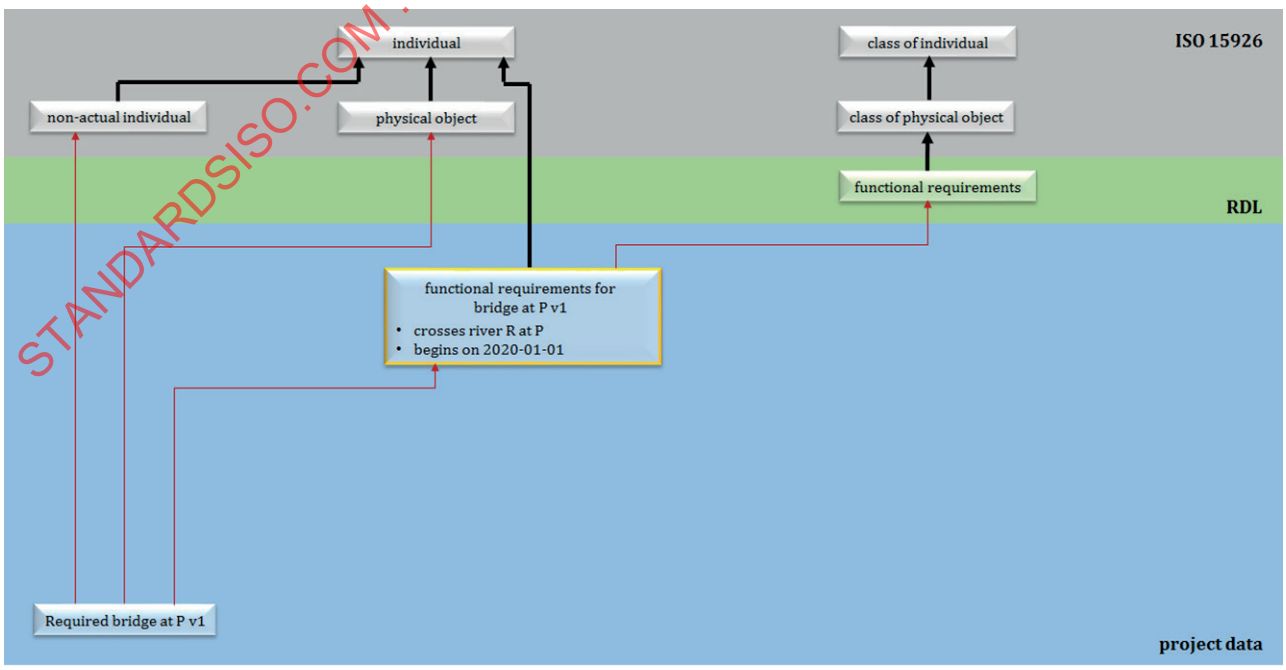


Figure F.1 — Required bridge and its initial functional specification