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Dossier
Software Interoperability for Petroleum Applications
Interopérabilité logicielle : les applications dans l'industrie pétrolière

ISO 15926 "Life Cycle Data for Process Plant": An Overview

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Résumé — ISO 15926 « Données de procédés au long du cycle de vie » — Cet article donne les raisons pour lesquelles la norme ISO 15926 *Life Cycle Data for Process Plant* (données de procédés au long du cycle de vie) a été développée, ainsi que ses relations avec la norme STEP (ISO 10303) pour l'échange de données d'ingénierie. Nous utilisons l'approche « 4D » pour représenter les modifications. Nous montrons que cette approche permet une représentation de l'information d'ingénierie basée sur la logique du premier ordre, ce qui permet donc d'utiliser le formalisme RDF/OWL.

Abstract — ISO 15926 "Life Cycle Data for Process Plant": An Overview — *This paper explains why ISO 15926 "Life Cycle Data for Process Plant" has been developed and its relationship to the STEP (ISO 10303) standard for engineering data exchange. The use of the "4D approach" to the representation of change is described. It is shown that this approach allows a representation of engineering information using first order logic, and hence that ISO 15926 can be represented using RDF/OWL.*

1 BACKGROUND TO PROCESS PLANT DATA EXCHANGE STANDARDS

1.1 First Data Exchange Standards

Data exchange has been a problem for as long as computer systems have been used in engineering. Draughting and then 3D modelling were amongst the first areas to be computerised, and immediately there was a need to exchange 2D and 3D geometry information between different CAD systems.

In order to provide a standard file format for geometry information exchange, the ANSI standard IGES (Initial Graphic Exchange Standard) was developed by *Boeing*, *General Electric* and *NIST* in 1979.

IGES had two problems:
– it was limited to geometric information, and did not support information about the nature of the object with the shape (*i.e.* is it a pump, vessel, or heat exchanger?);
– the design of the standard did not separate the definition of the information from the definition of the format used to represent it.

In order to address these problems a replacement standard STEP (STandard for the Exchange of Product data [1]), was begun in 1984. This standard was intended to encompass a wide range of engineering information including and process plant design and finite element analysis.

The first release of ISO 10303 was in 1994, and was limited to geometry (with much the same scope as IGES) and product structure configuration. By 2000 STEP has demonstrated its superiority to IGES and was becoming widely used, especially in the aerospace and automotive industries.

The second release of STEP in 2000 encompassed finite element analysis, printed circuit board design and the spatial layout of process plants. In these areas, STEP is now beginning to have industrial applications. In particular, *Airbus* is making use of the STEP standard for finite element analysis data.

1.2 First Data Exchange Standards for the Process Industries

The possibility of using STEP for process industry data was recognised in 1990, and industry consortia were formed in Europe, United States and Japan to promote its use.

The United States focused upon spatial information about process plant, and the US PlantSTEP consortium funded the development ISO 10303 part 227 “Plant spatial configuration”, known as AP (Application Protocol) 227 [2].

Note: ISO 10303 defines data structures for the exchange of many different types of information. An “Application Protocol” specifies a subset of these data structures for a particular industrial application. An “Application Protocol” may also make the meaning of some generic data structures more precise.

Europe focused upon functional information about process plant, and the European EPISTLE consortium funded the development of AP 221 “Functional data for process plant and their schematic representation” [3] in parallel with AP 227. This standard encompasses schematics such as P&IDs (Piping and Instrumentation Diagrams) and PFDs (Process Flow Diagrams), and the engineering facts that the schematics represent.

Work upon AP 221 encountered technical difficulties because the EPISTLE consortium requires a standard that can record changes to a process plant throughout its life. The EPISTLE objective is to define a standard for a process plant data warehouse which can contain information about:
– the requirements for a process plant, and changes to the requirements;
– the design for a process plant, and changes to the design;
– the physical objects that exist in a process plant and changes to these physical objects.

This objective is outside the scope of STEP. As a result, ISO 15926 “Life cycle data for process plant” [4] was developed as a companion standard to STEP. Both STEP and ISO 15926 are products of ISO committee TC184/SC4.

AP 221 remains but does not consider the evolution of a process plant through time. The relationship between AP 221 and ISO 15926 is discussed in Section 4.

2 THE ISO 15926 SCOPE AND APPROACH

2.1 Parts of the Standard

ISO 15926 standard contains:

Part 1: Introduction

Part 2: Information Model [5]

The information model is written using the STEP information modelling language EXPRESS [6]. The scope of the information model is:
– generic concepts associated with set theory and functions;
– concepts and relationships that implement the “4D approach” to describing changes to physical objects, which is described in Section 5.3;
– generic relationships relevant to engineering such as connection, composition, containment and involvement (in an activity).

Part 4: Reference Data Library [7]

The reference data library contains a dictionary of basic classes and properties used within the process industries.

The dictionary specialises the generic concepts within the information model. The first release of the reference data library will contain about 10,000 classes and properties.

It is intended that the reference data library will be subject to continual revision and extension as an ISO register. ISO 15926 parts 5 and 6 define the methodology for maintaining the register.

Terminology: the terms "dictionary", "catalogue", "reference data library" and "ontology" are regarded as synonyms in this paper.

A hierarchy of process industry ontologies is shown in Figure 1.

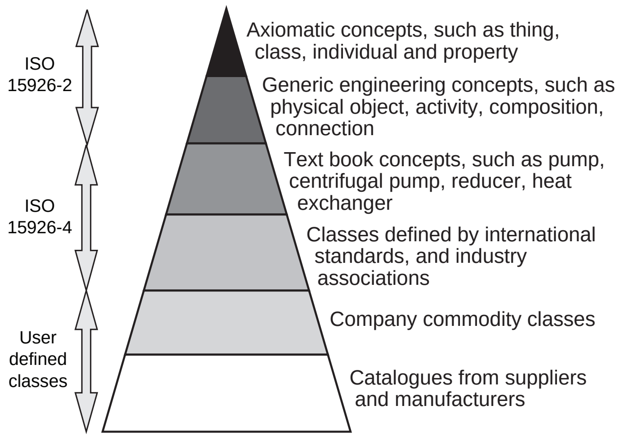

Figure 1

Hierarchy of process industry ontologies.

The number of classes and properties in the different ontologies increases rapidly, as you go down the pyramid. There are about 200 classes and properties in ISO 15926-2 and about 10 000 in the first release ISO 15926-4. It is expected that a full coverage of classes defined by process industry standards bodies and associations, such as API and NORSOK, will require hundreds of thousands of items.

The processes necessary for organising and indexing such a large number of classes are still being developed. A basic organisation is provided by the requirement that each class be a subclass of another class further up the pyramid, and hence of a class defined in ISO 15926-4.

A second level of organisation is provided by giving each class and property a URN [8], and also a URL so that a definition can be found on the Internet. A proposal for a URN namespace and URI scheme for ISO standards was presented to the October 2004 meeting of ISO TC184/SC4. The use of this scheme will ensure that each class and property defined within ISO 15926-4 has a URN.

3 A DESCRIPTION OF THE ISO 15926 APPROACH

3.1 Physical Objects and Dictionaries

ISO 15926 defines a format for the representation of information about a process plant. The basis for ISO 15926 is a record of:

- the physical objects that exist within a process plant;
- identifications of the physical objects;
- properties of the physical objects;
- classifications of the physical objects;
- how the physical objects are assembled;
- how the physical objects are connected.

ISO 15926 does not only record the process plant as it exists at an instant, but also:

- how the process plant changes as a result of maintenance and refurbishment activities;
- the requirements for a process plant and the design for a process plant; which may not directly correspond to a process plant as it exists.

The class, or type, of a physical object is defined by reference to a dictionary. There are hundreds of thousands of classes of physical object used within the process industry. ISO 15926 does not attempt to standardise all these classes, but instead provides a small set of basic engineering classes which can be specialised by reference to a dictionary.

Note: The reference is made by instantiating a proxy for the class defined in a dictionary and by associating information with this proxy, such as:

- the name of the source dictionary, which defines a namespace for the identification of the class;
- the identifier of the class within the source dictionary.

Referencing is straightforward if the class has a global unique identifier such as a URI [8].

ISO 15926 part 4 standardises an initial set of a few thousand generic classes. It is hoped that companies and industry associations will create dictionaries that extend this initial set.

3.2 A Record of What Exists

The use of ISO 15926 to record the physical objects that exist within a process plant is illustrated by the example shown in Figure 2.

In the example, there is a physical object that:

- has identifier P4506a;
- is classified as a centrifugal pump.

This information is recorded by the two relationships shown in Figure 3.

The relationships **identification** and **classification** are defined within ISO 15926-2. The class **centrifugal pump** is defined within ISO 15926-4. The physical object can be

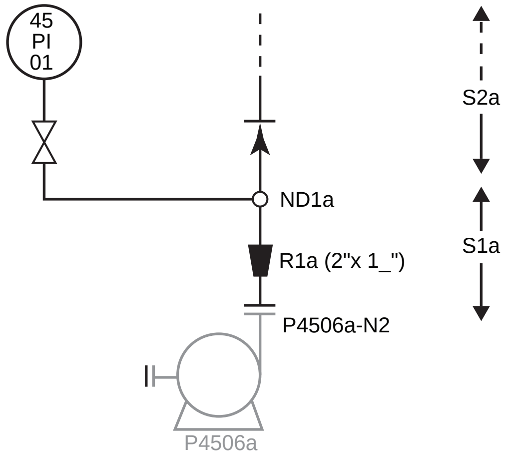

Figure 2

A fragment of a P&ID.

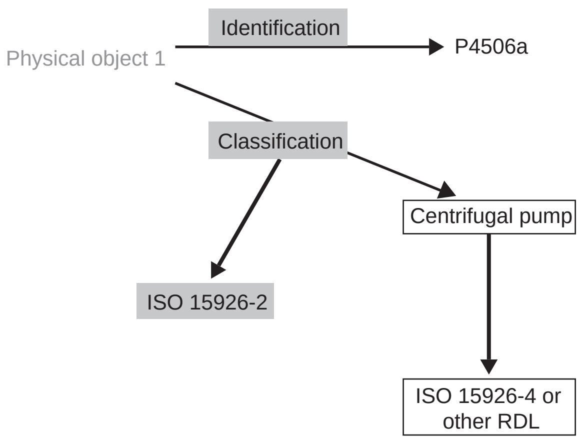

Figure 3

Identification and classification relationships.

given additional more precise classifications by reference to a company commodity dictionary or to a manufacturers catalogue.

Note: A P&ID defines the identification and connectivity of objects in a process plant. The symbol on the P&ID also provides a basic classification of the objects. Figure 2 also shows a reducer R1a, a pressure instrument 45 PI 01, and two pipe segments S1a and S2a.

3.3 Composition and Connection

Pump P45-6a has an outlet nozzle P4506a-N2 (shown in Figure 2). The nozzle is a physical object that:

– has a composition relationship with pump P4506a;
– is classified as both a nozzle and an outlet.

This information is recorded by the relationships shown in Figure 4.

Nozzle P4506a-N2 is connected to pipe segment S1a (shown in Figure 2). The pipe segment is a physical object that:

– has a connection relationship with nozzle P4506a-N2;
– is classified as a pipe segment.

This information is recorded by the relationships shown in Figure 5.

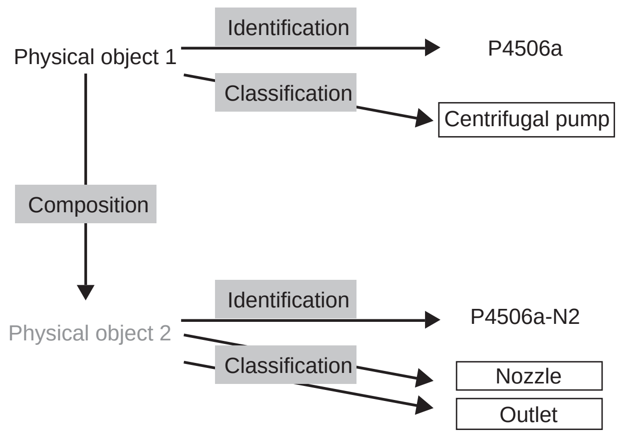

Figure 4

Composition relationship.

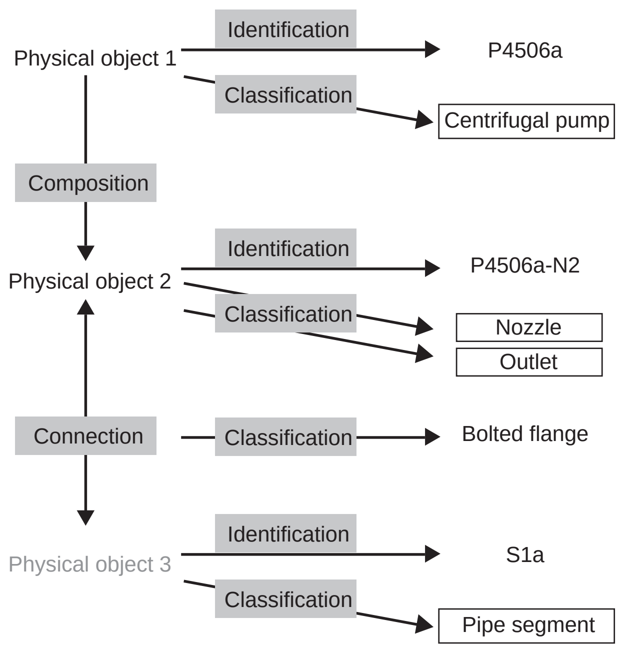

Figure 5

Connection relationship.

3.4 Detail as Required

The analysis of the information shown in the P&ID in Figure 2 can continue in a similar fashion showing that:

- reducer R1a is a part of segment S1a;
- S1a is connected to node ND1a.

It may is necessary to record additional detail, such as the ends of the individual lengths of pipe within the segment, as shown in Figure 6.

In Figure 6, detail has been added to the P&ID to show that:

- segment S1a decomposes into pipe P1a, reducer R1a and pipe P2a;
- P1a-end2 connects to R1a-end1.

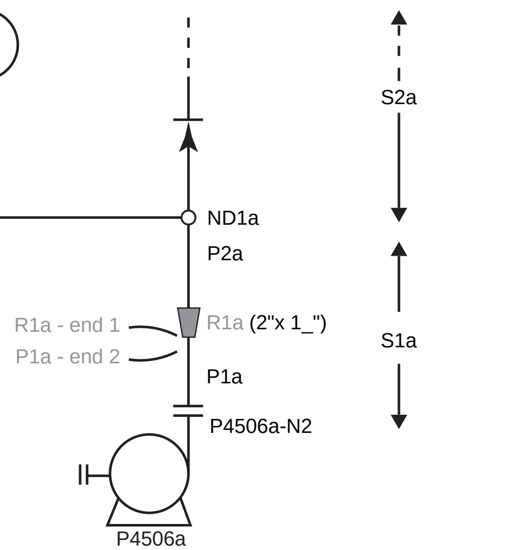

Figure 6

P&ID with additional detail.

If R1a-end1 is specified to be the small end of the reducer, then the additional detail makes the orientation of the reducer unambiguous.

Note: This example presents the engineering facts about the process plant at an instant as objects and relationships. This is first order logic which can be represented using RDF. ISO 15926 has extended this approach to represent engineering facts about how a process plant changes as first order logic. This is a much more difficult task.

4 ROLE OF AP 221

4.1 Representing the Graphics

The engineering facts represented by the relationships are within the scope of the initial release ISO 15926-2, but not the P&ID as a schematic drawing.

ISO 15926-2 has a companion standard ISO 10303 part 221 which can represent the graphics. ISO 10303 part 221 (known as AP, Application Protocol) 221 is part of the STEP family of standards for engineering data. STEP has APs which cover a wide range of engineering topics, including:

- 2D draughting;
- 3D shape representation;
- finite element analysis;
- printed circuit board layout;
- process plant spatial arrangements;
- automotive design.

The STEP APs share a common set of basis data specifications. Hence the AP 221 approach to graphics is similar to the 2D draughting AP and to schematics within the automotive design AP.

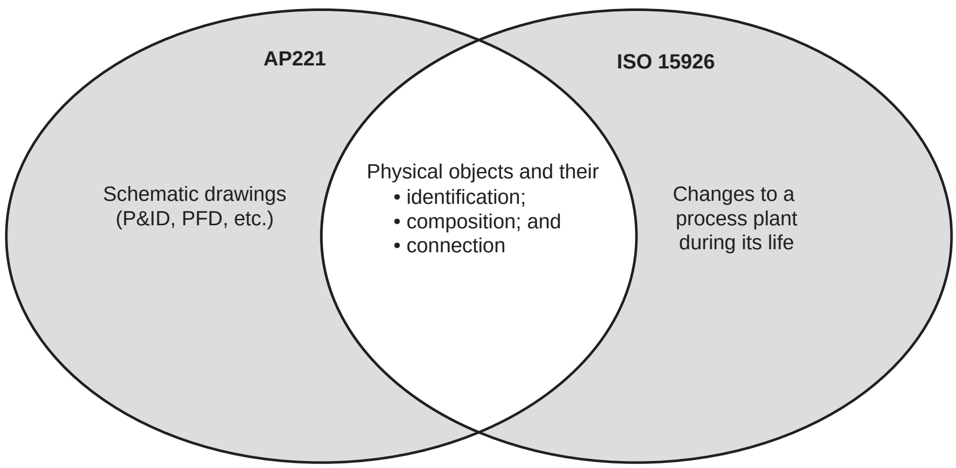

Figure 7

AP 221 and ISO 15926-2.

The limitations of the STEP architecture make it difficult for a STEP AP to record the changes to a process plant during its life. However, AP 221 can record the information about physical objects that exist at an instant, as illustrated by the example in Section 3.

The overlap between AP 221 and ISO 15926-2 is shown in Figure 7.

For each AP 221 entity within the overlap, there is an ISO 15926-2 entity with the same meaning. The transfer of information between the two standards is merely a question of reformatting, and does not require a mapping between different sets of concepts.

4.2 A Useful Exchange Format

AP 221 is intended to be used for the exchange of data between intelligent P&ID systems and between an intelligent P&ID system and an engineering data warehouse defined in accordance with ISO 15926.

Note: An intelligent P&ID system is a computer system that can create a P&ID as a drawing and also record the engineering facts that the drawing represents.

The intended use of AP 221 is shown in Figure 8.

5 CHANGES TO A PROCESS PLANT

5.1 Function and Equipment

Different people see change within a process plant differently. Consider pump P4506a in the example in Figure 2. This pump is not a material object, but a "tag" or "function".

A particular item of equipment will be installed to perform the function. This item of equipment is a material object and will have a manufacturer's serial number, and perhaps a owner-operator company's asset number.

A maintenance activity can change the material object that is installed as pump P4506a. An operations engineer will regard the plant as unchanged by this activity, but a maintenance engineer will not.

5.2 Qualified Relationships

The simplest way to record changes to a process plant is to assign time stamps to each relationship. For each relationship we could record:

- the activity that created the relationship;
- the instant in time at which the relationship came into existence;
- the activity that destroyed the relationship;
- the instant in time at which the relationship ended.

A key relationship in this approach to change is "installation" which is between:

- a functional physical object (also called a tag);
- a materialised physical object (also called a material, equipment item or asset).

A maintenance activity can end the installation relationship between pump tag P4506a and the material pump with asset number 4567 (now broken) and create a new installation relationship between pump tag P4506a and the material pump with asset number 6789 (taken from the stores).

Relationships with the functional and the materialised physical objects are shown in Figure 9.

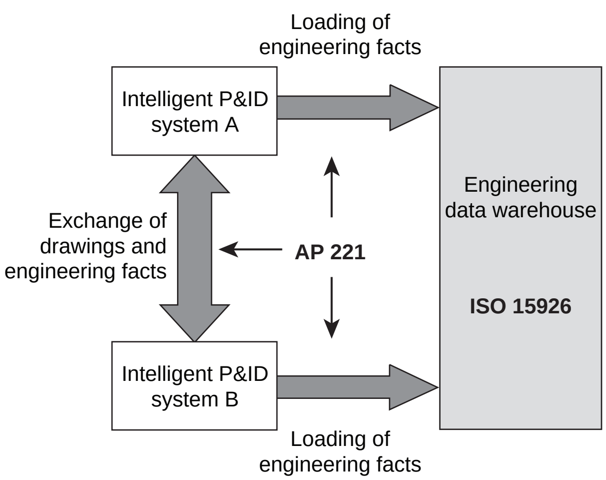

Figure 8

Loading a data warehouse.

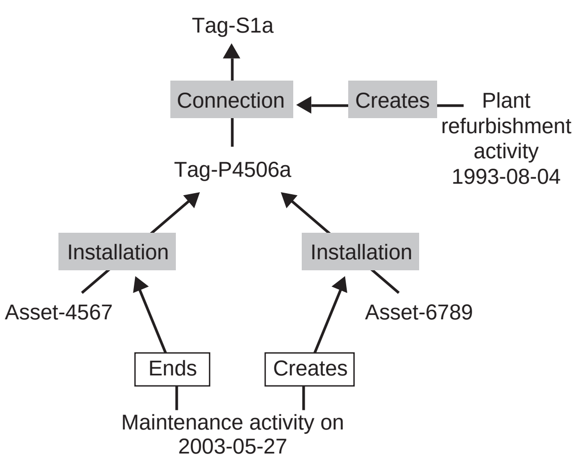

Figure 9

Functional and materialised physical objects.

The pipe segment S1a is also a functional object or tag. The material pipes that create the segment can be changed when damaged by corrosion or abrasion. A major refurbishment of a process plant can change the relationships between functional objects.

The "qualified relationship" approach to process plant data is simple and intuitive. This approach is widely used in industry, and was specified in the version of ISO 15926 issued for CD (Committee Draft) ballot. However, in the final published version of ISO 15926-2:2003, the qualified relationship approach was replaced by the "4D approach".

5.3 4D Approach

There are problems with the "qualified relationship" approach. For example: at an instant in time, tag P4506a and asset 4567 are the same thing. Hence at this time a property such as "volumetric flow rate" is necessarily possessed identically by both objects.

This constraint is not explicit using the "qualified relationship" approach.

The alternative 4D approach recognises that physical objects can have a temporal as well as a spatial decomposition. This approach is illustrated in Figure 10.

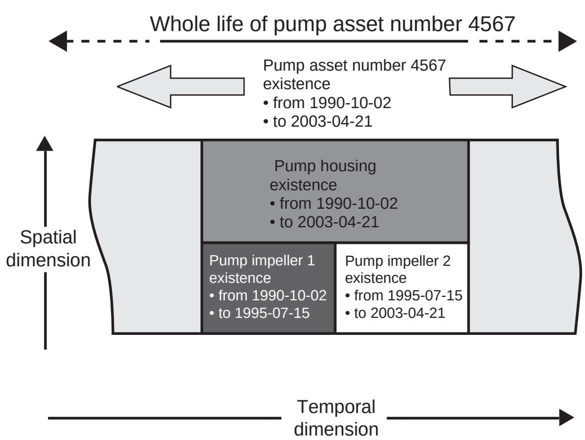

Figure 10

Spatial and temporal decomposition of a pump.

A physical object can be a "whole life object". A physical object can be a segment of the life of another physical object, called a "temporal part". There is a temporal composition relationship between:

– **whole** physical object: pump asset number 4567 for its whole life;
– **part** physical object: pump asset number 4567 existence 1990-10-02 to 2003-04-12.

The physical object "pump asset number 4567 existence 1990-10-02 to 2003-04-12" has three parts:

– pump housing existence 1990-10-02 to 2003-04-12;
– pump impeller 1 existence 1990-10-02 to 1995-07-15;
– pump impeller 2 existence 1995-07-15 to 2003-04-12.

The two composition relationships with pump impellers, indicate that the pump impeller was changed. With the 4D approach, the composition relationship does not need to be qualified by a start time and end time. This is because the part is not the whole life of the impeller, but a defined segment of the life of the impeller. The start time and end time are properties of the segment.

Note: The term "4D" is used to indicate that spatial (3D) and temporal (1D) composition relationships are handled in a similar way.

5.4 Installation in 4D

With the 4D approach, there is no need for a special **installation** relationship. Consider the tag P 4506a which has asset 4567 installed from 1990-10-02 to 2003-05-27. The installation means that:

– tag P4506a existence 1990-10-02 to 2003-05-27;
– asset 4567 existence 1990-10-02 to 2003-05-27;

is the same physical object.

This physical object is a single instance on the data base for which the following information is recorded:

– it is temporal part of the whole life of tag P4506a;
– it is temporal part of the whole life of asset 4567;
– it starts its existence on 1990-10-02;
– it ends its existence on 2003-05-27.

The relationship between the three objects is shown in Figure 11.

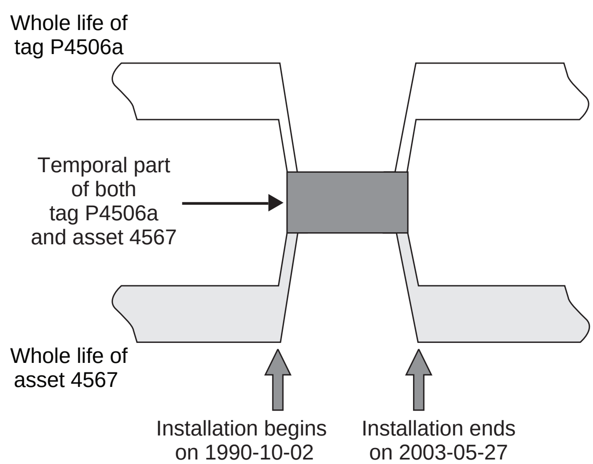

Figure 11

4D approach to installation.

A change to an tag or to an asset can also be recorded by the use of temporal parts. Suppose that the plant is refurbished on 2004-10-14 such that the concept of tag P4506a remains, but is changed so that after refurbishment:
– it is connected to segment S2a rather than S1a;
– the operating pressure is increased from 15 to 16 bar.

This refurbishment is recorded by defining a new physical object that is P4506a after refurbisment. The following information is recorded about this new physical object:
– it is a temporal part of P4506a;
– it starts its existence on 2004-10-14;
– it is connected to segment S2a;
– it has an operating pressure of 16 bar.

6 FIRST ORDER LOGIC

The published version of ISO 15926-2, which uses the 4D approach to change, is first order logic. This means that ISO 15926-2 can be implemented using the Web Ontology Language [9], published by W3C.

An RDF (Resource Description Framework) [10] diagram for the installation example is shown in Figure 12.

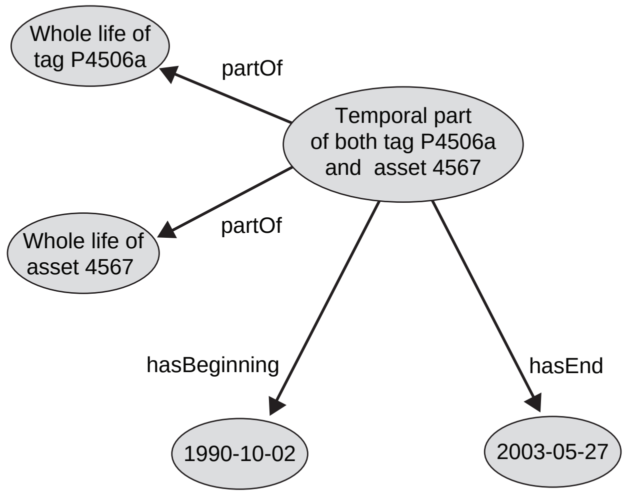

Figure 12

RDF representation of installation.

The corresponding XML serialisation is:

```
< owl:Individual ID = “P4606a” >
  < rdf:type rdf:resource = “&iso15926_2;#WholeLifeIndividual” / >
  < rdf:type rdf:resource = “&iso15926_2;#FunctionalPhysicalObject” / >
  < rdf:type rdf:resource = “&iso15926_4;#CentrifugalPump” / >
< / owl:Individual >

< owl:Individual ID = “Asset4567” >
  < rdf:type rdf:resource = “&iso15926_2;#WholeLifeIndividual” / >
  < rdf:type rdf:resource = “&iso15926_2;#MaterializedPhysicalObject” / >
  < rdf:type rdf:resource = “&iso15926_4;#CentrifugalPump” / >
< / owl:Individual >

< owl:Individual >
  < rdf:type rdf:resource = “&iso15926_4;#CentrifugalPump” / >
  < iso15926_2:partOf rdf:resource = “#P4506a” / >
  < iso15926_2:partOf rdf:resource = “#Asset4567” / >
  < iso15926_2:hasBeginning >
    < iso15926_2:InstantInTime >
      < iso15926_2:dayIdentifier > 1990-10-02 < / iso15926_2:dayIdentifier >
    < / iso15926_2:InstantInTime >
  < / iso15926_2:hasBeginning >
  < iso15926_2:hasEnd >
    < iso15926_2:InstantInTime >
      < iso15926_2:dayIdentifier > 2003-05-27 < / iso15926_2:dayIdentifier >
    < / iso15926_2:InstantInTime >
  < / iso15926_2:hasEnd >
< / owl:Individual >
```

Notes on the XML serialisation:

1. the classes WholeLifeIndividual, MaterializedPhysical Object, FunctionalPhysicalObject and InstantInTime are defined in ISO 15926-2;
2. the class CentrifugalPump is defined in ISO 15926-4;
3. the property partOf is equivalent to "composition of individual" in ISO 15926-2;
4. the ISO 15926 approach to the identification of a time is simplified for this example. However the key aspect, which is that an InstantInTime is an object, has been retained.

CONCLUSION

ISO 15926 can record information about:

– the physical objects that make up a process plant;
– the way in which the properties of the physical object, and their relationships change.

ISO 15926 relies upon dictionaries (or ontologies) of classes and properties. ISO 15926-4 defines:

– generic classes such as pump, centrifugal pump and positive displacement pump;
– generic properties such as normal operating pressure; normal operating temperature.

These generic classes and properties can be specialised within company or industry standard dictionaries.

The ISO 15926 is conceptually first order logic, but the implementation defined in the standard uses the EXPRESS information modelling language. There is no mention of new technologies such as RDF/OWL within ISO 15926.

In the future, RDF/OWL will provide an additional implementation method of ISO 15926. The use of RDF/OWL will also make ISO 15926 an ontology of basic engineering concepts for the wider engineering community.

ACKNOWLEDGEMENTS

Many of the key ideas in ISO 15926 were developed by Dr. Matthew, *West of Shell Petroleum*, London. In particular, he introduced the "4D approach" for the description of engineering change. The example was provided by Andries van Renssen of *Shell Petroleum*, The Hague. The pyramid diagram of ISO 15926 ontologies was provided by Magne Valen-Sendstad of *DNV*, Oslo.

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