



BSI Standards Publication

Representation of process control engineering — Requests in P&I diagrams and data exchange between P&ID tools and PCE-CAE tools

NO COPYING WITHOUT BSI PERMISSION EXCEPT AS PERMITTED BY COPYRIGHT LAW

raising standards worldwide™

Full document details: BS EN 62424:2009

National foreword

This British Standard is the UK implementation of EN 62424:2009. It is identical to IEC 62424:2008.

The UK participation in its preparation was entrusted to Technical Committee GEL/65, Measurement and control.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© BSI 2010

ISBN 978 0 580 69275 8

ICS 25.040.40; 35.240.50

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 May 2010.

Amendments issued since publication

Amd. No.	Date	Text affected
----------	------	---------------

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 62424

August 2009

ICS 35.240.50; 25.040.40

English version

Representation of process control engineering - Requests in P&I diagrams and data exchange between P&ID tools and PCE-CAE tools (IEC 62424:2008)

Représentation de l'ingénierie
du contrôle-commande des processus -
Requêtes dans les diagrammes P&ID
et échanges de données
entre les outils P&ID et PCE-CAE
(CEI 62424:2008)

Darstellung von Aufgaben
der Prozessleittechnik -
Fließbilder und Datenaustausch
zwischen EDV-Werkzeugen
zur Fließbilderstellung und CAE-Systemen
(IEC 62424:2008)

This European Standard was approved by CENELEC on 2009-07-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: Avenue Marnix 17, B - 1000 Brussels

© 2009 CENELEC - All rights of exploitation in any form and by any means reserved worldwide for CENELEC members.

Ref. No. EN 62424:2009 E



Documents
Document Sharing Hub

Foreword

The text of document 65/420/FDIS, future edition 1 of IEC 62424, prepared by IEC TC 65, Industrial-process measurement, control and automation, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62424 on 2009-07-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2010-04-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2012-07-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62424:2008 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60848	NOTE Harmonized as EN 60848:2002 (not modified).
IEC 61512-1	NOTE Harmonized as EN 61512-1:1999 (not modified).
IEC 61987-1	NOTE Harmonized as EN 61987-1:2007 (not modified).
ISO 13628-6	NOTE Harmonized as EN ISO 13628-6:2006 (not modified).
ISO 13703	NOTE Harmonized as EN ISO 13703:2000 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 61346-1	- ¹⁾	Industrial systems, installations and equipment and industrial products - Structuring principles and reference designations - Part 1: Basic rules	EN 61346-1	1996 ²⁾
IEC 61511-1	- ¹⁾	Functional safety - Safety instrumented systems for the process industry sector - Part 1: Framework, definitions, system, hardware and software requirements	EN 61511-1	2004 ²⁾
ISO 10628	- ¹⁾	Flow diagrams for process plants - General rules	EN ISO 10628	2000 ²⁾
ISO 13849-1	- ¹⁾	Safety of machinery - Safety-related parts of control systems - Part 1: General principles for design	EN ISO 13849-1	2008 ²⁾
XML 1.0	2004	Extensible Markup Language, W3C Recommendation	-	-

¹⁾ Undated reference.

²⁾ Valid edition at date of issue.

CONTENTS

INTRODUCTION.....	8
1 Scope.....	10
2 Normative references	10
3 Terms and definitions	10
4 Abbreviations	14
5 Conformity.....	15
6 Representation of PCE requests in a P&ID	16
6.1 PCE request and PCE loop	16
6.2 Objectives and principles	17
6.3 Requirements for the identification and representation of PCE requests	17
6.3.1 General	17
6.3.2 Types of lines	18
6.3.3 Displaying the location of the operator interface	18
6.3.4 PCE categories and processing functions	19
6.3.5 PCE request reference designation scheme	22
6.3.6 PU-vendor and typical identification.....	23
6.3.7 Device information.....	23
6.3.8 Alarming, switching and indicating	24
6.3.9 Safety-relevant, GMP and quality-relevant PCE requests	24
6.3.10 PCE control functions	25
7 Neutral data exchange of PCE relevant P&ID information	26
7.1 Objectives	26
7.2 Meaning of P&ID elements	26
7.3 PCE relevant information of P&ID tools	27
7.4 Formal description of PCE relevant information of P&ID tools.....	28
7.4.1 General	28
7.4.2 Modeling PCE relevant information using the CAEX system description language	29
7.4.3 Basic CAEX mappings.....	29
7.4.4 Mapping of a PCE request interface to an external interface of the corresponding plant hierarchy item	31
7.4.5 CAEX description of direct links between PCE request interfaces of different plant hierarchy items	33
7.4.6 PCE loops	34
8 Additional PCE attributes.....	35
Annex A (normative) CAEX – Data model for machine information exchange	36
Annex B (informative) Examples of PCE requests	109
Annex C (normative) Full XML schema of the CAEX Model.....	119
Annex D (informative) CAEX modelling examples	128
Bibliography.....	135
Figure 1 – Information flow between P&ID and PCE tool.....	9
Figure 2 – Organization of PCE requests	17
Figure 3 – General representation of a PCE-Request in a P&ID	18

Figure 4 – Multi-sensor element	18
Figure 5 – Local interface	19
Figure 6 – Manually operated switch in local control panel.....	19
Figure 7 – Pressure indication in central control room.....	19
Figure 8 – Example of PCE request identification	23
Figure 9 – Example of flow measurement with indication in the CCR delivered by vendor A specified by typical A20	23
Figure 10 – Example of pH-measurement with indication in the CCR	23
Figure 11 – Example of flow measurement with indication in the CCR and high and low alarm	24
Figure 12 – Flow measurement with indication in the CCR and high alarm and a high- high switching function.....	24
Figure 13 – Flow measurement with indication in the CCR and a high-high switch limit, a high alarm, a low alarm and a low-low switch limit for a safety function.....	24
Figure 14 – GMP relevant, safety relevant and quality relevant flow measurement with indication in the CCR	25
Figure 15 – Control function.....	25
Figure 16 – Safety relevant control function	25
Figure 17 – P&ID elements and associations (PCE relevant items are shown in dark lines)	27
Figure 18 – Process data model (PCE relevant items are shown in dark lines).....	28
Figure 19 – PCE request data model	30
Figure 20 – Example of two plant sections and a signal connection via external interfaces.....	32
Figure 21 – Simplified CAEX model of indirect links between PCE requests across different plant hierarchy items.....	32
Figure 22 – Example of two plant sections and a direct connection	33
Figure 23 – Simplified CAEX model of direct links between PCE requests across different plant hierarchy items.....	34
Figure A.1 – CAEX architecture of a SystemUnitClass	42
Figure A.2 – Example of a SystemUnitClassLib.....	42
Figure A.3 – Examples of Attributes	44
Figure A.4 – Examples of an InterfaceClassLib	46
Figure A.5 – Usage of Links.....	47
Figure A.6 – Example of a RoleClassLib	48
Figure A.7 – CAEX Role Concept.....	50
Figure A.8 – CAEX data definition for use case 1	50
Figure A.9 – CAEX data definition for use case 2	51
Figure A.10 – CAEX data definition for use case 3	51
Figure A.11 – CAEX data definition of a MappingObject.....	53
Figure A.12 – Example for a hierarchical plant structure	53
Figure A.13 – CAEX data structure	54
Figure A.14 – Distribution of data in several CAEX files	54
Figure A.15 – Referencing of external CAEX files	54
Figure A.16 – Example of how to use alias names	55
Figure A.17 – Multiple crossed structures	55

Figure B.1 – Local level indication, 1 process connection	109
Figure B.2 – Local level indication, 2 process connections.....	109
Figure B.3 – Local flow indication	109
Figure B.4 – Local pressure indication	109
Figure B.5 – Local temperature indication	109
Figure B.6 – Local control panel, pressure indication, high alarm	110
Figure B.7 – Local temperature indication, CCR temperature high alarm.....	110
Figure B.8 – Local pressure indication, CCR pressure high alarm and switch.....	110
Figure B.9 – CCR flow indication, device information: Orifice Plate	110
Figure B.10 – CCR pressure indication, low, low low and high alarm	110
Figure B.11 – CCR temperature indication and registration	111
Figure B.12 – CCR level indication and registration, 1 process connection	111
Figure B.13 – CCR level indication, 2 process connections	111
Figure B.14 – Two flow indications and flow ratio control in CCR	111
Figure B.15 – CCR flow indication and high alarm, flow control, control valve with extra interlock and open/close indication	112
Figure B.16 – Local pressure indication, CCR pressure indication, high alarm and high high safety relevant switch.....	112
Figure B.17 – Local pressure indication, CCR pressure indication, alarms and switches	112
Figure B.18 – CCR pressure indication, high and low alarm, safety relevant switch action on on/off valve.....	112
Figure B.19 – Switched valve with on/off indication and switching action, safety relevant switched valve	113
Figure B.20 – Pressure restriction.....	113
Figure B.21 – Flow restriction	113
Figure B.22 – PT compensated flow control, safety-relevant pressure switch (two out of three (2oo3) shutdown), switched control valve with on/off indication and switching action at open position	114
Figure B.23 – CCR temperature control, additional manual switch actions from CCR with indication and local control panel.....	114
Figure B.24 – Motor typical, local on/off control, CCR off control, current, fault with alarm and running indication	115
Figure B.25 – Multivariable controller	115
Figure B.26 – On/off valve with position indication	116
Figure B.27 – On/off valve with safety relevant switch and position indication	116
Figure B.28 – Level control with continuous controller.....	116
Figure B.29 – Level control with on/off switch	116
Figure B.30 – Cascade control for temperature as control input, flow control as follow- up controller	117
Figure B.31 – Safety directed high control to a subsequent valve, manual control for reset function and manual control for manual/automatic switch of the valve, valve with open/close indication and safety-relevant switch to subsequent valve	117
Figure B.32 – Flow control in CCR	117
Figure B.33 – Temperature control with high alarm and high switch	117
Figure B.34 – Manual control from CCR.....	118
Figure B.35 – Flow measurement with display and alarms in CCR, high high switch on process control function and switch on/off valve	118

Figure B.36 – Local P-/F-/T-/S- control without auxiliary power (stand-alone).....	118
Figure D.1 – Example CAEX interface library.....	128
Figure D.2 – Example CAEX role library	129
Figure D.3 – Example to be mapped with CAEX.....	131
Figure D.4 – CAEX model of the example described in Figure D.3	132
Table 1 – Abbreviations	15
Table 2 – PCE categories	20
Table 3 – PCE processing function	21
Table 4 – Sequence combinations	22
Table 5 – PCE processing functions for actuators	22
Table 6 – P&ID attributes relevant in PCE environment	35
Table 7 – Data handling attributes	35
Table A.1 – XML notation conventions	36
Table A.2 – CAEX data types and elements.....	37

INTRODUCTION

Efficient process engineering requires highly sophisticated tools for the different needs of the involved work processes and departments. These engineering tools are normally specialized in Process Design (PD), in Process Control Engineering (PCE), etc. Therefore a working interoperability is essential to optimize the engineering process in total. Thus, the definition of a harmonized interface and data management is a core task to ensure a smooth workflow during the whole project and to guarantee data consistency in the different tools.

This standard defines procedures and specifications for the exchange of PCE relevant data provided by the Piping and Instrumentation Diagram (P&ID) tool. The basic requirements for a change management procedure are described. A generally accepted technology for machine information exchange, the Extensible Markup Language (XML) is used. Hereby, a common basis is given for information integration.

However, a definition for uniform semantics is still necessary. CAEX (Computer Aided Engineering eXchange) as it is defined in this document is an appropriate data format for this purpose. This concept of data exchange is open for different applications.

The main task of a data exchange is transporting/synchronizing information from the P&ID database to the PCE databases and vice versa. The owner's reference designation system and a unique description of the processing requirement is the key for a unique identification. For detailed information about representation of PCE loops in P&ID's see Clause 6.

The data exchange system may be a stand-alone, vendor independent application or a module in an engineering environment. The data between a P&ID tool and a PCE tool and vice versa is exchanged via CAEX.

After the data exchange, there are three places where information about the plant is stored. Both the proprietary databases of the considered tools include private and common information. Both are stored at different places and different divisions that are working on them. Hereby, the intermediate database CAEX only stores common information. In a wider approach, the intermediate database should store both common and private information. This becomes important if a third application is connected to the neutral database. If the intermediate database is used as a temporary data stream only (without storing the information in a file), the information will be lost after processing the data conciliation.

Figure 1 illustrates the information flow for the P&ID and the PCE database reconciliation. The data exchange is done via a neutral intermediate CAEX database, not directly from database to database. The intermediate CAEX database should be a file (for file based data exchange) or a stream (for network based data exchange). The term "CAEX database" within this standard has to be understood in this way, it does not denominate a database product as e. g. SQL.

Annex C of this standard contains the full XML schema of the CAEX Model. It is attached to this publication in XSD format.

NOTE Buyers of this publication may copy it for their own purposes only in the required amount.

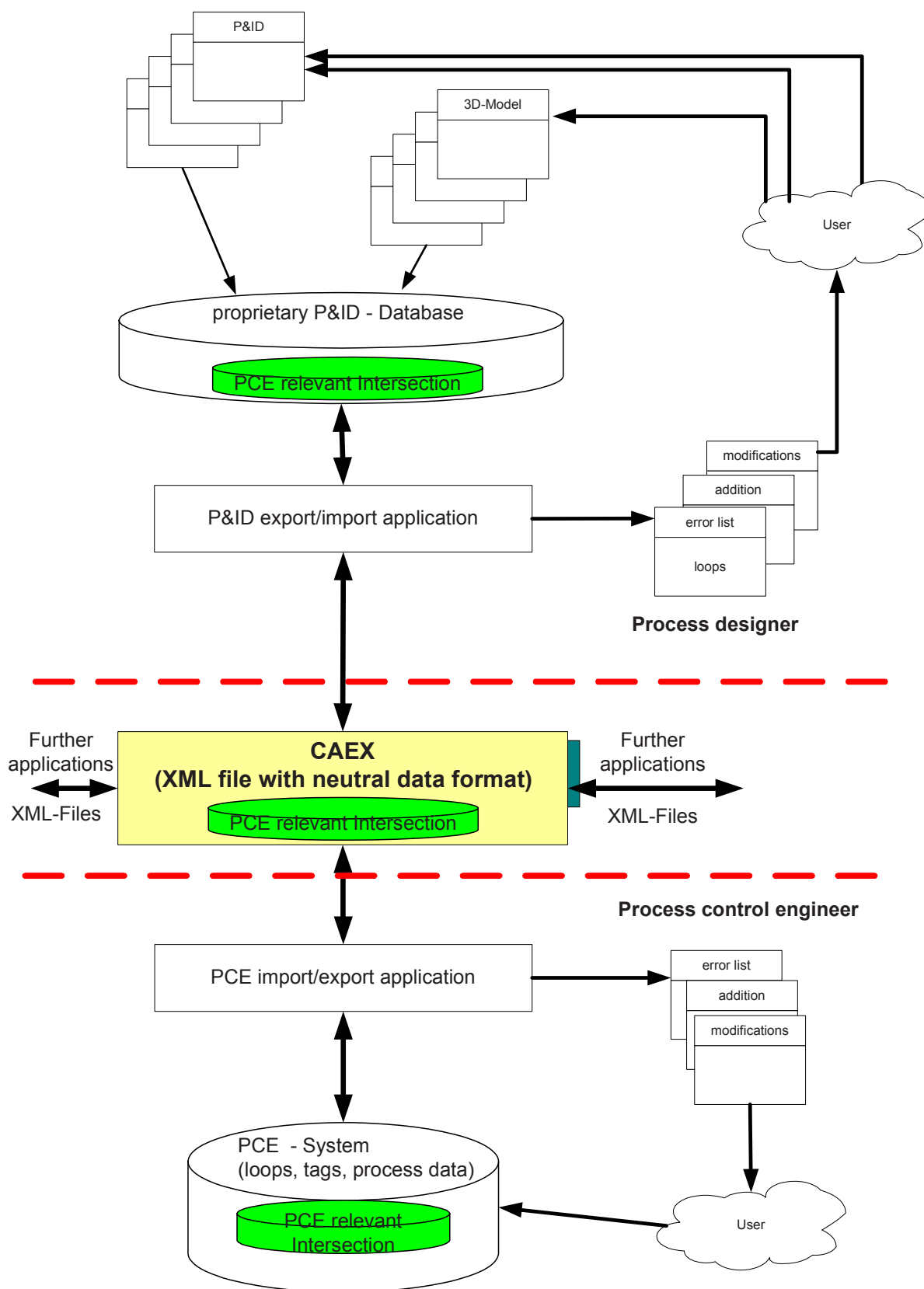


Figure 1 – Information flow between P&ID and PCE tool

REPRESENTATION OF PROCESS CONTROL ENGINEERING – REQUESTS IN P&ID DIAGRAMS AND DATA EXCHANGE BETWEEN P&ID TOOLS AND PCE-CAE TOOLS

1 Scope

This International Standard specifies how process control engineering requests are represented in a P&ID for automatic transferring data between P&ID and PCE tool and to avoid misinterpretation of graphical P&ID symbols for PCE.

It also defines the exchange of process control engineering request relevant data between a process control engineering tool and a P&ID tool by means of a data transfer language (called CAEX). These provisions apply to the export/import applications of such tools.

The representation of the PCE functionality in P&ID'S will be defined by a minimum number of rules to clearly indicate their category and processing function, independent from the technique of realization (see Clause 6). The definition of graphical symbols for process equipment (e. g. vessels, valves, columns, etc.), their implementation and rules for the reference designation system are not in the scope of this standard. These rules are independent from this standard.

Clause 7 specifies the data flow between the different tools and the data model CAEX.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 61346-1, *Industrial systems, installations and equipment and industrial products – Structuring principles and reference designations – Part 1: Basic rules*

IEC 61511-1, *Functional safety – Safety instrumented systems for the process industry sector – Part 1: Framework, definitions, system, hardware and software requirements*

ISO 10628, *Flow diagrams for process plants – General rules*

ISO 13849-1, *Safety of machinery – Safety-related parts of control systems – Part 1: General principles for design*

Extensible Markup Language (XML) 1.0 (Third Edition), W3C Recommendation 04 February 2004, available at <<http://www.w3.org/TR/2004/REC-xml-20040204/>>

3 Terms and definitions

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

3.1

actuator

functional unit that generates from the controller output variable the manipulated variable required to drive the final controlling element

NOTE If the final controlling element is mechanically actuated, it is controlled via an actuating drive. The actuator drives the actuating drive in this case.

[IEV 351-28-07]

EXAMPLE A practical example of an actuator acting directly on the final controlling element is a pneumatic control valve.

3.2

adjusted nominal pipe size

size of the related pipe for the process connection of the PCE request in case of pipe diameters size reduction based on process requirements

3.3

bubble

oval symbol used to denote the PCE category and processing function of a PCE request and to uniquely identify a PCE request

NOTE On the basis of ISA S5.1, Clause 3.

3.4

control narrative

verbal description of a functional control scheme

3.5

design pressure

maximum pressure for which the system or component was designed for continuous usage

[ISO 13628-6, 3.4]

3.6

design temperature

maximum temperature for which the system or component was designed for continuous usage

3.7

equipment ID

unique identifier of equipment

3.8

equipment/pipe flag

unique identifier of equipment/pipe type

3.9

function chart

graphic description tool with symbolic representation of sequential control systems

NOTE 1 The symbolic representation of steps, commands, transitions and directed links is based on input and output Boolean variables and also on internal state variables and binary delay elements.

NOTE 2 The elements, rules and basic structures for function charts are given in IEC 60848.

[IEV 351-29-22]

3.10

heat tracing

heating system for pipe to prevent freezing of process requirements

3.11

heat tracing type

type of heating system for pipe

EXAMPLE Steam or electrical heating system.

3.12

heat tracing temperature set point

set point for the controller of a heat tracing

3.13

insulation type

description of the used insulation type

EXAMPLE Sound insulation.

3.14

insulation thickness

thickness of insulation added to the outer diameter of the pipe size

3.15

intermediate database

intermediate data storage system between source and target tool

3.16

material balance point

balance point of the process calculation

3.17

medium code

abbreviation and identifier for the fluid running through a process pipe

3.18

medium code description

description of the fluid running through a process pipe

3.19

neutral database

vendor independent data storage system

3.20

PCE category

letter that designates the kind of process control engineering request

NOTE Unlike other standards, this standard uses the term "PCE category" instead of "measured variable" (e.g. temperature measurement) for the first digit of the PCE request. The PCE category as defined in this standard allows to unambiguously identify the kind of PCE request, without the need to specify a second letter as modifier for actuators. Based on this, only one letter for sensor and actuator identification of PCE request is necessary.

3.21

PCE control function

function in a PCE control

NOTE According to IEC 61512-1.

3.22

PCE loop

collection of PCE requests and PCE control functions depicting their functional coherence

3.23

PCE request

requirement for process control equipment. Each PCE request is graphically represented by a bubble which collects all information on the functional requirements

3.24**pipe diameter size**

nominal size of the related pipe for the process connection of the PCE request

3.25**pipe ID**

unique identifier of pipe

EXAMPLE Isometrics number.

3.26**pipe specification**

abbreviation and identifier for the specification of piping equipment. Defines the size, material, design, pressure and temperature for all elements of a pipe

3.27**process control equipment**

entirety of devices and programs and, in a broader sense, all instructions and programs used for the task of controlling equipment having a process control function

NOTE 1 Control equipment also comprises the process control station and instructions include operating manuals.

NOTE 2 Providing a process with control equipment is denoted as process automation.

[IEV 351-32-32, modified with respect to process supervision and control]

3.28**process control function**

function to work on process variables (variable quantities), which is composed of basic functions of process control, specific to units of the plant

NOTE In addition to process control functions associated with specific control levels, there can also be process control functions that link input and output variables across several control levels. For instance, a process control function in the feedback path with the controlled variable as input variable and the manipulated variable as output variable, describes the action path from the sensor via the controller to the final controlling element. Another process control function connects the operator with the indicators for the process variables. In view of the diversity of definitions of process control functions, standardization is not appropriate at this time.

[IEV 351-31-17]

3.29**processing function**

function in a process

NOTE A processing function serves a control module according to IEC 61512-1, 3.10 and 5.2.2.4.

3.30**proprietary database**

vendor specific data storage system, with syntax and/or semantic not complying to any standard

3.31**PU-vendor****Package Unit vendor**

supplier of a process unit in a plant

3.32**reference designation**

identifier of a specific object formed with respect to the system of which the object is a constituent, based on one or more aspects of that system

NOTE 1 According to IEC 61346-1.

NOTE 2 Terms "object", "aspect" and "system" are defined in IEC 61346-1.

3.33 schema

XML based description of rules to which an XML document must conform in order to be considered "valid" according to that schema

NOTE On the basis of Extensible Mark-up Language (XML) 1.0 (Third Edition), W3C Recommendation, Clause 2.

3.34 sensor

functional unit that senses the effect of a measured variable at its input and places a corresponding measurement signal at its output

NOTE 1 The corresponding physical unit is named sensor or detecting device.

NOTE 2 Examples of sensors are

- a) thermocouple
- b) foil strain gauge
- c) pH electrode.

[IEV 351-32-39, modified]

3.35 source database

data storage system of the source tool

3.36 target database

data storage system of the target tool

3.37 typical

abbreviation and identifier for a graphical diagram in a database or a group of signals

4 Abbreviations

Table 1 shows abbreviations used in this standard.

Table 1 – Abbreviations

CAE	Computer Aided Engineering
CAEX	Computer Aided Engineering eXchange
CCR	Central Control Room
GMP	Good Manufacturing Practice
N.A.	Not Applicable
PCE	Process Control Engineering
PCS	Process Control System
P&ID	Piping and Instrumentation Diagram
PD	Process design
PL	Performance level according to ISO 13849-1
PU	Package Unit
SIL	Safety Integrity Level acc. to IEC 61511-1
SIS	Safety Instrumented System according to IEC 61511-1
XML	Extensible Markup Language

5 Conformity

To claim conformity to this standard with respect to the graphical representation of PCE requests in P&ID's, the requirements of Clause 6 shall be fulfilled.

To claim conformity to this standard with respect to the PCE relevant data exchange, the requirements of Clause 7 and the following requirements shall be fulfilled.

The data exchange shall be performed by a separate or integrated **import/export application** that provides for the data exchange between the related tool and CAEX.

NOTE The goal of the import/export application is to provide for data reconciliation for the intersection of the source and target databases. It is able to read the proprietary database of the considered tool and to reconcile the data with the neutral CAEX database.

The export/import application shall check, report and provide the intersection data of both databases. The neutral database shall be open for additional applications.

The data import function shall enforce a configurable checking step (e. g. rule based) during the import process; it shall not allow unguided automatic changes. The configurable checking step shall include functionality for automatic or manual acceptance of data changes, allowing single decisions up to bulk data management.

All changes in the proprietary database and all discovered data inconsistencies shall be reported by the import application. The generation of the report shall be configurable. The import/export application has to assure that the intersection of the different databases contains the same information, and that additional division specific data is handled in a consistent way. Data manipulation by a project division is an ongoing process during the whole project and beyond it. Thus the creation, changing and deletion of data shall be possible during the life-cycle of the plant.

CAEX databases have to be consistent. This requires a consistency check before exporting the data. This procedure has to be followed after a successful data manipulation in a P&ID tool or PCE tool in order to bring the new information into the neutral database or vice versa. Before any data changing action is carried out, the user shall be informed and asked for confirmation. The consistency check shall encompass at least the following steps and fulfill the following requirements:

Data export from source database to neutral database shall comprise the following activities:

- a) check P&ID and PCE database for at least:
 - 1) duplicate PCE requests or loop designations;
 - 2) mandatory fields being filled in;
 - 3) correct use of numbering system of the PCE requests.

Inconsistent data shall not be exported.

- b) generate PCE relevant information;
- c) check for changed information in comparison with previously stored data in the neutral database;
- d) renaming of PCE request shall be supported by the export functionality;
- e) perform data export from proprietary into neutral database:
 - 1) e. g. if the PCE request has been changed, the old PCE request within the neutral database has to be deleted and the new one shall be exported from the proprietary database into the neutral database. The old PCE request information shall be stored in a backup storage system;
 - 2) Other changes shall be performed with the existing object.
- f) generate reports after each data exchange:
 - e. g. new PCE requests list, missing PCE requests list, changed PCE requests list, deleted PCE requests list, problems and error list.

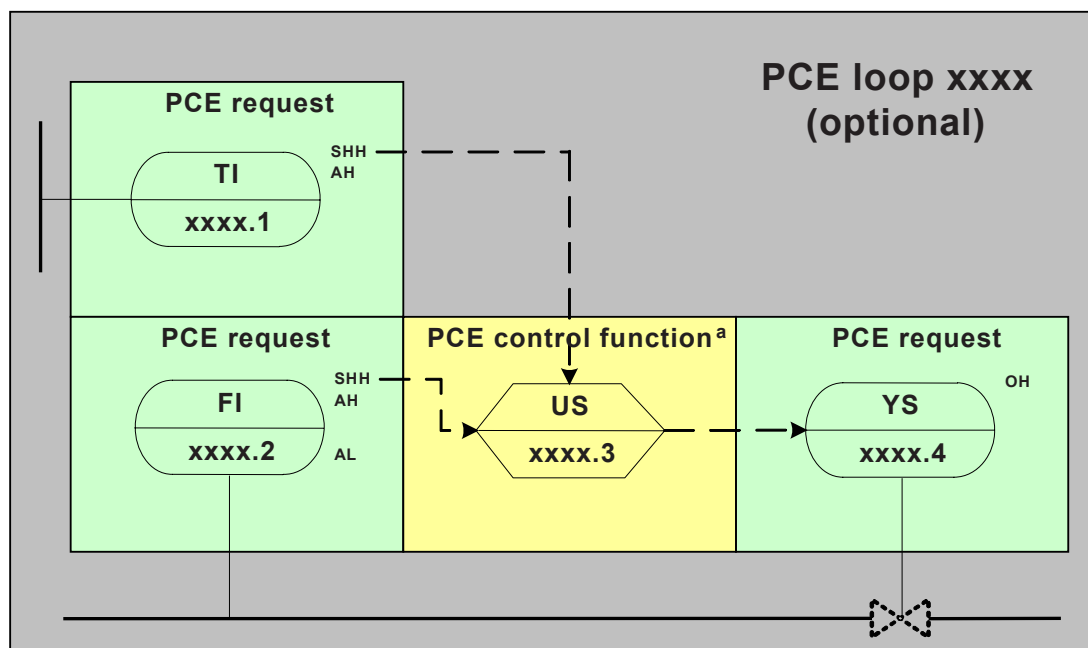
Data import from neutral database into the target database shall comprise the following activities:

- g) generate PCE relevant information from neutral database;
- h) check for changed information by comparing the neutral database with the target database;
- i) perform data import from the neutral into the proprietary database;
- j) renaming of PCE request shall be supported by the import functionality;
- k) generate reports after each data exchange:
 - 1) e. g. error lists;
 - 2) inconsistencies due to imported data shall be detected by the target application during the import process and are not considered within this standard.

6 Representation of PCE requests in a P&ID

6.1 PCE request and PCE loop

In a P&ID the functional design of a plant is determined. Details of technical equipment are given only if functions are correlated with the design of specific equipment. Consequentially, the P&ID describes requirements for the design of the process control equipment. Each PCE request shall be illustrated in the P&ID with an individual identification. In order to meet the requirements of data handling, the same identification shall not be used for different PCE requests. Functional coherence should be depicted by collecting the individual PCE requests in a PCE loop. A PCE loop does not have a graphical representation. Depending on the engineering strategy, a PCE loop thereby consists of at least one, but may also combine several PCE requests. If PCE loops are used, these shall be represented in the identification of all concerned PCE requests. An example of this concept is given in Figure 2.



^a The PCE control function used in Figure 2 is defined in 6.3.10

Figure 2 – Organization of PCE requests

6.2 Objectives and principles

This subclause defines how to represent the process control engineering functionality in P&ID's. *Technical details of the used equipment shall not be depicted in general.* This is due to the goal to ensure a smooth engineering workflow by separating process and instrumentation design.

Therefore the following items are set out in the standard:

- the PCE categories and functions;
- the graphical representation of PCE requests in a P&ID;
- the type of functional connection between the PCE requests: *the control functions*;
- the graphical representation of signals in a P&ID.

In addition the reference designation scheme used for PCE requests in a P&ID shall be specified.

Detailed information on complex control functions shall not be part of the P&ID. Therefore, additional documentation (e.g. control narratives, function charts) has to be prepared to define the required functionality. A control function shall also be individually identified and shall be represented on the P&ID.

6.3 Requirements for the identification and representation of PCE requests

6.3.1 General

Each PCE request shall be graphically represented by a bubble, which collects all information about the functional requirements. Three data fields inside and ten data fields outside the bubble are defined to hold all the information of a PCE request (see Figure 3). For detailed information see 6.3.3 to 6.3.9.

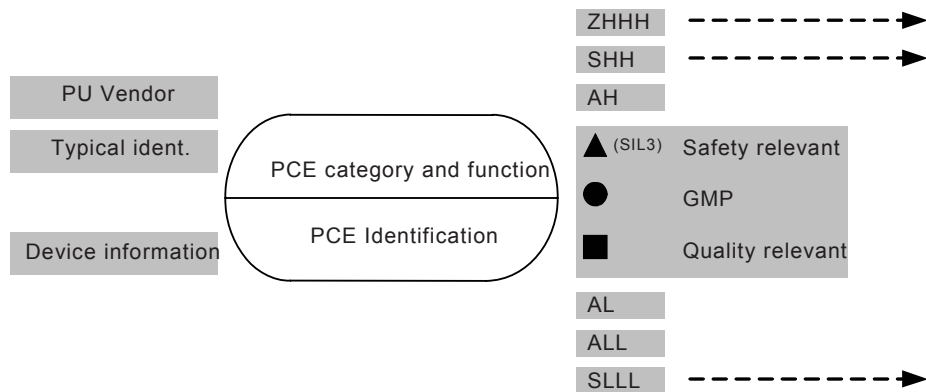


Figure 3 – General representation of a PCE-Request in a P&ID

As stated before, only the PCE functionality shall be depicted on the P&ID, not the PCE implementation. In exceptional cases however, there might be constellations where the presentation of detailed realization information is inevitable. For example, in the case of a *multi-sensor element* which means an instrument that produces measurements for different categories, every category shall be represented by its own bubble. The bubbles are stacked up, as shown in Figure 4.

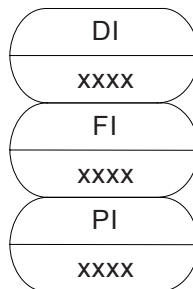


Figure 4 – Multi-sensor element

In all cases where the PCE request is connected to the equipment or pipe, this shall be shown by a full line, connecting the bubble with the equipment or pipe.

6.3.2 Types of lines

Signal lines are used to illustrate the functional relationship between PCE requests. A signal line shall be depicted as a dashed line with an arrow to indicate the information flow. Source of information flow shall be a bubble of a PCE control function or request or switching action consisting of the six fields right outside the bubble. The sink of information flow shall be a bubble of a PCE request or a control function.

Process connections shall be depicted by a solid line without a direction. Multi-sensor instruments with only one process connection shall have an extra bubble for each category and only one process connection.

6.3.3 Displaying the location of the operator interface

Each PCE request is graphically represented by a bubble. This standard distinguishes the location of the operator interface between a local interface, a local control panel and a central control room. The location does not reflect any realization in systems.

A local interface shall be represented as shown in Figure 5. It could be e. g. a pressure gauge.

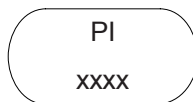


Figure 5 – Local interface

Operator action/information on a local control panel shall be represented as shown in Figure 6.

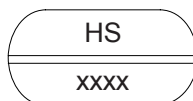


Figure 6 – Manually operated switch in local control panel

Remote requests operated in a central control room shall be represented as shown in Figure 7.

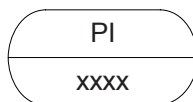


Figure 7 – Pressure indication in central control room

6.3.4 PCE categories and processing functions

6.3.4.1 Indication of PCE categories and processing functions

The upper part of the bubble shall show the information of the PCE category and its PCE processing function. Each bubble shall have at least one PCE category and one PCE processing function. As exception for the processing function see 6.3.4.3.

6.3.4.2 PCE categories

The first letter represents the PCE request and shall be selected from Table 2 if the measuring or initiating variable is listed in that Table. If this is not the case, a new category may be defined. A unique definition is recommended to provide for an automatic transfer to the specific equipment specification for the process control engineer. In case of amendments of categories of Table 2, a coding via letter X as described in table footnote ^b may be used.

Modifying letters for the PCE category shall not be used to avoid misinterpretation in the course of automatic transfer to the specific equipment specification for the process control engineer.

Table 2 – PCE categories

Letter	PCE category
A	Analysis
B	Burner or combustion
C	^a
D	Density
E	Voltage
F	Flow
G	Distance, length, position
H	Hand or manual and manually initiated operation
I	Current
J	Power
K	Time based function
L	Level
M	Moisture or humidity
N	Actuation setting (motor) ^c
O	^a
P	Pressure
Q	Quantity or counter
R	Radiation
S	Speed or frequency
T	Temperature
U	N.A. (see 6.3.10)
V	Vibration or mechanical analysis
W	Weight, mass, force
X	^b
Y	Actuation setting (valve) ^c
Z	^a
^a The definition of this letter should be defined by users. ^b The unclassified letter X is intended to cover unlisted meanings that will be used only once or used to a limited extent. If used, the letter may have any number of meanings as a PCE category and any number of meanings as a PCE function. ^c The use of N for motor driven actuators and Y for valve actuators is based on different PCE activities and maintenance requirements for both types of actuators. Moreover, in the light of increased maintenance requirements in the plant, immediate identification for transferring of data and relevant attributes of the actuator to asset management systems is necessary.	

6.3.4.3 PCE processing functions

Starting with the second character, the successive letters *in the upper part* of the bubble shall represent the processing function of the PCE request. The letters given in Table 3 shall be used to indicate the processing function of a PCE request.

Table 3 – PCE processing function

Letter	Processing function
A	Alarm, message
B	Restriction
C	Control
D	Difference
E	N.A.
F	Ratio
G	N.A.
H	High limit, on, opened
I	Indication of analogue values
J	N.A.
K	N.A.
L	Low limit, off, closed
M	N.A.
N	N.A.
O	Local or PCS status indication of binary signals
P	N.A.
Q	Integrating or counting
R	Recorded value
S	Binary control function or switching function (not safety relevant)
T	N.A.
U	N.A.
V	N.A.
W	N.A.
X	^b
Y	Computing function
Z ^a	Binary control function or switching function (safety relevant)
^a The <i>triangle</i> may also be used to indicate in a redundant way that the processing function is safety relevant (see Figure 3). ^b The unclassified letter X is intended to cover unlisted meanings that will be used only once or used to a limited extent. If used, the letter may have any number of meanings as a PCE category and any number of meanings as a PCE function.	

The letters I and R refer to the result of the preceding processing function, e. g. FIQI means the indication of a flow and its quantity.

The PCE processing functions A, H, L, O, S and Z shall only be used outside the bubble. In this case the PCE category may stand as a single value in the upper part of the bubble. In addition, a detailed definition for the signal information (see 6.3.2) to be transferred automatically to the control equipment specification for the process control engineer is given by this way.

The combination of processing functions shall be used in the sequence given in Table 4. The table hierarchy shall be from left to right and per column top down.

Table 4 – Sequence combinations

Category	Sequence	1	2	3	4
See Table 3	1	F	D	Y	C
	2	B	Q	X	--

6.3.4.4 PCE processing functions for actuators

The PCE processing functions shall be used for actuators in the same way as for sensors. Some examples are shown in Table 5.

Table 5 – PCE processing functions for actuators

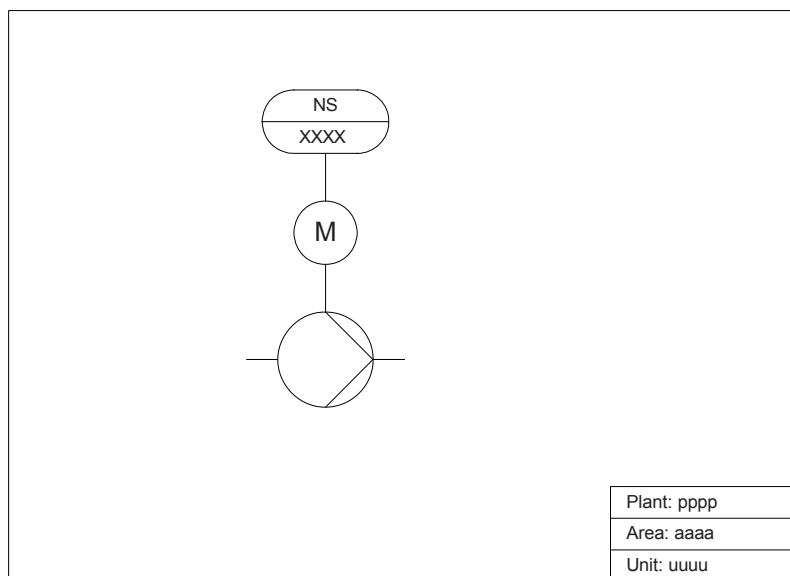
Letter	Processing function
YS	On/off valve
YC	Control valve
YCS	Control valve with on/off function
YZ	On/off valve (safety relevant)
YIC	Control valve continuous position indication
NS	On/off motor
NC	Control motor

The valve operating mechanism, e. g. electric, pneumatic or hydraulic, is not specified by its presentation in the bubble in the P&ID.

Graphical representation of the equipment valve including further functional details in the equipment symbols in accordance to ISO 10628 in the P&ID cannot be used in the CAEX model. Such details shall be placed in the database.

6.3.5 PCE request reference designation scheme

A reference designation scheme (e. g. IEC 61346-1) shall be used in order to identify the PCE request unambiguously. This identification shall be independent of the PCE processing function of the PCE request and depicted in the lower part of the bubble. Preceding identification levels (e. g. site, plant, unit, area) may be omitted in the bubble if the request within the context of the P&ID is unique (see Figure 8). If PCE requests are combined in a PCE loop, their identification shall have separated levels for the loop and the request.



NOTE In the bubble of the depicted request only the last level of the identification system is shown. The plant, area and unit information can be taken from the lower left corner. Thus the complete identification of the request is: pppp-aaaa-uuuu-xxxx.

Figure 8 – Example of PCE request identification

6.3.6 PU-vendor and typical identification

If applicable, PU vendor information shall be given above the horizontal line, but outside the bubble on its upper left side, as shown in Figure 9. If this field is not used for PU vendor information, it may be used to show other project specific information.



Figure 9 – Example of flow measurement with indication in the CCR delivered by vendor A specified by typical A20

To support automatic loop, request and tag generation with PCE CAE tool requests, especially motor requests should be indicated by a “typical” number on the upper left side, outside the bubble. These “typicals” are fixed by the project-team and are used to determine the composition of the PCE request, e. g. how the motor drive should be switched (with start-stop only, with start-stop and running indication, with current measurement, etc.) or a combination of measuring systems.

6.3.7 Device information

If, because of the PCE category, additional device information is needed (e.g. orifice for flow measurement), this shall be indicated in the lower zone outside the bubble on the left side (see Figure 10).

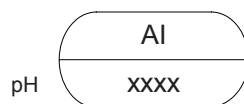


Figure 10 – Example of pH-measurement with indication in the CCR

6.3.8 Alarming, switching and indicating

The characters H and L as PCE processing functions, indicating the high or low limit, shall be used in combination with A, O, S or Z only if an automatic action (S or Z), an operator action (A) or an indication (O) is activated when the limits are reached. In each level (e. g. H, HH, HHH) it shall be possible to combine alarming and switching function, e.g. AS or AZ. These functions shall always be indicated outside the bubble, as shown in Figure 11. Up to three levels for high and also for low alarm/switching/indication shall be possible.



Figure 11 – Example of flow measurement with indication in the CCR and high and low alarm

The representation shall be: <processing function><alarm level>, whereas the order of the processing function shall be O, A, S, Z.

It shall be unambiguous and shall be connected to the controlling function or the actuator starting with the SH, SHH, SHHH, SL, SLL or SLLL symbols as shown in Figure 12.

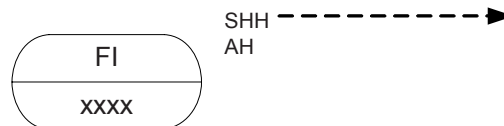


Figure 12 – Flow measurement with indication in the CCR and high alarm and a high-high switching function

The combination of Figure 11 and 12 with additional safety relevant switches may be used as shown in Figure 13.

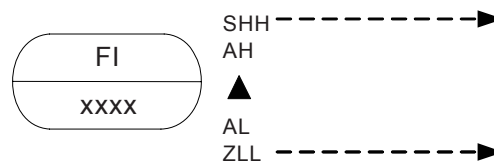


Figure 13 – Flow measurement with indication in the CCR and a high-high switch limit, a high alarm, a low alarm and a low-low switch limit for a safety function

6.3.9 Safety-relevant, GMP and quality-relevant PCE requests

Outside the bubble, a circle symbol should be used as an indication for GMP relevant sensors or actuators and a square for the indication of a quality-relevant PCE request. A triangle should be used for a safety function (categorized by SIL or PL) (see Figure 14).

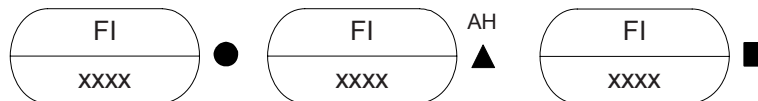


Figure 14 – GMP relevant, safety relevant and quality relevant flow measurement with indication in the CCR

These symbols shall be placed as closely as possible to the bubbles on the right side. Crossing of signal lines connected in the center is acceptable.

6.3.10 PCE control functions

PCE control functions essentially contain the functional relationship between sensors and actuators. These control functions are the “building stones”, the elements of the entire process-functionality. Mostly they are technically achieved via control system configuration. Safety-related control functions are usually implemented by SIS configurations (logic solver) according to IEC 61511-1.

In simple configurations, e.g. one sensor and one actuator, where the relation is unambiguously represented in the P&ID, the PCE control function should be omitted.

The symbol for the PCE control function is the hexagon. This hexagon, see Figure 15, *symbolizes the control functionality* which has one or more sensors as inputs, and one or more actuators as outputs.

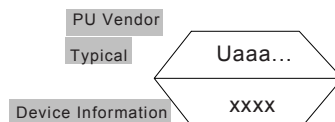


Figure 15 – Control function

The hexagon symbol shall be connected with signal lines (see 6.3.2.) to the various bubbles that represent the relevant PCE requests (see Annex B). The arrows indicate the direction of the information (sensor to PCE control function and PCE control function to actuator).

If applicable, PU vendor information shall be given above the horizontal line, but outside the hexagon on its upper left side. If this field is not used for PU vendor information, it may be used to show other project specific information.

To support automatic loop, request and tag generation with PCE CAE tool requests, especially functional logic design should be indicated by a “typical” number on the upper left side, outside the hexagon.

In case of a safety relevant control function, UZ....., required SIL or PL shall be indicated in the lower zone outside the hexagon on the left side as shown in Figure 16. Other relevant information, e.g. 2oo3 configuration should be added as appropriate. For non-safety control functions this field should be used for additional relevant information.



Figure 16 – Safety relevant control function

The PCE control functions shall be identified separately. The PCE control function shall be identified unambiguously within the reference designation scheme used. This identification shall be independent of the PCE processing function of the PCE control function and depicted in the lower part of the hexagon. Preceding identification levels (e. g. site, plant, unit, area) may be omitted in the hexagon if the control function within the context of the P&ID is unique (see 6.3.5). If control functions are integrated in a PCE loop, their identification shall have different levels for the loop and control function.

The detailed and complete function of the U shall be documented in a separate document, entitled with the U identification.

The upper part of the hexagon symbol shall contain *Uaaa*, where *a* is one or more of the PCE processing functions A, C, D, F, Q, S, Y or Z (see Table 3).

It is possible, for example, that a US has a partial UZ-character. In that case the U shall become the designation USZ. Every USZ shall have *at least one sensor and one actuator which is safety relevant*, this means that at least one sensor and one actuator connected to a USZ has the Z as a processing function.

7 Neutral data exchange of PCE relevant P&ID information

7.1 Objectives

P&ID's include a variety of information relevant for process control engineering purposes. Clause 6 defines how basic information concerning PCE requests and their process-relevant functionality shall be represented in a P&ID. The given specification concerns primarily the graphical notation, but of course, this establishes structural and semantic fixings too. In this clause these structural and semantic fixings will be mapped to a semiformal form. To do this, the CAEX system description language (see Annex A) is used. For this language, an XML-representation is given in Annex C, which allows an open exchange of the modeled data between the P&ID system and the PCE systems.

7.2 Meaning of P&ID elements

P&ID's show a plant (or a part of it) in its function as a physical framework. Aspects are the material flow through vessels and pipes, physical actuations (pumps, stirrers, electrical heating), the coupling between the physical and the control world (PCE requests), and the main dependencies between the control functions.

P&ID's, representing PCE requests in accordance with this standard show functional requirements (roles) and not the assembly of equipment. A shown pump symbolizes not the equipment "pump" but the requirement: At this place a "pumping functionality" is needed. Additional attribute-requirements concerning this pumping functionality like "flow rate", "inlet pressure" and so on can be added.

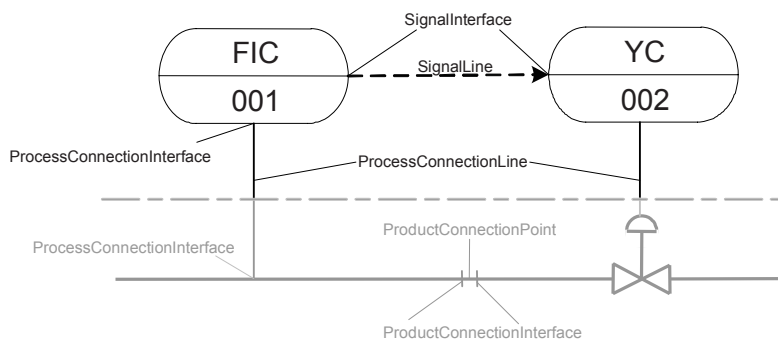


**Figure 17 – P&ID elements and associations
(PCE relevant items are shown in dark lines)**

P&ID's show graphically the functional relationship between the elements. In the example given in Figure 17 four main classes of relationships are shown.

NOTE Graphical representations of the equipment including further functional details in the equipment symbols in accordance to ISO 10628 used in the P&ID cannot be used in the CAEX model. Such details will be placed in a database.

a) Signal connections

Signal connections are notated as declared in Clause 6 by a dashed line, the so-called “SignalLine”. The SignalLine only symbolizes the functional influence between PCE requests and not electrical wiring.

b) Process connections

Process connections are notated as declared in Clause 6 by a plain line, the so-called “ProcessConnectionLine”. The ProcessConnectionLine symbolizes the information flow from the control world to the physical process or vice-versa. The ProcessConnectionLine only symbolizes the functional coupling between a PCE request and the material balance point but not the actual layout in the plant.

c) Product connections

Product connections symbolize the coupling of two pieces of equipment with the possibility of material transfer between them (pipe-pipe, pipe-vessel). The properties of this kind of association are not subject of this standard.

d) Mechanical connections

Mechanical connections symbolize the mechanical coupling within actuation elements (drive-valve, motor-pump). The properties of this kind of connections are not subject of this standard.

7.3 PCE relevant information of P&ID tools

Besides general structural and functional information, P&ID tools handle a variety of information which is of direct interest to the PCE.

a) Control relevant information

PCE requests, process connections, signal lines with all their attributes and interfaces as described in Clause 6 comprises the process-relevant information needed for the process control engineering.

b) Additional information

In many cases, the P&ID tools support additional process-relevant or technology-relevant functional requirements concerning the process connections. Examples are maximum pressure, pipe diameters, information concerning the medium and so on. That information

is usually important for the process control engineering tools too. Clause 8 gives a minimum list of relevant additional parameters.

7.4 Formal description of PCE relevant information of P&ID tools

7.4.1 General

The P&ID is the most important interface between process engineering and process control engineering. It is of fundamental interest to standardize not only the graphical notation of the PCE relevant information but also a data exchange format which supports an open information flow from the P&ID tools to the PCE tools and vice versa.

The PCE data model for PCE relevant information as described in Clause 6 is shown in Figure 18.

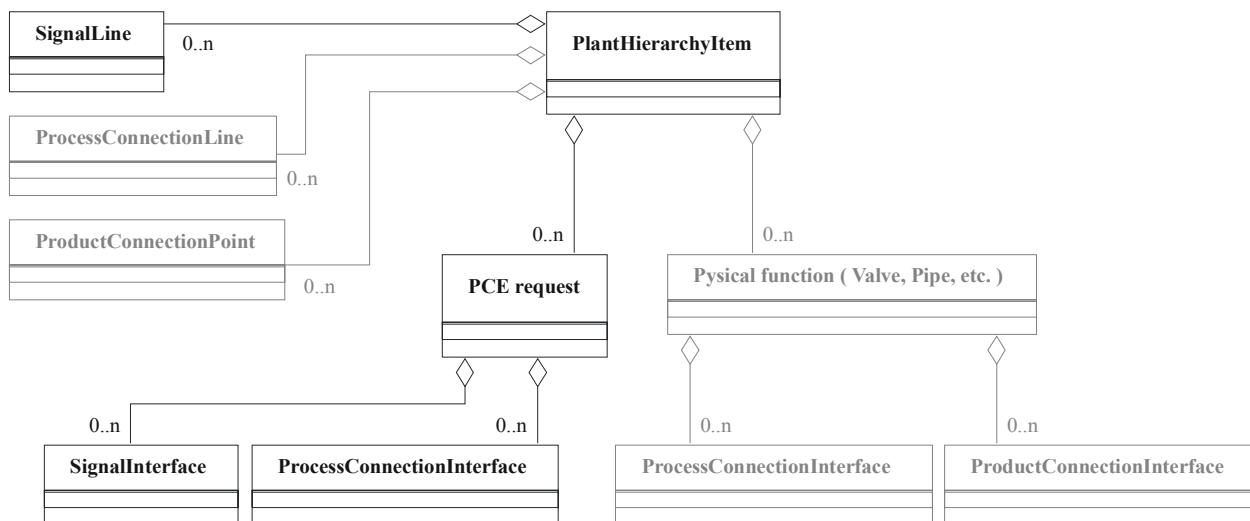


Figure 18 – Process data model (PCE relevant items are shown in dark lines)

The specifications in Clause 6 provide that

- a plant hierarchy item is a logical element collecting PCE request, SignalLines, Physical functions, ProcessConnectionLines and ProductConnectionPoints. The shaded objects shown in Figure 18 are not in the scope of this standard. Plant hierarchy items may contain other nested plant hierarchy items (this allows creating a hierarchical breakdown structure of the plant),
- each PCE request contains 0...n ProcessConnectionInterfaces and 0...n SignalInterfaces,
- each plant hierarchy item, PCE request, SignalLine, ProcessConnectionInterface and SignalInterface shall have a set of attributes,
- each PCE request is part of one and only one plant hierarchy item, and
- control functions shall be handled in the same way as PCE requests but do not include ProcessConnectionInterfaces.

7.4.2 Modeling PCE relevant information using the CAEX system description language

The CAEX system description language provides a schema that supports an exchange of CAE data by means of an XML file. The syntax of CAEX and the semantic definitions of this standard allow for the exchange of instance data (plant data), type data (class data) and complete libraries as well. Further it comprises a means to support the change management process.

The XML schema of CAEX and the concepts behind are specified and explained in Annex A (normative). The schema file is given in Annex C (normative). Examples are given in Annex D (informative).

7.4.3 Basic CAEX mappings

CAEX supports object oriented concepts, e.g. classes and instances. Classes represent predefined typical object information, called “template” in the following text. Instances represent concrete object information and consider the instance as individual. Instance are also called “concrete” objects in the following text.

a) CAEX descriptions of templates for PCE requests, interfaces and plant hierarchy items

A template for a PCE request and a SignalLine shall be predefined as each one CAEX RoleClass, e.g. “PCE_Request” and “SignalLine”. These predefined RoleClasses define standard attributes and standard interfaces required for the data exchange. An example for a CAEX role class library is given in D.2.

A template for common interfaces shall be predefined as CAEX InterfaceClasses, e.g. “SignalSource”, “SignalSink”, “ActuatorSource”, “SignalNode”, “AlarmSource”, “SensorLink” and “IndicationSource”. An example for a CAEX interface class library is given in D.1.

A template for a plant hierarchy item may be predefined as CAEX RoleClass, e.g. “PlantHierarchyItem” which predefines typical properties of a plant hierarchy item. This definition is not in the scope of this standard.

b) CAEX description of a concrete plant hierarchy item

A concrete plant hierarchy item shall be represented by a CAEX InternalElement with an optional association to a RoleClass “PlantHierarchyItem”. InternalElements may contain further InternalElements as nested objects. This allows for defining the desired breakdown structure.

c) CAEX description of a concrete PCE request

A concrete PCE request which is part of a certain plant hierarchy item shall be represented in CAEX as InternalElement within the plant hierarchy item with an associated RoleClass “PCE_Request”. The name of the InternalElement shall represent the name of the PCE request. The associated RoleClass “PCE_Request” delivers common attributes and interfaces. The concrete requirements for the PCE request and the required interfaces (attribute values) shall be stored in the RoleRequirements of the InternalElement. If applicable, additional attributes and interfaces, which are not predefined in the RoleClass, shall be added here too.

NOTE In a later engineering phase, the same InternalElement can additionally be assigned to a corresponding SystemUnitClass which describes the concrete technical implementation of the PCE request. This is not in the scope of this standard. See A.2.9 for related CAEX concept details.

Figure 19 depicts the data model of a PCE request. A PCE request shall consist of 1...n interfaces and a set of attributes which may be extended by additional attributes and additional interfaces. Furthermore, common types of interfaces are presented.

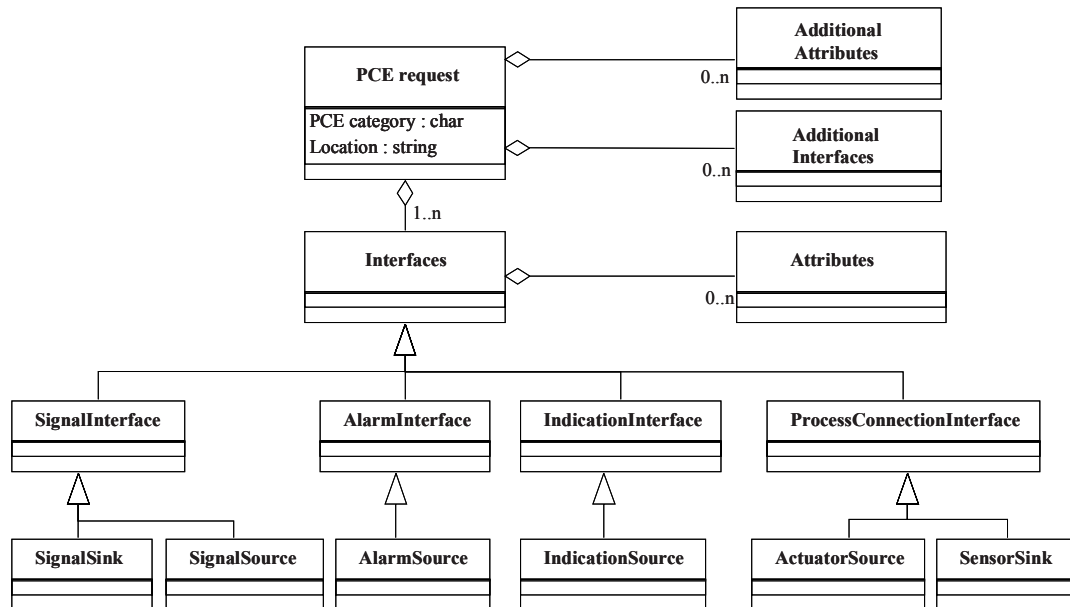


Figure 19 – PCE request data model

Each concrete PCE request possesses at least either a SignalInterface or a ProcessConnectionInterface with respect to the signal output of its processing function. A PCE request without any interface makes no sense.

Each PCE request shall have the following attributes (mandatory):

- PCE category (see Table 2);
- Location (Local, Local Panel, Central).

Each PCE request should have one or more of the following attributes (optional):

- PU vendor (string);
- Typical identification(string);
- Device information (string);
- Processing function (string) (see Table 3);
- GMP relevant (Boolean);
- Safety relevant (Boolean);
- Quality relevant (Boolean).

Additional PCE relevant attributes are defined in Clause 8.

The graphical symbol for a PCE request – bubble or hexagon – carries no additional information and is not mapped to the CAEX-Model.

d) CAEX description of concrete signal lines

CAEX provides two concepts in order to map signal lines. A signal line between two PCE requests of the same plant hierarchy item is described with CAEX either by means of an InternalLink of the superior plant hierarchy item which directly links the corresponding interfaces of the two PCE requests. InternalLinks do not support properties, therefore they can only represent simple relations. An example for those signal lines is given in Annex D.3. Or the signal line is represented as a CAEX object for itself.

If the SignalLine is considered as an object for itself with its own properties, this shall be represented as a CAEX InternalElement with an associated RoleClass "SignalLine". A signal line implements two external interfaces which shall be named "SideA" and "SideB". The connection between two PCE requests is modeled by means of each, an InternalElement for both PCE requests and, another InternalElement for the SignalLine. Furthermore, two InternalLinks have to be defined: One InternalLink connects the source PCE request interface with the "SideA" interface of the signal line, and a second InternalLink connects the signal line interface "SideB" with the sink interface of the second PCE request.

A signal line between two plant hierarchy items of the same level shall be described in CAEX in the same way as signal lines between two PCE requests, linking the corresponding interfaces of the two plant hierarchy items. An example for those signal lines is given in Figure 20.

e) CAEX description of concrete interfaces

Interfaces allow the definition of relations between objects. PCE requests associated to the RoleClass "PCE_Request" inherit the predefined interfaces of this RoleClass. Additionally required interfaces shall be additionally implemented by means of the CAEX element "ExternalInterface" within the corresponding InternalElement.

Each defined alarming function (AH, A, ALL...) implements an additional AlarmInterface (source) within the PCE request.

Each defined additional switching function (SH, SHH,...,SL,...,ZH,...) implements an additional SignalInterface (source) within the PCE request.

Each defined indication function (I, O, OH, ...) implements an additional IndicationInterface.

NOTE The function OSH creates an IndicationInterface and a SignalInterface as well.

f) CAEX description of concrete process connections

Process connections are outside the scope of PCE and are not mapped to the CAEX model within this standard. All additional information given by the P&ID tool with respect to a process connection shall be mapped to attributes of the corresponding ProcessConnectionInterface. Each end of a process connection at a PCE request implements an additional ProcessConnectionInterface within this PCE request.

7.4.4 Mapping of a PCE request interface to an external interface of the corresponding plant hierarchy item

If a signal interface of a PCE request represents an external interface of the corresponding plant hierarchy item, the internal signal interfaces of the considered PCE request shall be mapped to the external interfaces of the corresponding plant hierarchy item. The mapping between a PCE request interface and an external interface of the corresponding plant hierarchy item is defined by means of an additional InternalLink stored in the corresponding plant hierarchy item.

The described mapping and a corresponding use case is illustrated in Figure 20 which gives an example in which a SignalLine couples a PCE request of PlantSection A1 with a PCE request of PlantSection A2. In this case, the plant sections themselves get each external signal interfaces "In" and "Out" respectively.

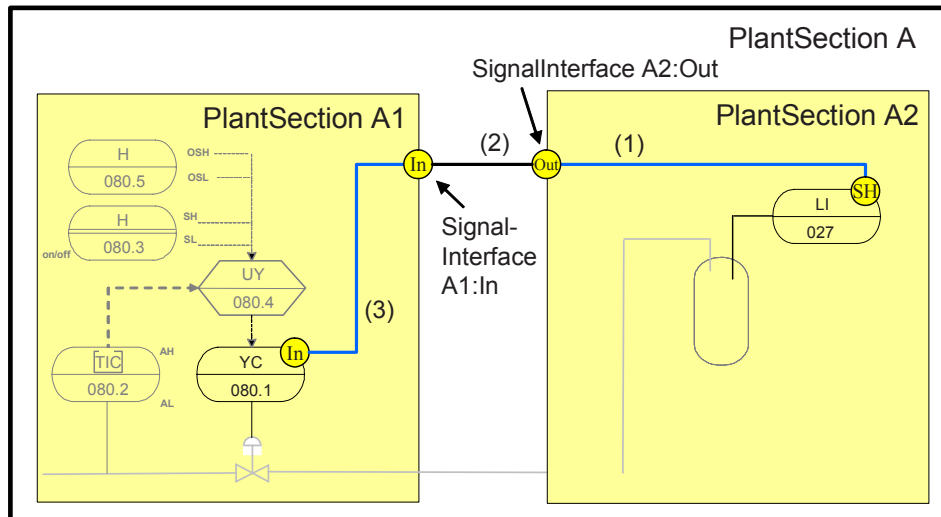


Figure 20 – Example of two plant sections and a signal connection via external interfaces

NOTE The SignalLine in this case is described in CAEX by means of three links:

- 1) link which is part of plant section A2, connecting A2/027:SH with A2/Out
- 2) link which is part of the superior plant section A, connecting A2:Out with A1:In
- 3) link which is part of plant section A1, connecting A1:In with A1/080.1:In

A corresponding CAEX model is shown in Figure 21 which demonstrates how the signal line parts are defined separately in the InternalElements A, A1 and A2. Note that this simplified CAEX representation does only model involved PCE requests.

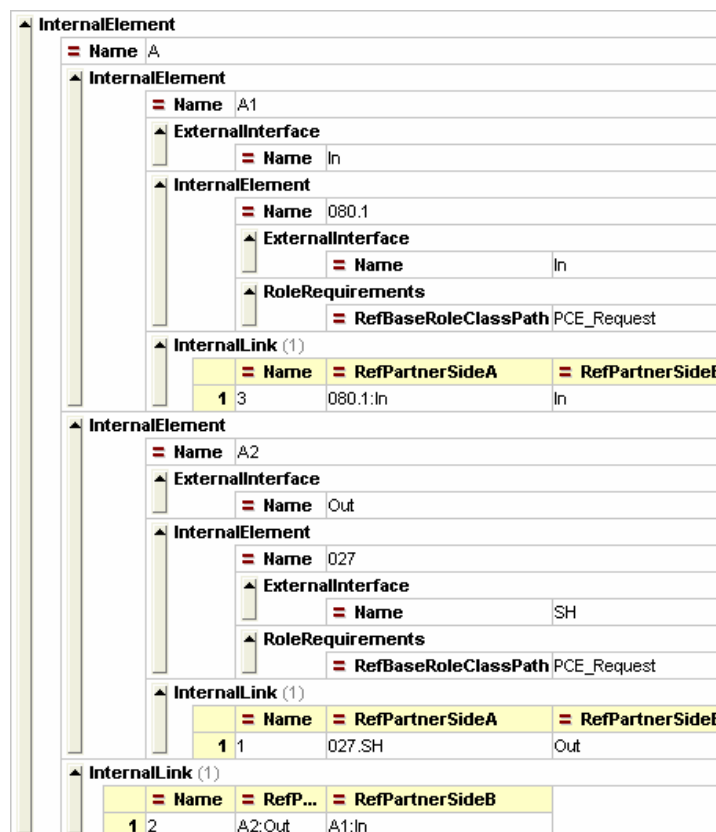


Figure 21 – Simplified CAEX model of indirect links between PCE requests across different plant hierarchy items

In the following, the full XML-text is shown for this example.

```

<InternalElement Name="A">
  <InternalElement Name="A1">
    <ExternalInterface Name="In"/>
    <InternalElement Name="080.1">
      <ExternalInterface Name="In"/>
      <RoleRequirements RefBaseRoleClassPath="PCE_Request"/>
    </InternalElement>
    <InternalLink Name="3" RefPartnerSideA="080.1:In" RefPartnerSideB="In"/>
  </InternalElement>
  <InternalElement Name="A2">
    <ExternalInterface Name="Out"/>
    <InternalElement Name="027">
      <ExternalInterface Name="SH"/>
      <RoleRequirements RefBaseRoleClassPath="PCE_Request"/>
    </InternalElement>
    <InternalLink Name="1" RefPartnerSideA="027.SH" RefPartnerSideB="Out"/>
  </InternalElement>
  <InternalLink Name="2" RefPartnerSideA="A2:Out" RefPartnerSideB="A1:In"/>
</InternalElement>

```

7.4.5 CAEX description of direct links between PCE request interfaces of different plant hierarchy items

If a signal interface of a PCE request is not represented by an external interface of the corresponding plant hierarchy item, a link to other PCE request interface of other plant hierarchy items shall be described in CAEX by a CAEX InternalLink that references both PCE request interfaces directly by means of their paths (see Figure 22). The link is part of a higher level plant hierarchy element.

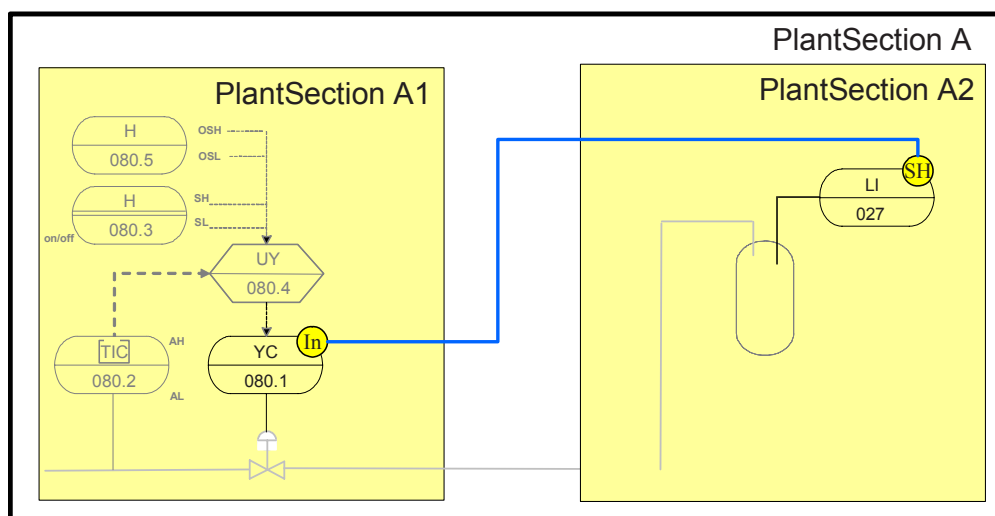


Figure 22 – Example of two plant sections and a direct connection

A corresponding CAEX model is shown in Figure 23 which demonstrates how the signal line is defined as part of the InternalElement A (PlantSection A). Note that this simplified CAEX representation does only model involved PCE requests.

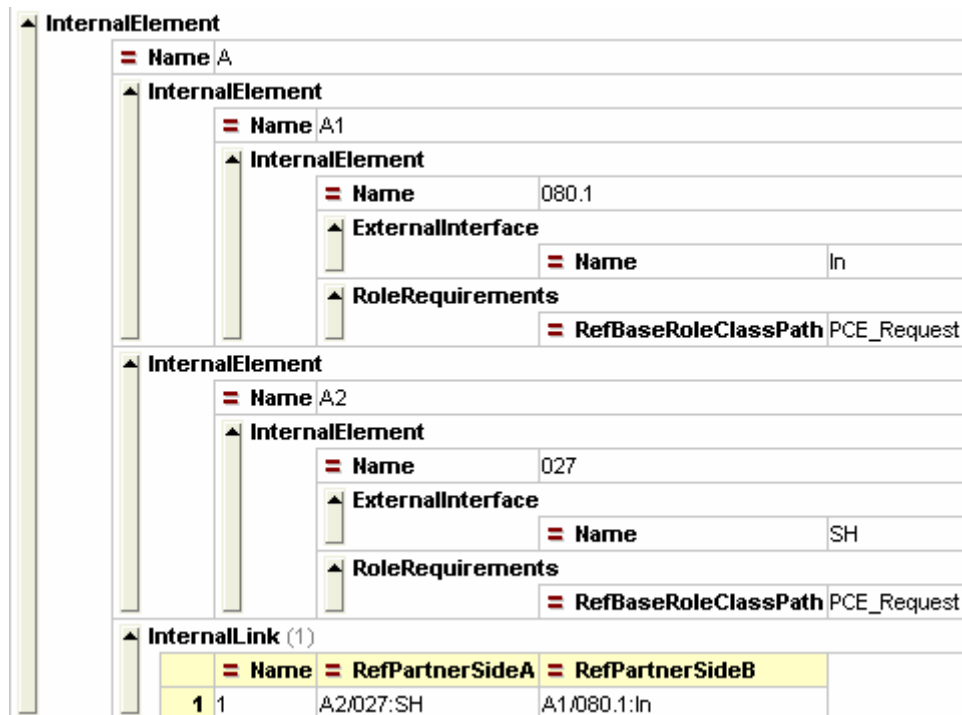


Figure 23 – Simplified CAEX model of direct links between PCE requests across different plant hierarchy items

In the following, the full XML-text is shown for this example.

```
<InternalElement Name="A">
  <InternalElement Name="A1">
    <InternalElement Name="080.1">
      <ExternalInterface Name="In"/>
      <RoleRequirements RefBaseRoleClassPath="PCE_Request"/>
    </InternalElement>
  </InternalElement>
  <InternalElement Name="A2">
    <InternalElement Name="027">
      <ExternalInterface Name="SH"/>
      <RoleRequirements RefBaseRoleClassPath="PCE_Request"/>
    </InternalElement>
  </InternalElement>
  <InternalLink Name="1" RefPartnerSideA="A2/027:SH" RefPartnerSideB="A1/080.1:In"/>
</InternalElement>
```

7.4.6 PCE loops

PCE loops are identified by reference designation scheme. PCE loops will not be mapped to CAEX structural elements. The target tool has to know the special meaning of the reference designation scheme to be able to identify PCE loops.

8 Additional PCE attributes

The objective of this clause is to give a minimum set of typical attributes which are usually stored in P&ID systems and are relevant in the PCE environments. If applicable, these attributes shall be exchanged using the syntax as shown in Table 6 via the CAEX data exchange format.

The attributes given in Table 6 describe information with respect to the special process connections. These attributes shall be mapped to additional attributes of corresponding process connection interfaces.

Table 6 – P&ID attributes relevant in PCE environment

Attributes	CAEX mapping
Medium Code	RoleClass/Attribute (see A.3.19)
Medium code description	RoleClass/Attribute (see A.3.19)
Material balance point	RoleClass/Attribute (see A.3.19)
Pressure rating	RoleClass/Attribute (see A.3.19)
Design temperature	RoleClass/Attribute (see A.3.19)
Design pressure	RoleClass/Attribute (see A.3.19)
Pipe specification	RoleClass/Attribute (see A.3.19)
Pipe diameter size	RoleClass/Attribute (see A.3.19)
Adjusted nominal pipe size	RoleClass/Attribute (see A.3.19)
Heat tracing	RoleClass/Attribute (see A.3.19)
Heat tracing type	RoleClass/Attribute (see A.3.19)
Heat tracing temperature set point	RoleClass/Attribute (see A.3.19)
Equipment/pipe flag	RoleClass/Attribute (see A.3.19)
Equipment ID	RoleClass/Attribute (see A.3.19)
Pipe ID	RoleClass/Attribute (see A.3.19)
Insulation type	RoleClass/Attribute (see A.3.19)
Insulation thickness	RoleClass/Attribute (see A.3.19)

The attributes given in Table 7 concern information with respect to the internal object management. They shall be mapped to additional attributes of the corresponding object.

Table 7 – Data handling attributes

Attributes	CAEX mapping
InternalUniqueID	RoleClass/Attribute (see A.3.19)
Short description	RoleClass/Attribute (see A.3.19)

Annex A (normative)

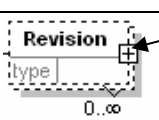
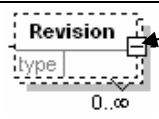
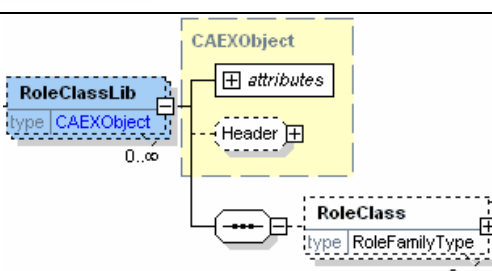
CAEX – Data model for machine information exchange

A.1 CAEX and its diagram conventions

The neutral data format CAEX defines structures for the definition and storage of objects with their characteristics and its relationships. CAEX is a basis of a general exchange format for CAE planning data and is specified as XML schema.

The schema diagrams use the following conventions in order to illustrate the structure of the CAEX schema elements, the types of the elements, the attributes, the rules for optional elements and the repetitions (see Table A.1).

Table A.1 – XML notation conventions

Diagram element	Description	Example
Rectangle with solid border	Indicates a mandatory XML Element	
Rectangle with dashed border	Indicates an optional XML Element that may be implemented	
Datatype	Indicates the datatype of an Element – after the keyword “type” in the second line of an Element	 Datatype of the XML Element
Namespace	Indicates the namespace of the used datatype. (Keyword “xs:”) The described CAEX schema refers only to the namespace of W3C (xs:schema xmlns:xs= “http://www.w3.org/2001/XMLSchema”)	 Used Namespace
Sequence	Indicates that the following elements shall be in the defined order	
Range	Indicates the allowed number of occurrence. For example 1 to infinite	 Range of the element
Plus Sign	Indicates that this xml-element contains other elements. The containing elements are hidden	 Contains sub-elements
Minus Sign	Indicates that all containing XML-elements are shown	 All contained sub-elements are shown
Greying background with dashed rectangle	Indicates that the shown elements are composed in a defined datatype. The name of the datatype is shown at the top of the dashed rectangle with dashed lines	

A.2 General CAEX concepts

A.2.1 General CAEX terms

This clause describes all CAEX terms (see Table A.2).

Table A.2 – CAEX data types and elements

Data types and elements	Detail description
AdditionalInformation	Optional auxiliary field that may contain any additional information about a CAEX object. It shall be used in the substructure of the header
Alias	Describes the alias name of an external CAEX file to enable referencing elements of the external CAEX file
Attribute	Characterizes properties of a SystemUnitClass, RoleClass, InterfaceClass, InternalElement or RoleRequirements
AttributeDataType	Describes the data type of the attribute using XML notation
AttributeNameMapping	Allows the definition of the mapping between attribute names of corresponding RoleClasses and SystemUnitClasses
AttributeType	Defines base structures for attribute definitions
AttributeValueRequirementType	Defines base structures for definition of value requirements of an attribute
CAEXBasicObject	CAEX basis object that comprises a basic set of attributes and header information which exist for all CAEX elements
CAEXFile	Root-element of the CAEX schema
CAEXObject	CAEX basis object derived from CAEXBasicObject, augmented by Name (required) and ID (optional)
ChangeMode	Optionally describes the change state of a CAEX object. If used, the ChangeMode shall have the following value range: state, create, delete and change. This information should be used for further change management applications
Constraint	Element to restrict the range of validity of a defined attribute
Copyright	Organizational information about copyright
DefaultValue	A predefined default value for an attribute
Description	Textual description for CAEX objects
ExternalInterface	Description of an external interface of a RoleClass, SystemUnitClass or InternalElement
ExternalReference	Container element for the alias definition of external CAEX files
FileName	Describes the name of the CAEX file
Header	Defines a group of organizational information, like description, version, revision, copyright, etc.
ID	Optional attribute that describes a unique identifier of the CAEX object

Table A.2 (continued)

Data types and elements	Detail description
InstanceHierarchy	Root element for a system hierarchy of object instances
InterfaceClass	Class definition for interfaces
InterfaceClassLib	Container element for a hierarchy of InterfaceClass definitions. It shall contain any interface class definitions. CAEX supports multiple interface libraries
InterfaceClassType	Shall be used for InterfaceClass definition, provides base structures for an interface class definition
InterfaceFamilyType	Defines base structures for a hierarchical InterfaceClass tree. The hierarchical structure of an interface library has organizational character only
InterfaceNameMapping	Mapping of interface names of corresponding RoleClasses and SystemUnitClasses
InternalElement	Shall be used in order to define nested objects inside of a SystemUnitClass or another InternalElement. Allows description of the internal structure of a CAEX object
InternalElementType	Type for definition of nested objects inside of a SystemUnitClass
InternalLink	Shall be used in order to define the relationships between internal interfaces of InternalElements
MappingObject	Host element for AttributeNameMapping and InterfaceNameMapping
MappingType	Base element for AttributeNameMapping and InterfaceNameMapping
Name	Describes the name of the CAEX object
NominalScaledType	Element to define constraints of nominal scaled attribute values
OrdinalScaledType	Element to define constraints of ordinal scaled attribute values
Path	Describes the path of the external CAEX file. Absolute and relative paths are allowed
RefBaseClassPath	Stores the reference of a class to its base class. References contain the full path to the referred class object
RefBaseSystemUnitPath	Stores the reference of an InternalElement to a class or instance definition. References contain the full path information
RefSemantic	A reference to a definition of a defined attribute, e. g. to an attribute in a standardized library, this allows the semantic definition of the attribute
RequiredMaxValue	Element to define a maximum value of an attribute
RequiredMinValue	Element to define a minimum value of an attribute
RequiredValue (NominalScaledType)	Element to define a required value of an attribute. It may be defined multiple times in order to define a discrete value range of the attribute
RequiredValue (OrdinalScaledType)	Element to define a required value of an attribute
Requirements	Defines informative requirements as a constraint for an attribute value

Table A.2 (continued)

Data types and elements	Detail description
Revision	Organizational information about the state of the revision
RoleClass	Definition of a class of a role type
RoleClassFamilyType	Defines base structures for a hierarchical RoleClass tree. The hierarchical structure of a role library has organizational character only
RoleClassLib	Container element for a hierarchy of RoleClass definitions. It shall contain any RoleClass definitions. CAEX supports multiple role libraries
RoleClassType	Shall be used for RoleClass definition, provides base structures for a role class definition
RoleRequirements	Describes role requirements of an InternalElement. It allows the definition of a reference to a RoleClass and the specification of role requirements like required attributes and required interfaces
SchemaVersion	Describes the version of the schema. Each CAEX document shall specify which CAEX version it requires. The version number of a CAEX document shall fit to the version number specified in the CAEX schema file
SupportedRoleClass	Allows the association of the corresponding SystemUnitClass to a RoleClass. This describes, which role the SystemUnitClass can play. A SystemUnitClass may reference multiple roles
SystemUnitClass	Shall be used for SystemUnitClass definition, provides definition of a class of a SystemUnitClass type
SystemUnitClassLib	Container element for a hierarchy of SystemUnitClass definitions. It shall contain any SystemunitClass definitions. CAEX supports multiple SystemUnitClass libraries
SystemUnitClassType	Defines base structures for a SystemUnit class definition
SystemUnitFamilyType	Defines base structures for a hierarchical SystemUnitClass tree. The hierarchical structure of a SystemUnit library has organizational character only
Unit	Describes the unit of a variable
UnknownType	Element to define constraints for attribute values of an unknown scale type
Value	Element describing the value of an attribute
Version	Organizational information about the state of the version

A.2.2 General CAEX concept description

A.2.2.1 CAEX basic concept

The general goal of CAEX is the vendor independent storage of hierarchical object information. Object oriented concepts as encapsulation, classes, class libraries, instances, instance hierarchies, inheritance, relations, attributes and interfaces are explicitly supported.

CAEX supports 3 types of classes and corresponding libraries.

- a) **SystemUnitClasses** describe physical or logical plant objects or units including their technical realization and internal architecture. They consist of attributes, interfaces, nested internal elements and relations between the internal elements. The internal elements may contain further nested elements - this allows for description of predefined structures with multiple hierarchy levels. The concept of internal elements

allows describing the internal architecture of a plant object.

SystemUnitClasses are collected in libraries of the type **SystemUnitClassLib**: This CAEX element allows collecting an arbitrary number of objects of the type **SystemUnitClassType** within a library. CAEX supports the definition of multiple **SystemUnitClass** libraries. **SystemUnitClasses** can be arranged within the library as tree in order to depict the user's library breakdown structure. A **SystemUnitClass** can further be inherited from another **SystemUnitClass** by means of a reference. **SystemUnitClassLib**'s can e.g. be used to store product catalogues.

- b) **RoleClasses** also describe physical or logical plant objects, but, compared to **SystemUnitClasses**, they are an abstraction of a concrete technical realization. **RoleClasses** consist of attributes and interfaces, but do not describe the concrete internal implementation of the object. It is used in order to define requirements for a plant object.

RoleClassLib: This CAEX element allows for collecting an arbitrary number of objects of the type **RoleClassType** within a library. CAEX supports the definition of multiple **RoleClass** libraries. **RoleClasses** can be arranged within the library as tree in order to depict the user's library breakdown structure. A **RoleClass** can further be inherited from another **RoleClass** by means of a reference.

- c) **InterfaceClasses** describe types of interfaces. **InterfaceClasses** comprise a set of specific attributes and are used in order to specify interfaces for e.g. **RoleClasses** and **SystemUnitClasses**. Interfaces are required in order to define relations between objects.

InterfaceClassLib: This CAEX element allows collecting an arbitrary number of objects of the type **InterfaceClassType** within a library. CAEX supports definition of multiple **InterfaceClass** libraries. **InterfaceClasses** can be arranged within the library as tree in order to depict the user's library breakdown structure. An **InterfaceClass** can further be inherited from another **InterfaceClass** by means of a reference.

The CAEX element **InstanceHierarchy** allows storage of instance data. Individual objects are in the following named "instances", the term "instance" describes an individual object with individual properties. Each class can be instantiated multiple times, e.g. a class "c" can be the class of the object instances "c1", "c2" and "c3". The CAEX element **InstanceHierarchy** consists of an arbitrary number of internal elements which are recursively nested – this allows for describing arbitrary object hierarchies. CAEX supports multiple instance hierarchies.

The **InstanceHierarchy** can be used in one of the following ways:

- a) **working without classes**: All hierarchy objects can be defined in the instance hierarchy in form of nested **InternalElements** as an object tree. For each single object, all required attributes, interfaces and links etc. are defined on instance level. This workflow supports data storage without classes at all. This might be of interest e.g. if existing libraries are not the objective of the data exchange;
- b) **working with classes only**: The desired plant hierarchy is defined by a single **InternalElement** in the **InstanceHierarchy**. This **InternalElement** references a complex **SystemUnitClass** which comprises the complete system description including the plant topology, units, components, attributes etc. This workflow is of interest if the plant or unit structure to be stored in CAEX is a standard solution and is intended to be used several times;
- c) **mixed workflow**: This is the typical workflow for practical use. Typical components are defined as **SystemUnitClasses**; sub-structures of the **SystemUnitClass** are defined by aggregation of objects as **InternalElements**. Attributes may be predefined, default attribute values may be set. The **InstanceHierarchy** is being used for the plant topology definition. In the next step, each defined internal hierarchical element can be associated with a **RoleClass** in order to define the requirements to this object. Finally,