Common Format for Measurement and Analysis Data

JIS K 0200: 2024

This document is a provisional translation excerpt

Contents

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Common Format for Measurement and Analysis Data

1. Scope

This standard specifies the structural portions of data format conventions that should be satisfied by measuring/analytical instruments and software, either for research and development use or industrial use, when performing actions a) to c) indicated below.

a) Recording acquired measurement/analysis data, measurement/analysis processes, sample information, pretreatment processes, and log events

b) Sending or receiving acquired measurement/analysis data between different systems

c) Indicating information about the design or instructions for measurement/analysis processes

This standard applies to data acquired using a measuring/analytical instrument operating device, control computer, or data analysis computer and for digitally exporting sample information or measurement/analysis conditions from such devices. Data indicated in accordance with this standard can be shared in cyberspace or elsewhere independently from the measuring/analytical instrument, control computer, or data analysis computer used to generate the data.

Note: When “measurement/analysis” is used in this standard as an independent term, it refers to the entire series of actions involved in measuring, analyzing, or other processes performed specifically for that purpose.

2. Cited Standards

By citation in this standard, a portion or the entirety of the following cited standards are considered part of the requirements of this standard. The most recent version (including addenda) of the cited standards should apply.

JIS X 0001 Glossary of terms used in information processing—Fundamental terms

JIS X 4158 Namespaces in XML

Note: Conforms to the World Wide Web (W3C) Recommendation (hereinafter “W3C Recommendation”), “XML Namespaces,” and “Namespaces in XML” (January 14, 1999).

JIS X 4159 Extensible Markup Language (XML) 1.0

Note: Conforms to the W3C Recommendation, XML, and Extensible Markup Language (XML) 1.0 (Third Edition) (February 4, 2004).

JIS X 5093 Long-term signature profiles for XML advanced electronic signatures (XAdES)

Note: Conforms to ETSI TS 101 903 XML Advanced Electronic Signatures (XAdES) v1.3.2.

JIS X 5810-1 Multipurpose Internet Mail Extensions (MIME)—Part 1: Format of Internet Message Bodies

Note: Conforms to Internet Engineering Task Force (IETF) Request for Comments (RFC) 2046 Multipurpose Internet Mail Extensions (MIME) Part Two: Media Types.

ISO/IEC 21320-1, Information technology - Document Container File - Part 1: Core

Note: This is a standard for ZIP formats and conforms to ISO/IEC 26300-3:2015, ISO/IEC 26300:2006, and ISO/IEC 29500-1:2016.

3. Terms and Definitions

Key terms and definitions for this standard conform to JIS X 0001 and JIS X 4159, in addition to the following.

3.1 URI (Uniform Resource Identifier)

The URI uses a uniform format to provide information necessary for differentiating a specific item from other items within an identification system.

Note: The identification method conforms to IETF RFC 3986.

3.2 UUID (Universally Unique Identifier)

UUIDs are identifiers used to uniquely identify things in accordance with IETF RFC 4122.

Note: The identifiers are expressed as 128-bit numbers. They are also sometimes expressed as 32-digit hexadecimal values.

3.3 XML (Extensible Markup Language)

This extensible markup language uses character strings called tags to express the structure and other attributes of data.

3.4 Namespaces

Namespaces divide the overall name string into independent parts so different identifiers can be assigned to respective partial namespaces in order to avoid potential conflicts with names included within that partial space and to make it easier to refer to items.

3.5 XML namespaces

XML namespaces are a collection of namespaces used to indicate element types and attribute names in XML documents by referencing URIs as identifiers.

Note 1: Referencing a URI to identify names makes referencing easier while avoiding the risk of conflicts. When referencing URIs to identify namespaces, if the characters in the character string used for URI referencing are completely identical, then the namespaces are considered to be identical.

Note 2: The identifier used to identify namespaces is defined as prefixes in the form “identifier:name.”

3.6 MaiML (Measurement Analysis Instrument Markup Language)

MaiML is the name of the XML-compliant data format specified by this standard.

3.7 maiml

This is the XML namespace specified by this standard and used to differentiate the MaiML data format.

3.8 Tags (XML)

Tags are characters indicated between “<” and “>” symbols. They are specified to indicate the names and attributes of elements specified in XML.

3.9 Opening tag (XML)

This tag indicates the start of an element specified in XML.

Note: If the element name is “XXX,” then it is clearly indicated as <XXX> to mark where the element content starts.

3.10 Closing tags (XML)

This tag specifies the end of an element specified in XML.

Note: If the element name is “XXX,” then it is clearly indicated as </XXX> to mark where the element content ends.

3.11 Elements (XML)

Elements are the basic unit of information in XML. They start with an opening tag and end with a closing tag.

Note: This includes XML elements and attributes. It also includes text and other data.

3.12 Element names (XML)

These are element names specified using XML tags.

Note: An element with the name “X” would be indicated as the <X> element.

3.13 Content (XML)

Content is character data located between the opening and closing tags specified by XML.

3.14 Attributes (XML)

An attribute is information specified within the opening tag that designates additional information about XML elements.

3.15 Element type (MaiML)

The MaiML element type specifies content and attributes included in the MaiML element.

3.16 Level 0 elements <maiml>

These elements are positioned at the highest level of the data format specified by this standard.

3.17 Log

This is a history of measurement/analysis events specified by this standard.

3.18 Cyberspace

Cyberspace is a virtual space configured from mainly computers and networks.

3.19 Files

Files are units of collective data in information systems.

Note 1: Refers to the minimum unit of data recorded on a hard drive or other external storage device used by users.

Note 2: Unit of data sent/received during communications between computers.

Note 3: Unit of data indicated by level 0 elements in the MaiML data format.

3.20 Independent availability

Independent availability refers to the characteristic that all information necessary for measurement/analysis can be obtained from only the content in files (3.19) independently from the measuring/analytical instrument and software.

3.21 Traceability

Traceability is the ability to trace the measurement/analysis and data analysis processes and history involved in obtaining the data.

Note 1: That means the date and time of measurements/analyses and data analysis, the methods used, and other information necessary for tracing the data history should be recorded.

Note 2: This is the same “traceability” term specified in JIS Q 9000.

3.22 Reproducibility

Reproducibility is the ability to reproduce the same procedure from the information provided about conditions and methods used for measurement/analysis and data analysis.

Note: Sufficient information should be provided about the methods and conditions used for measurement/analysis and data analysis.

3.23 Operation

Operation refers to operating instrument software or other resources according to the specified methods and recording the operations as log events.

Note: It refers specifically to the operations involved in using the measuring/analytical instruments or software to perform measurements/analyses, which are referred to as measurement/analysis operations.

3.24 Process

Processes indicate the sequence and stages for executing operations.

Note: Processes that indicate the sequence and stages for executing measurement/analysis operations are referred to as measurement/analysis processes.

3.25 Series of measurement/analysis processes

This refers to an entire series of process steps, ranging from inputting data for conditions, samples, and data

analysis, to acquiring measurement/analysis output by performing one or more measuring/analytical operations using specific measuring/analytical instruments or software.
Note 1: The MaiML data format includes the elements for expressing a series of measurement/analysis processes.
Note 2: If multiple series of measurement/analysis processes are indicated independently, it is referred to as a set of series of measurement/analysis processes, which can be expressed with elements available in the MaiML data format.

3.26 Nesting
In software programs and data structures, nesting refers to including an identical structure within a given structure.

3.27 Directed graph
A directed graph is a diagram composed of a set of nodes connected by edges that indicate the sequence between those nodes.

3.28 Element type
The element type indicates the content and attributes of elements.
Note: In the MaiML data format, it indicates the content and attribute of the specified value included in the element.

3.29 Simple element type
Of the elements specified by the MaiML data format, this element type includes the minimum content.
Note: Elements with a simple element type are referred to as simple elements.

3.30 Global element type
Of the elements specified by the MaiML data format, this element type includes a UUID value as content and is used to indicate the element’s unique existence in cyberspace.
Note: Elements with a global element type are referred to as global elements.

3.31 Unique global element type
This global element type includes a UUID value for ensuring the uniqueness of specific hardware, software, a person, or organization.
Note: Elements with a unique global element type are referred to as unique global elements.

3.32 Reference element type
This element type is used to reference another element within a file written in the MaiML data format.
Note: Elements with a reference element type are referred to as reference elements.

3.33 Referencing global element type
This element type contains a global element as content and a reference element type as an attribute.
Note: Elements with a referencing global element type are referred to as referencing global elements.

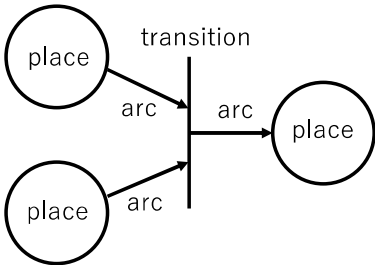
3.34 Directed graph element type

This contains an MaiML data format source attribute and target attribute, links two reference elements, and is used to indicate directed graphs.

Note: Elements with a directed graph element type are referred to as directed graph elements.

3.35 Petri net

Petri nets are directed graphs that contain two types of nodes (place and transition nodes) connected by edges, referred to as arcs, that indicate sequential direction (as shown).



Note 1: Petri nets are a type of data structure used to model system actions and provide a way to express process steps visually.

Note 2: The MaiML data format uses Petri nets as data structures for expressing an entire series of measurement/analysis processes.

3.36 Pretreatment process

Pretreatment processes include preparing samples for measurement/analysis and processing data, such as for entering data in data analysis software.

3.37 General purpose data container

This data structure is used to hold various data types.

Note: In the MaiML data format, they are used to indicate <property>, <content>, and <uncertainty> elements.

3.38 Line feed code

This code executes the line feed action.

Note: In the MaiML data format, it can be expressed using either the ASCII code “CR” (carriage return), “LF” (line feed), or “CR+LF.”

3.39 Template

A template is data that serves as a template, such as for creating other data.

Note: In the MaiML data format, it is used to indicate a standard series of measurement/analysis processes

and contains elements used to express the template.

3.40 Instance

An instance is actual data generated based on template data.

Note: In the MaiML data format, it contains an element that indicates an instance that references a template that indicates a standard series of measurement/analysis processes.

3.41 Similar measurement/analysis process

In the MaiML data format, this refers to measurement/analysis processes with similar process steps but with materials or conditions that contain different general purpose data container types or values.

Note: The MaiML data format includes the elements necessary for expressing similar measurement/analysis processes and their results.

3.42 ZIP format

A file format used to compress multiple files into a single file.

Note: ZIP format files are created according to the methods specified in ISO/IEC 21320-1.

3.43 Metadata

Data attributes and other supplemental information about data, rather than the data itself.

3.44 MIME (Multipurpose Internet Mail Extensions)

This email protocol extension is used to enable handling a variety of formats in Internet emails that only permit US-ASCII text.

Note: The format for the body of Internet messages is regulated by JIS X 5810-1.

3.45 Standard XES (eXtensible Event Stream) format

Standard XES is an XML-compliant format that enables information system designers to determine system behavior based on event log or other information.

Note: Methods for creating standard XES formats are regulated by the IEEE Standards Association in accordance with the IEEE Std 1849 approved by ANSI.

3.46 Life cycle

The transition in the state of all measurement/analysis and other processes.

Note: All changes in the transition of process states, such as successful completion (complete), are modeled and expressed as a life cycle.

3.47 Ordered list

A set of general purpose data containers indicated as multiple parallel lists.

Note: To divide an ordered list into multiple general purpose data containers, list them in parallel, in the same order as the data list.

3.48 QName (Qualified Name)

The QName is a modified name composed of the namespace prefix and local name.

Note 1: The definitions of a “modified name,” “namespace,” and “local name” are specified by JIS X 4158.

Note 2: The type that includes a <name> element and key attribute is defined as “xs:QName.”

3.49 MaiML file

MaiML files are files indicated using the MaiML data format.

3.50 UPA constraint (Unique Particle Attribution Constraint)

Constraint for uniquely determining content models in XML files based on schema.

Note: Specifications for constraint conditions are specified in the W3C recommendation W3C XML Schema Definition Language (XSD) 1.1 Part 1: Structures (5 April 2012).

3.51 Parent element

The element positioned hierarchically directly above a particular element.

3.52 Child element

The element positioned hierarchically directly below a particular element.

3.53 Ancestor element

An element hierarchically above and directly connected to a particular element.

3.54 Descendant element

An element hierarchically below and directly connected to a particular element.

3.55 xsi:type

This attribute indicates the secondary data type in the MaiML data format.

Note 1: The prefix xsi is used for namespaces.

Note 2: This indicates a data type governed by rules for XML schema instance namespaces, as specified in the W3C recommendation W3C XML Schema Definition Language (XSD) 1.1 Part 1: Structures (5 April 2012).

4. Symbols and Abbreviations

4.1 Symbols

QName	This abbreviation of “Qualified Name” indicates a special character string used in XML.
xmlns	XML namespace
xsi	This prefix is an abbreviation of “XMLSchema-instance” used as an XML namespace.
xs	This prefix is an abbreviation of “XML Schema” used as an XML namespace.

4.2 Abbreviations

IETF	Internet Engineering Task Force
DSDL	Document Schema Definition Languages
OWL	Web Ontology Language
RDF	Resource Description Framework
RDFS	Resource Description Framework Scheme
RFC	Request for Comments
MIME	Multipurpose Internet Mail Extensions
SEM	Scanning Electron Microscope
TEM	Transmission Electron Microscope
UPA	Unique Particle Attribution
URI	Uniform Resource Identifier
UUID	Universally Unique Identifier
W3C	World Wide Web Consortium
XES	eXtensible Event Stream
XML	Extensible Markup Language
XSD	XML Schema Definition

5. Overview of Format

5.1 Structure of Format

The format described in clauses 6 and 7 is compliant with XML requirements specified in JIS X 4159, but also includes XML extensions that allow it to be used for sharing measurement/analysis methods, results, and other information obtained using different measuring/analytical instruments or software in cyberspace. That format is called MaiML. The MaiML format also includes methods for indicating elements that are traceable and reproducible. Furthermore, it includes methods for preventing data tampering and encryption. Consequently, it provides independent availability of all information necessary for using that data in cyberspace.

The elements and data used to indicate the overall structure of files and ensure independent availability are listed in Tables 1 and 2. The elements in Table 1 that indicate structure have structural hierarchy levels from 0 to 4. In addition, the elements that indicate structure in Table 1 should not be used to encrypt opening and closing tags. In contrast, descendant elements of Table 1 elements that are not listed in Table 1 and include an element indicated in Table 2 can be used to encrypt opening/closing tags using xmlenc-core1 from the W3C recommendation as indicated in 7.3. Details about how to encrypt content are indicated in Tables 6, 20, and 22, and section 7.3.

Table 1 Elements that Indicate File Structure in MaiML

Layer 0	Layer 1	Layer 2	Layer 3	Layer 4
<maiml> 6.1	<document> a) 6.2	<Signature>	—	
		<uuid> <creator> b) <owner> b) <vendor> b) <instrument> b) <date> <chain> a) <parent> a)		
	<protocol> a) 6.3	<method> a)	<pnml> a)	<place> <transition> <arc>
			<program> a)	<instruction> a) <resultTemplate> a),f) <materialTemplate> a),f) <conditionTemplate> a),f)
			<resultTemplate> a),e) <materialTemplate> a),e) <conditionTemplate> a),e)	
		<resultTemplate> a),d) <materialTemplate> a),d) <conditionTemplate> a),d)		
	<data> a) 6.4	<results> a)	<result> c) <material> c) <condition> c)	
	<eventLog> a) 6.5	<log> c)	<trace> c)	<event> c)

Note: The top hierarchical level is level 0, with elements in the lower levels serving as content for elements in higher levels.
Note a) Global element as specified in 6.1.4.
Note b) Unique global element as specified in 6.1.4.
Note c) Referencing global element as specified in 6.1.6.
Note d) Multiple <method> elements below the <protocol> element level can be shared.
Note e) Multiple <program> elements below the <method> element level can be shared.
Note f) Elements below the <program> element level can be used.

Elements related to data in the MaiML format are indicated in Table 2. In this table, elements are grouped separately based on their purpose, with elements for ensuring data uniqueness, elements for ensuring the expression of general purpose data, and elements for encrypting and preventing data tampering are listed grouped together.

Table 2 Main Elements Related to Data Indicated in MaiML

Category	Elements for Ensuring Uniqueness	Elements for General Purpose Data Containers	Elements for Linking Files	Elements for Encrypting and Preventing Data Tampering
Subclauses	6.1.4 7.10	7.1	6.2.9 6.2.10 7.4 7.8 7.9.2	6.2.2 7.2 7.3 7.9.1
Element	<uuid> <name>	<property> <content> <uncertainty>	<parent> <chain> <insertion> <hash>	<Signature> <EncryptedData> <childUri> <childHash> <childUuid>

Criteria for the number of elements to indicate are described in Table 3.

Table 3 Criteria for Number of Elements to Indicate

Criterion	Description
1	Always indicate one element but never multiple elements.
0 or 1	One element may be indicated but never multiple elements.
0 or more	An element or multiple elements may be indicated.
1 or more	At least one element should be indicated.

5.2 Indicating Measurement/Analysis Pretreatment Processes

In addition to indicating direct action steps for devices and software involved in measurement, analysis, and data analysis, also indicate information about preparing samples for measurement/analysis, pretreatment processes for sample preparation, and preprocessing data for data analysis and acquisition software. Specifically, indicate the unpretreated raw materials, reagents and other materials required for pretreatment processes, operating conditions required for pretreatment processes, information about specific technologies used in processes, and corresponding results in the content of <protocol> and <data> elements. Indicate processes involved in each step of the operations using <pnml> elements as the content of <protocol> elements. For policies on the indication of code for measuring/analysis processes, refer to 5.3.

5.3 Policies for Implementation

Policies for using the elements specified in Tables 1 and 2 to indicate measurement/analysis data are described in paragraphs a) to e) below.

a) Modeling: Use Petri net diagrams to model and visualize processes involved in acquiring measurement/analysis data. Specifically, indicate the entire series of measurement/analysis processes by using

<materialTemplate>, <conditionTemplate>, <resultTemplate>, <instruction>, and <pnml> elements as content for a <protocol> element specified for each operation and measurement/analysis process. Use <method> and <program> elements to indicate the system boundaries between measuring/analytical instrument and software. Record the results and information acquired from measurement/analysis processes indicated in <protocol> elements in a file, with <material>, <condition>, and <result> elements that reference <materialTemplate>, <conditionTemplate>, and <resultTemplate> elements, as content for <data> elements.

b) Preventing data tampering: Use a format with data tampering prevention measures. Specifically, use UUIDs to ensure the uniqueness of entire files and specified elements, apply digital signatures, and link files to detect data modifications based on hash values for entire files.

c) Traceability: Record a history of generated data so that data is traceable. Specifically, use <event> elements to record the data acquisition time or other information as content in <eventLog> elements. Also, use <owner> and <creator> elements respectively to indicate data owner information, measuring/analytical instrument information, and software information as <document> element content. In addition, use <instruction> and <transition> elements to specify each operation for data acquisition processes as content for <protocol> elements.

d) Indicating general purpose data containers: Indicate numeric data and text data generated from individual operations involved in acquiring measurement/analysis data and the sequence the data was generated. Also, indicate information, with the data type attached, about the samples and operating conditions necessary for those operations. Specifically, indicate the information using <property> and <content> elements. In that case, indicate the metadata for the data container as a key attribute and indicate the corresponding data type as an xsi:type attribute.

e) Using external files: Data required for each operation involved in acquiring measurement/analysis data can be indicated as external files. Specifically, external files generated by individual measuring/analytical instruments or corresponding data analysis software based on MaiML or other data formats can be indicated using an <insertion> element.

Element details are described in clauses 6 and 7.

Note 1: A guideline for compliance with shared data formats is posted at “http://www.maiml.org/guideline/” and definitions of XML schema are posted at “http://www.maiml.org/schemas/.”

Note 2: The guideline for compliance with shared data formats includes case studies from applying this standard and describes how to create data and how to utilize case studies and data.

Note 3: Definitions of XML schema compatible with shared data formats are included to help build systems for creating data in accordance with XML schema specified in JIS X 4177-3.

6. Elements that Indicate Format Structure

6.1 Overall Structure of Measurement/Analysis Data Files

6.1.1 Definition of XML Namespaces

To prevent conflicts between namespaces with different XML identifiers, such as an element name or a type name specified by an xsi:type attribute, all MaiML files differentiate between XML identifiers used in MaiML files

by referencing URIs in XML namespaces specified by JIS X 4158. To create an MaiML file, an xmlns declaration without a prefix specified is used to declare MaiML XML namespaces. In addition, if other XML namespaces are used within an MaiML file, then the corresponding XML namespaces can be specified by using an xmlns declaration with a prefix attached.

Namespaces specified by an <maiml> element attribute conform to 6.1.9 and Table 12.

An example of using a namespace is shown in Example 1.

Example 1 The following is an example of indicating an <maiml> element. In this case, a schema specified by “http://www.maiml.org/schemas” is used to indicate a part of MaiML data format code with an maimlRootType type specified within the schema.

```
<?xml version="1.0"encoding="UTF-8"?>
<maiml version="1.0"xmlns="http://www.maiml.org/schemas"
        xmlns:xsi="http://www.w3.org/200l/XMLSchema-instance"
        xsi:type="maimlRootType">
    <document id="MaimlSampleDocument">
        <!--include all content indicated in the document—>
    </document>
    <!--include all content indicated other than in the document—->
</maiml>
```

Note 1 The <document> element indicates that it is the MaiML namespace tag element specified by xmlns. In this case, the <document> element does not define the prefix. If the xmlns attribute is specified in the form “xmlns="http://www.maiml.org/schemas",” that indicates that all tag and attribute names without an <maiml> element prefix are defined by URIs indicated in “http://www.maiml.org/schemas.”

Note 2: In this example, the <maiml> element has three attributes, which are xmlns, version, and xsi:type. The “http://www.maiml.org/schemas” used as an xmlns value is a URI that ensures the uniqueness of the XML namespace.

To use an maiml from another format, use the identifier maiml to differentiate between them and use a prefix maiml or XML namespace. An example of using an maiml element from another format (XXX) is shown in Example 2.

Example 2

```
<?xml version="1.0"encoding="UTF-8"?>
<XXX xmlns:maiml="http://www.maiml.org/schemas"
        xmlns:xsi="http://www.w3.org/200l/XMLSchema-instance">
    <maiml:document id="MaimlSampleDocument">
        <!--include all content indicated in maiml:document—->
    </maiml:document>
</XXX>
```

Note 3: This shows an example of indicating an <maiml:document> element as a <document> element specified in an MaiML namespace.

Manage MaiML namespaces based on the version specified in 6.1.2. Elements specified in an MaiML namespace have a type specified in 6.1.3 to 6.1.10, 6.2 to 6.5, and 7.1 to 7.10. 6.1.3 to 6.1.8 specifies the simple element type, global element type, reference element type, referencing global element type, directed graph element type, and general purpose data container type. <maiml> elements and general purpose data container elements specified in 6.1.8 have the type indicated in 7.1. The derivative type is explicitly specified in MaiML files by an attribute specified in W3C xml schema 11-1 as “xsi:type.”

Xmlns attributes used for XML namespaces are described in more detail in subclauses 6.1.3, 6.1.4, 6.1.5, 6.1.7, 6.1.9, 6.2.2, 7.1.1, 7.1.2, and 7.3. However, the following prefixes a) to d) are used in this standard unless specifically specified otherwise.

a) xmins:xs="http://www.w3.org/200l/XMLSchema"
b) xmlns:xs="http://www.w3.org/2001/XMLSchema-instance"
c) xmlns:ds="http://www.w3.org/2000/09/xmldsig#"
d) xmlns:xenc="http://www.w3.org/2001/04/xmlenc#"

Note 4: Either “nsl:” or “exm:” is used to indicate namespaces for terminology in this standard, unless specifically specified otherwise.

6.1.2 Version Management

The attribute for MaiML file versions should be included as an <maiml> element version attribute value. “x.y” should be the format for character strings used to indicate the version attribute, where x indicates the version number and y the sub-version number. The version of this standard is 1.0.

Note: The XML schema used for the MaiML data format indicates version attributes in the form “x.y.z,” where z is an errata release number that indicates the number of corrections.

6.1.3 Simple Elements

The content and attributes of simple elements are indicated in Tables 4 and 5, respectively.

Table 4 Content Included in Simple Elements

Element	Child Element	Type	Description	Criterion
Simple Element	<name>	xs:QName	Indicates the parent element name.	0 or 1
	<description>	xs:string	Indicates the content to display if the meaning or name of a parent element is to be displayed, such as in data analysis software.	0 or 1

Table 5 Attributes Included in Simple Elements

Element	Attribute	Type	Description	Criterion
Simple Element	id	xs:ID	Specified as an identifier for linking data within the same file. Uniqueness should be ensured within files.	1

6.1.4 Global Elements

The content and attributes of global elements are indicated in Tables 6 and 7, respectively. The content element <uuid> includes a UUID value for ensuring the uniqueness of global elements.

Table 6 Content Included in Global Elements

Element	Child Element	Type	Description	Criterion
Global Element	<uuid>	xs:string	Specifies a UUID value for ensuring the uniqueness of global elements. If an element is identical to an element in an MaiML expression, then it should have the same UUID value.	1
	<childUri>	xs:anyURI	If an <insertion> element is included among collectively encrypted <insertion>, <name>, <description>, <annotation>, <property>, and <content> elements, then all their URI values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<childHash>	xs:base64Binary	If an <insertion> element is included among collectively encrypted <insertion>, <name>, <description>, <annotation>, <property>, and <content> elements, then all their Hash Value values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<childUuid>	xs:string	If an <insertion> element is included among collectively encrypted <insertion>, <name>, <description>, <annotation>, <property>, and <content> elements, then all their UUID values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<EncryptedData>	xenc:EncryptedData	<insertion>, <name>, <description>, <annotation>, <property>, and <content> elements can be encrypted collectively. If encrypted, the elements are replaced by an <EncryptedData> element.	0 or 1
	<insertion>	Refer to Table 28	Indicates an external file, as specified in 7.4, as information linked to a global element.	0 or more
	<name>	xs:QName	Specifies the parent element name.	0 or 1
	<description>	xs:string	Indicates the content to display if a global element is to be displayed, such as in data analysis software.	0 or 1
	<annotation>	xs:string	Indicates the character string to use for describing global elements.	0 or 1
	<property>	General Purpose Data Container	Indicates an element that contains general purpose data or metadata structurally below a global element, such as numeric values or text information included in measurement/analysis data.	0 or more
	<content>	General Purpose Data Container	Indicates an element with vector data with an axis for numeric values or text information included in measurement/analysis data, tabular data, or metadata in a structure below a global element.	0 or more
Character strings specified by “xs:string” in <uuid> elements indicate 128-bit numeric values. Indicate hexadecimal values in the form “xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx,” with the character “x” representing				

each place value as either an alphanumeric character from 0 to 9, A to F or 0 to 9, or a to f. An example is 82flffa4-5675-4a13-8fa3-213213f12312.
Version 4 UUID values defined by RFC 4122 and generated from random numbers are used for <uuid> elements. However, version 3 or 5 values may be used for global elements that are designated as unique global elements, if UUID values that ensure uniqueness can be generated, such as based on specific hardware, software, people, or organizations, in accordance with 7.10.

Table 7 Global Element Attributes

Element	Attribute	Type	Description	Criterion
Global Element	id	xs:ID	Specified as an identifier for linking data within the same file.	1

Global elements can indicate an ordered list for a <property> element or a <content> element in a general purpose data container as content.

An example of a <property> element ordered list is shown below.

Example

The code

```
<property xsi:type="intListType"key="nsl:SampleList">
    <value>1 2 3 4 5 6</value>
</property>
```

can also be indicated split as:

```
<property xsi:type="intListType"key="nsl:SampleList">
    <value>1 2 3</value>
</property>
<property xsi:type="intListType"key="nsl:SampleList">
    <value>4 5 6</value>
</property>
```

However, the order of <property> elements should not be changed.

If a global element is indicated in an external file included in a ZIP format file, then the <insertion> element should be used to indicate the external file. Because that involves checking the external file for modifications, the <uri> element that specified the external file URI value and the <hash> element that ensures the uniqueness of the external file should be specified. In that case, it is recommended to specify a <format> element to explicitly indicate supplemental information, such as the external file type and whether encryption was used. For more details about the <insertion> element, refer to 7.4. Also refer to B.10.3.

6.1.5 Reference Elements

The content of reference elements is indicated in Table 8. For the attributes indicated in Table 9, if reference element X references another element Y, then the id attribute for Y is specified as the X ref attribute value.

Tables 8 Content of Reference Element Type Elements

Element	Child Element	Type	Description	Criterion
Reference Element	<name>	xs:QName	Specifies the parent element name.	0 or 1
	<description>	xs:string	Indicates the content to display if a global element is to be displayed, such as in data analysis software.	0 or 1

Table 9 Attributes of Reference Element Type Elements

Element	Attribute	Type	Description	Criterion
Reference Element	id	xs:ID	Specified as an identifier for linking data within the same file.	1
	ref	xs:IDREF	Indicates the ID value for the id attribute of data to be referenced when referencing an identifier for linking data within the same file.	1

6.1.6 Referencing Global Elements

Referencing global elements contain global element type content indicated in Table 6 and have an attribute with a reference element type indicated in Table 9. These global elements require an identifier for linking data within the same file.

6.1.7 Directed Graph Elements

Content of directed graph elements is indicated in Table 10 and attributes in Table 11.

Table 10 Content of Directed Graph Elements

Element	Child Element	Type	Description	Criterion
Directed Graph Element	<name>	xs:QName	Specifies the parent element name.	0 or 1
	<description>	xs:string	Indicates the content to display if a global element is to be displayed, such as in data analysis software.	0 or 1

Table 11 Attributes of Directed Graph Elements

Element	Attribute	Type	Description	Criterion
Directed Graph Element	id	xs:ID	Specified as an identifier for linking data within the same file.	1
	source	xs:IDREF	Indicates the ID value for the starting point id attribute of directed graphs.	1
	target	xs:IDREF	Indicates the ID value for the ending point id attribute of directed graphs.	1

The following is an example of an <arc> element defined in 7.6 that indicates an edge of a directed graph element.

Example

```
<pnml id="MaimlSamplePnml">
    <!-- Examples of <arc> elements that are directed graphs -->
    <arc id="a1" source="p4" target="t7">
        <name>ns1:place-4-to-7</name>
    </arc>
    <arc id="a2" source="p5" target="t7">
        <name>ns1:place-5-to-7</name>
    </arc>
    <arc id="a3" source="t7" target="p6">
        <name>ns1:place-7-to-6</name>
    </arc>
</pnml>
```

The meaning of source and target attributes for directed graphs is shown in Fig. 1.

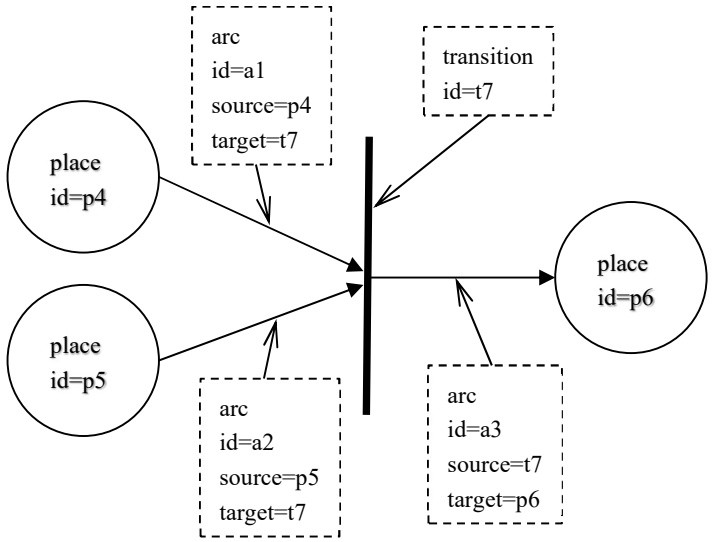


Fig. 1 Meaning of Source and Target Attributes for Directed Graph Elements

6.1.8 General Purpose Data Container Elements

<property> and <content> elements are specified as general purpose data container elements used to hold numeric data, text data, or other information. Corresponding details are specified in 7.1.

6.1.9 Overall Data Format Structure

Elements that start with <maiml> and end with </maiml> are referred to as <maiml> elements. Only one

<maiml> element is specified per file. That <maiml> element is referred to as the Level 0 element. Attributes of the <maiml> element are listed in Table 12.

Table 12 <maiml> Element Attributes

Element	Attribute	Type	Specified Data Values	Description	Criterion
<maiml>	version	xs:string	1.0	Indicates the MaiML file version.	1
	features	xs:string	nested-attributes [a)]	Indicates functions supported by the format. Multiple attributes are linked with spaces.	0 or 1[a)]
	xmlns	xs:anyURI	http://www.maiml.org/schemas	Indicates a URI for identifying a namespace.	1
	xmlns:xsi	xs:anyURI	http://www.w3.org/2001/XMLSchema-instance	Indicates a namespace that specifies an XML schema instance.	1
	xsi:type	xs:QName	—	Indicates either an maimlRootType or protocolFileRootType value[b)].	1
Content or key attribute values for xs:QName type <name> elements can be indicated using namespaces not specified by this standard (referred to as “other namespaces”). In that case, the other namespaces can be indicated as attributes of the <maiml> element or an ancestor element of the indicated element using an xmlns attribute with a prefix attached. Note a) This indicates that nested property/content values can be achieved by indicating “nested-attributes” as the specified value. Note b) For the maimlRootType, indicate all elements listed in Table 13, including <document>, <protocol>, <data>, and <eventLog> elements, as child elements of the <maiml> element. For the protocolFileRootType, indicate only the <document>and <protocol> elements listed in Table 13.					

An example of indicating the elements in an MaiML file is shown in Example 1.

Example 1: Example of Top-Level Tags for Indicating an MaiML File

In this example, “maimlRootType” is specified as the type for indicating measurement/analysis results when the schema specified in “http://www.maiml.org/schemas” is used.

```
<?xml version="1.0"encodingc"UTF-8"?>
<maiml version="1.0"features="nested-attributes"
        xmlns="http://www.maiml.org/schemas"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:type="maimlRootType">
      <!-- include all indicated content -->
</maiml>
```

To indicate the file uniqueness and the entire series of measurement/analysis processes, Level O <maiml> elements include a <document> element specified in 6.2 and a <protocol> element specified 6.3. To indicate measurement/analysis results and corresponding log events, they include <data> and <eventLog> elements. Content for <maiml> elements is listed in Table 13.

Table 13 Description of <maiml> Element Content and Criteria for Indicating the Content

Element	Description	Criterion
<document>	Ensures measurement/analysis uniqueness.	1
<protocol>	Indicates the entire series of measurement/analysis processes.	1
<data>	Indicates the data obtained by measurement/analysis.	0[a)] or 1[b)]

<eventLog>	Indicates log events if data was obtained by measurement/analysis.	0[a)] or 1[b)]

Note a) Indicate neither of these elements if protocolFileRootType is specified as the xsi:type attribute for the <maiml> element and a file with only the measurement/analysis technique expressed is indicated.
Note b) Indicate this element to specify maimlRootType as the xsi:type attribute for the <maiml> element.

An example of indicating the measurement/analysis techniques without having specific data is shown in Example 2.

Example 2 Example of Indicating Only Measurement/Analysis Techniques

In this example, “protocolFileRootType” is specified as the type for indicating only measurement/analysis techniques when the schema specified in “http://www.maiml.org/schemas” is used.

```
<?xml version="1.0"encoding="UTF-8"?>
<maiml version="1.0"features="nested-attributes"
        xmlns="http://www.maiml.org/schemas"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:type="protocolFileRootType">
    <document>
        <!-- include all content indicated in the document -->
    </document>
    <protocol>
        <!-- include all content indicated in the protocol -->
    </protocol>
</maiml>
```

To indicate measurement/analysis techniques, data, and log events during acquisition and include specific data, include all <document>, <protocol>, <data>, and <eventLog> elements. An example of configuring an MaiML file in that case is shown in Example 3.

Example 3 Example of Indicating Measurement/Analysis Techniques, Data, and Log Events

```
<?xml version="1.0"encoding="UTF-8"?>
<maiml version="1.0"features="nested-attributes"
        xmlns="http://www.maiml.org/schemas"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:type="maimlRootType">
    <document id="MaimlSampleDoc">
        <!-- include all content indicated in the document -->
    </document>
    <protocol id="MaimlSampleProtocol">
        <!-- include all content indicated in the protocol -->
    </protocol>
    <data id="MaimlSampleData">
        <!-- include all content indicated for data -->
    </data>
    <eventLog id="MaimlSampleEventLog">
        <!-- include all content indicated for eventLog -->
    </eventLog>
</maiml>
```

6.1.10 Handling MaiML Code as Files

To clearly indicate MaiML files as files created in accordance with the MaiML format, an “maiml” file extension is attached to file names. However, the extension can be shortened to “mai” for file systems that only permit 3-character file extensions.

If any local files are included as external files specified in 7.4, then the multiple files in the directory and subdirectory structure are handled collectively as one file. The format used for that purpose is the ZIP format specified by ISO/IEC 21320-1. In that case, the file extension “maiml.zip” is used.

6.2 Ensuring the Uniqueness of Files and Measurement/Analysis Data: <document>

6.2.1 <document> Element

To ensure the uniqueness of files and measurements/analyses and ensure they include no data tampering, the MaiML format requires including only one <document> element with a global element type in Level 1. In addition to the child elements of global elements, the <document> element also includes elements specified in 6.2.2 to 6.2.10. Content for <document> elements is listed in Table 14.

Table 14 Content of <document> Elements

Element	Child Element	Type	Description	Criterion
<document>	<Signature> 6.2.2	ds:Signature	Indicates a digital signature for ensuring that the file was not tampered with.	0 or 1
	<uuid> a) 6.2.3	xs:string	Indicates a UUID value for ensuring the uniqueness of the file.	1
	<creator> 6.2.4	Unique global element type	Indicates the measuring/analytical instrument and software used to generate data in the file.	1 or more
	<vendor> 6.2.6	Unique global element type	Indicates the company or organization that developed the measuring/analytical instrument and software used in the file.	1 or more
	<owner> 6.2.5	Unique global element type	Indicates the person who performed the measurement/analysis or owns the data in the file.	1 or more
	<instrument> 6.2.7	Unique global element type	Indicates the common name of the measurement/analysis in the file.	0 or more
	<date> 6.2.8	xs:dateTime	Indicates the date and time the file was generated.	1
	<chain> 6.2.9 7.8	Global element type	Indicates information about linked files specified to prevent data tampering.	0 or more
	<parent> 6.2.10 7.8	Global element type	Indicates information about the file on which a modified file was based.	0 or more
Elements specified in this table should not be used to encrypt an entire element. Note a) As a global element, the <document> element should include one <uuid> element.				

6.2.2 Signature: <Signature>

A <Signature> element is included to ensure that files have not been tampered with. This element is compliant with XML signature requirements specified in JIS X 5093 and ETSI TS 101 903. The enveloped signature, with a format specified to make the signature element subject to the signature, is indicated in the level below the <document> element. To create a signature, a hash value generated from the unsigned file is included as a digest value before the <Signature> element is added. To generate a hash value that includes a digest value, comply with 7.9.1 in the standard. If a <Signature> element is inserted, no other information may be inserted

other than the line feed code immediately after the closing tag for the <Signature> element. The attribute for the <Signature> element is indicated in Table 15.

Table 15 Attribute of <Signature> Element

Element	Attribute	Type	Specified Data Values	Description	Criterion
<Signature>	xmlns	xs:anyURI	http://www.w3.org/2000/09/xmldsig#	Indicates a namespace that specifies a signature.	0 or 1[a)]
Note a) If an xmlns attribute is added to an maiml or other ancestor element in a namespace with a signature specified, then an attribute does not need to be indicated. However, the xmlns attribute with a prefix specified and an element name with a prefix attached should be used. For example, if xmlns:ds is specified as a namespace, then <ds:Signature> should be used as the <Signature> element name.					

6.2.3 UUID: <uuid>

To ensure the uniqueness of files, UUID values are indicated as <uuid> element values. Only one <uuid> element is included in <document> elements. Use UUID values compliant with version 4 specified by RFC 4122.

6.2.4 Measuring/Analytical Instrument that Created Data: <creator>

Use the <creator> element to explicitly indicate the measuring/analytical instrument and software used to generate data handled in files. Indicate the <creator> element as a unique global element type. The <uuid> child element value for the <creator> element is the UUID value shared by the same measuring/analytical instrument and software that generated the data.

Each instrument should be assigned a different UUID value, even if they have the same model number, so that differences in results can be explicitly attributed to each measuring/analytical instrument. If another instrument, such as an attached device, is used for measurements/analysis, it is recommended that a <creator> element also be used to indicate information about the other instrument.

Each software version should be assigned a different UUID value, even if it is the same software, so that differences in results can be explicitly attributed to each software version. Even software with the same version should be assigned a different UUID value if there is a possibility that different results could be output due to different computational environments.

If multiple measuring/analytical instruments and software were used to generate data, include multiple <creator> elements as <document> elements to indicate each configuration in parallel. Include <vendorRef> or <instrumentRef> elements to indicate respective links to the <vendor> element specified in 6.2.6 or the <instrument> element specified in 6.2.7. <vendorRef> and <instrumentRef> elements indicate a reference to a corresponding <vendor> or <instrument> element. Content for <creator> elements is listed in Table 16.

Table 16 Content of <creator> Elements

Element	Child Element	Type	Description	Criterion
<creator>	<vendorRef>	Reference element type	Indicates a reference to a <vendor> element.	1 or more
	<instrumentRef>	Reference element type	Indicates a reference to an <instrument> element.	0 or more

6.2.5 Data Owner: <owner>

The <owner> element is used to explicitly indicate the person who performed the measurement/analysis (measurement/analysis operator) or the owner of the data indicated in an MaiML file. In that context, the “data owner” refers to the person/organization that performed the measurement/analysis or is responsible for the data. The <owner> element is a unique global element that includes a <uuid> element with a UUID value indicating the corresponding measurement/analysis operator or data owner. If no measurement/analysis operator or data owner exists (hereinafter referred to as the “data owner”), such as for automatically measured data, then the person responsible for that data or “anonymous” is indicated.

6.2.6 Developer/Manufacturer of Measuring/Analytical Instrument or Software: <vendor>

The <vendor> element is used to explicitly indicate the person, company, or organization that developed or manufactured the measuring/analytical instrument or software used to perform the measurement/analysis indicated in an MaiML file. The <vendor> element is a unique global element that includes a UUID value that indicates the person, company, or organization that developed or manufactured the specific measuring/analytical instrument or software. The person, company, or organization that developed or manufactured that same measuring/analytical instrument or software includes the same UUID value.

6.2.7 Generic Name of Measuring/Analytical Instrument, etc.: <instrument>

The <instrument> element is used to explicitly indicate the generic name of the measuring/analytical instrument, software, or other item used to perform the measurement/analysis indicated in an MaiML file. For example, “SEM” is a generic name of a measuring/analytical instrument. Refer to Table B.1 for the generic name to indicate in the <instrument> element.

For measurement/analysis processes that comprise multiple generic names, explicitly indicate each name in parallel or indicate a different generic name defined separately in accordance with the specified methods for indicating relationships to terminology in B.12.

6.2.8 File Creation Date: <date>

The <date> element is used to explicitly indicate the date and time a file was generated. The <date> element indicates the date and time the file was created. The xs:dateTime type is used to indicate the format for date and time values.

6.2.9 Linked Files: <chain>

To prevent data tampering, the <chain> element is used to explicitly indicate information about previously created files linked to the file being created. Content for the <chain> element is described in 7.8.1.

6.2.10 File Revisions: <parent>

The <parent> element is used to explicitly indicate file revisions. Content for the <parent> element is described in 7.8.1.

6.3 Measurement/Analysis Processes: <protocol>

6.3.1 <protocol> Element

One <protocol> element with a global element type should be included to indicate a measurement/analysis process. The <protocol> element should include at least one <method> element specified in 6.3.2. To indicate multiple independent measurement/analysis processes, specify multiple <method> elements. Content for <protocol> elements and content at a lower level is listed in Table 17.

Table 17 Content of <protocol> Elements

Element	Descendant Element	Type	Description	Criterion
<protocol>	<method> 6.3.2	Global element type	Indicates a set of series of measurement/analysis processes.	1 or more
	<pnml> 6.3.4 7.6	Global element type	Used as content for a <method> element, this indicates a Petri net that models the order and stages of measurement/analysis operations involved in a series of measurement/analysis processes or a set of series of measurement/analysis processes.	1 or more
	<place> 7.6	Simple element type	Used as a child element of <pnml> elements, it describes samples, conditions, or results. They indicate <materialTemplate>, <conditionTemplate>, or <resultTemplate> elements and express nodes in Petri net directional graphs.	1 or more
	<transition> 7.6	Simple element type	Used as a child element of <pnml> elements, it indicates specific measurement/analysis operations. They indicate <instruction> elements and express nodes in Petri net directional graphs.	1 or more
	<arc> 7.6	Directed graph element type	Used as a child element of <pnml> elements, it indicates the edges in Petri net directed graphs.	1 or more
	<program> 6.3.3	Global element type	Used as content for <method> elements, it indicates a series of measurement/analysis processes.	1 or more
	<instruction> 6.3.8	Global element type	Used as content for <program> elements, it indicates specific measurement/analysis operations.	1 or more
	<transitionRef> 6.3.10	Reference element type	Used as a child element of <instruction> elements, it references an id attribute of <transition> elements that is a child element of a <pnml> element in a series of measurement/analysis processes.	1 or more
	<materialTemplate> 6.3.6	Global element type	Used as content for <protocol>, <method>, or <program> elements, it indicates a template for materials being measured/analyzed.	0 or more
	<conditionTemplate> 6.3.5	Global element type	Used as content for <protocol>, <method>, or <program> elements, it indicates a template for conditions related to measurements/analysis.	0 or more
	<resultTemplate> 6.3.7	Global element type	Used as content for <protocol>, <method>, or <program> elements, it indicates a template for measurements/analysis results.	0 or more

	<placeRef> 6.3.9	Reference element type	Used as a child element of a <materialTemplate>, <conditionTemplate>, or <resultTemplate> element, it references the id attribute of <place> element included in a <pnml> element. If connected to 2 or more <place> elements, indicate each in parallel.	1 or more
	<templateRef> 6.3.11	Reference element type	Used as a child element of a <materialTemplate>, <conditionTemplate>, or <resultTemplate> element, it references the id attribute of a separate <materialTemplate>, <conditionTemplate>, or <resultTemplate> element to be input or output as a template for similar measurement/analysis processes.	0 or more
Elements specified in this table should not be used to encrypt an entire element.				

Furthermore, <conditionTemplate>, <materialTemplate>, and <resultTemplate> elements, specified in 6.3.5 to 6.3.7, can be listed in parallel to explicitly indicate a template for information shared by multiple <method> elements indicated as content for a <protocol> element. For those elements, use the <placeRef> element value specified in 6.3.9 as the id attribute value for the <place> element, which is a child element of the <pnml> element specified in 6.3.4.

If measurement/analysis operations are performed and a <materialTemplate>, <conditionTemplate>, or <resultTemplate> element indicated as a template for the child element of a <protocol> element (referred to as a “template” below) is used, then a <material>, <condition>, or <result> element that is a corresponding instance (referred to as “instance” below) should be indicated as the content of a <results> element specified in 6.4.2. In that case, the template id attribute value is used as the ref attribute value for respective corresponding instances. In addition, a general purpose data container that indicates information about the measurement/analysis is indicated in the template and/or instance referenced based on the instance ref attribute, with the same general purpose data container indicated by the key attribute also included in the template and instance. However, if the same key attribute general purpose data container is included in the corresponding template and instance, the <value> element value in the template general purpose data container will be overwritten by the <value> element value in the instance general purpose data container.

6.3.2 Set of Measurement/Analysis Processes: <method>

To explicitly indicate a set of series of measurement/analysis processes, the <protocol> element should include at least one global element type <method> element. If multiple <method> elements are used, they should be indicated in parallel as content of the <protocol> element.

To explicitly indicate of series of measurement/analysis processes, at least one <program> element, specified in 6.3.3, should be included as <method> element content. To explicitly indicate the process flow of a series of processes indicated in <method> and <program> elements, <pnml> elements specified in 6.3.4 should indicated in parallel as <method> element content.

In addition, to indicate multiple <program> elements as child elements of a <method> element, information shared by those <program> elements can be indicated as child elements of the <method> element. In that case, the shared information is indicated in parallel <conditionTemplate>, <materialTemplate>, or <resultTemplate> elements specified in 6.3.5 to 6.3.7. For those elements, use the <placeRef> element value specified in 6.3.9 as the id attribute value for the <place> elements in the content of <pnml> elements specified in 6.3.4 and 7.6.

If measurement/analysis processes are performed and a <materialTemplate>, <conditionTemplate>, or <resultTemplate> element indicated as a template for the child element of a <method> element (referred to as a “template” below) is used, then a <material>, <condition>, or <result> element that is a corresponding instance (referred to as “instance” below) should be indicated as the content of a <results> element specified in 6.4.2. Indicate the template id attribute value as the ref attribute value for respective corresponding instances. In addition, a general purpose data container that indicates information about the measurement/analysis is indicated in the template and/or instance referenced based on ref attribute, with the same general purpose data container indicated by the key attribute also included in the template and instance. However, if the same key attribute general purpose data container is included in the corresponding template and instance, the <value> element value in the template general purpose data container will be overwritten by the <value> element value in the instance general purpose data container.

6.3.3 Series of Measurement/Analysis Processes: <program>

To explicitly indicate a series of measurement/analysis processes, use a <program> element with a global element type. To explicitly indicate a measurement/analysis operation, the <program> element should include at least one <instruction> element specified in 6.3.8. Also, use the id attribute for the <transition> element specified in 6.3.4 and 7.6 as the ref attribute value for the <transitionRef> element that is a child element of the <instruction> element. Preferably, processes performed using the same measuring/analytical instrument and software should have only one <program> element. However, it is permissible to split the <program> element into two or more parts to indicate processes that are easier to differentiate separated.

Furthermore, <conditionTemplate>, <materialTemplate> <resultTemplate> elements, specified in 6.3.5 to 6.3.7, can be listed in parallel to explicitly indicate a template for information about measurement/analysis processes indicated in a <program> element. For those elements, use the <placeRef> element ref attribute value as the id attribute value for the <place> elements in the <pnml> elements specified in 6.3.4 and 7.6.

If measurement/analysis operations are performed and a <materialTemplate>, <conditionTemplate>, or <resultTemplate> element indicated as a template for the child element of a <program> element (referred to as a “template” below) is used, then a <material>, <condition>, or <result> element that is a corresponding instance (referred to as “instance” below) should be indicated as the content of a <results> element specified in 6.4.2. In that case, the template id attribute value is used as the ref attribute value for respective corresponding instances. In addition, a general purpose data container that indicates information about the measurement/analysis is indicated in the template and/or instance referenced based on ref attribute, with the same general purpose data container indicated by the key attribute also included in the template and instance. However, if the same key attribute general purpose data container is included in the corresponding template and instance, the <value> element value in the template general purpose data container will be overwritten by the <value> element value in the instance general purpose data container.

6.3.4 Modeled Series of Measurement/Analysis Processes: <pnml>

To indicate a series of measurement/analysis processes modeled as a Petri net, at least one <pnml> element with a global element type should be included as <method> element content. Indicate <pnml> and <program> elements in parallel as content of a <method> element content. Furthermore, if multiple series of measurement/analysis processes are indicated in a single <method> element, then indicate multiple <pnml> elements in parallel.

For a series of measurement/analysis processes, use <place>, <transition>, and <arc> elements to indicate the processes as <pnml> element content. For <conditionTemplate>, <materialTemplate>, or <resultTemplate> elements specified in 6.3.5 to 6.3.7 and <instruction> elements specified in 6.3.8, use the ref attribute values for <placeRef> and <transitionRef> elements as the respective id attributes for corresponding <place> and <transition> elements.

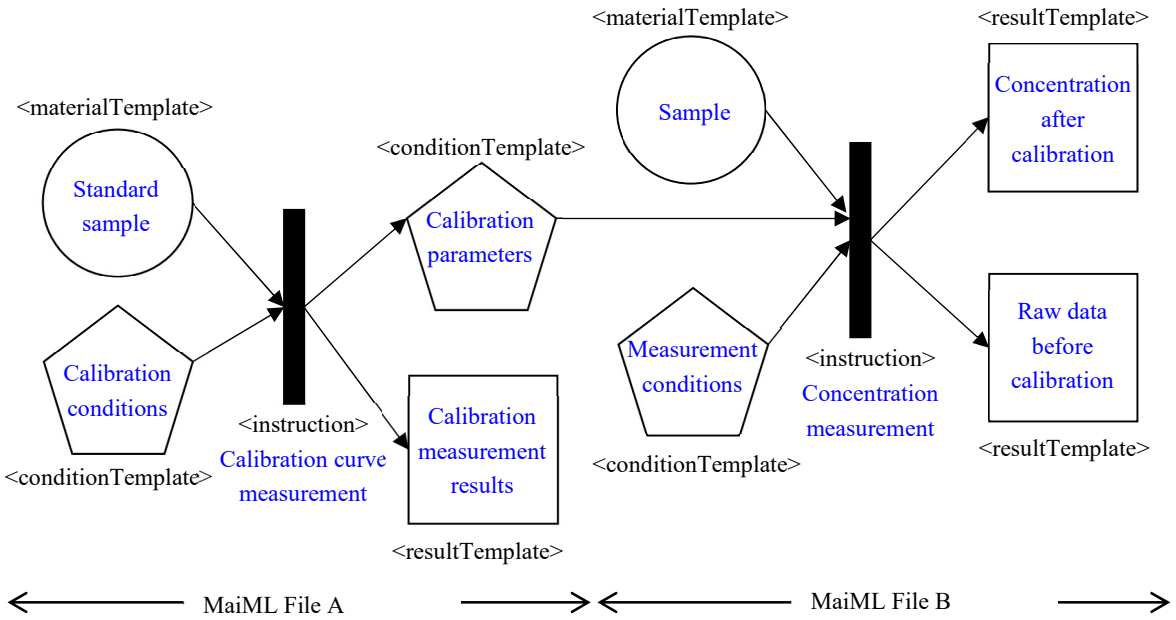
For more details about the <pnml> element, refer to 7.6.

6.3.5 Template for Measurement/Analysis Conditions: <conditionTemplate>

Use a <conditionTemplate> element with a global element type as content for <protocol>, <method>, or <program> elements for explicitly indicating conditions related to measurements/analysis in advance. In this context, “condition” refers to information or parameter settings that can be changed by applying criteria for measurement/analysis process actions. For example, it can specify the accelerating voltage for SEM. To indicate the same conditions, the <conditionTemplate> element should include the same <uuid> element.

The <conditionTemplate> element is usually used as an input for a measurement/analysis operation. However, it is also permissible to use it as an output in a series of measurement/analysis processes. For example, if measuring the concentration of a sample, the <conditionTemplate> element value can be used as a parameter value for expressing the calibration curve plotted based on standard sample concentration measurements. In that case, the parameter is used to set the <resultTemplate> element value based on the sample concentration value. An example is shown in Fig. 2.

The <conditionTemplate> element includes a general purpose data container with a <property> element (refer to Tables 20 and 21) or a <content> element (refer to Tables 22 and 23) to indicate measurement-related conditions. To indicate multiple conditions within one <conditionTemplate> element, indicate the <property> or <content> elements in parallel.



Note: The above describes the meaning of the content of each element.

Fig. 2 Example of Calibration Curve Based Concentration Measurements

If used as a template for measurement/analysis conditions, <conditionTemplate> elements indicated in MaiML files can be cited using an <insertion> element specified in 7.4. In that case, the <insertion> element used as a template and that indicates the MaiML file information is specified as content in <document> or <method> elements.

For example, Fig. 2 shows a case where processes are divided into two files, MaiML file A and MaiML file B. MaiML file A indicates the process of determining parameters for calibration from a standard sample. Next, MaiML file B cites MaiML file A to indicate the process of measuring sample concentrations using the calibration parameters indicated by MaiML file A. Furthermore, to measure multiple concentrations using the same calibration parameters and indicate them in different MaiML files for each set of measurement results, file B can be cited and used in respective MaiML files.

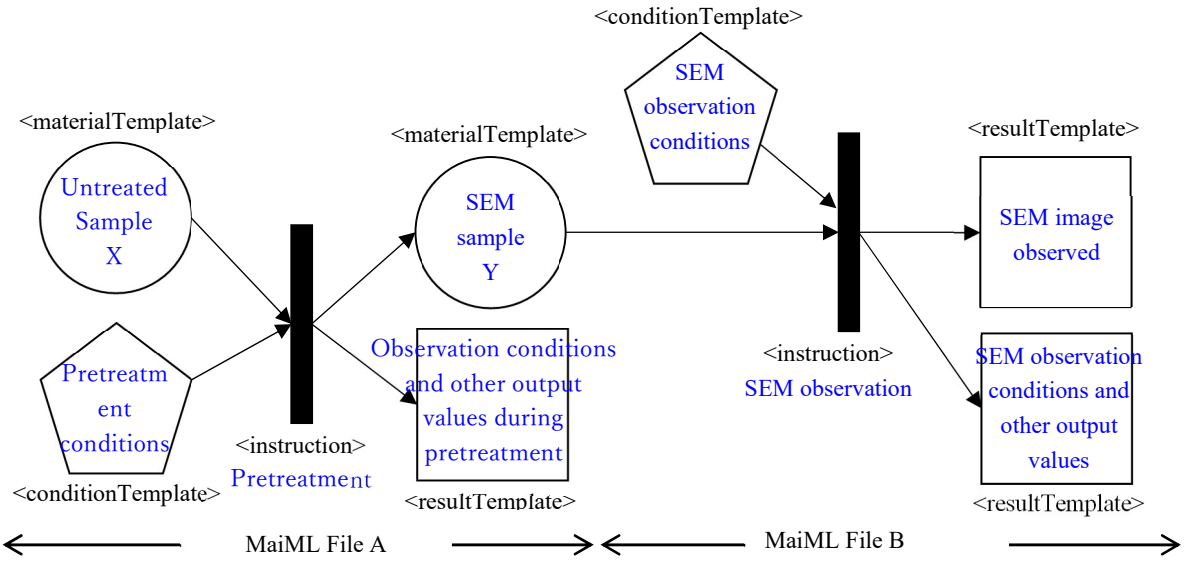
To indicate conditions for a series of measurement/analysis processes, <conditionTemplate> elements should include at least one <placeRef> element specified in 6.3.9. In that case, use the ref attribute value for the <placeRef> element as the id attribute value for one of the <place> elements in the <pnml> elements. To indicate multiple <place> elements, indicate the <placeRef> elements in parallel.

6.3.6 Template for Measurement/Analysis Materials: <materialTemplate>

Use a <materialTemplate> element with a global element type as content for <protocol>, <method>, or <program> elements for explicitly indicate physical samples, input data, and other information as materials for measurement/analysis in advance. In that context, “materials” refers to resources used specifically for the measurement/analysis processes, such as SEM observation samples. To indicate the same material, the <materialTemplate> element should include the same <uuid> element.

The <materialTemplate> element includes a general purpose data container with a <property> element (refer to Tables 20 and 21) or a <content> element (refer to Tables 22 and 23) that indicates information about materials used for measurement/analysis. To indicate information about multiple materials within one <materialTemplate> element, indicate the <property> or <content> elements in parallel.

The <materialTemplate> element is normally used as a measurement/analysis input, but it is also permissible to use it as an output within a series of measurement/analysis processes. For example, if pretreatment is performed before an SEM microscope is used to observe sample X, then sample X is pretreated to obtain SEM sample Y. In that case, SEM sample Y is an output of the pretreatment process. An example is shown in Fig. 3.



Note: The above describes the meaning of the content of each element.

Fig. 3 Example of SEM Observation with Sample Pretreatment Conditions Applied

If used as a pretreatment method template for SEM sample Y preparation, the <materialTemplate> element indicated in an MaiML file can be cited using an <insertion> element specified in 7.4. The <insertion> element is

specified as content in a <document> or <method> element in the MaiML file that cites the MaiML file used as a template. For example, Fig. 3 shows a case where processes are divided into two files, MaiML file A and MaiML file B. The SEM sample X pretreatment process in the first stage is indicated in MaiML file A and MaiML file A is cited by MaiML file B to indicate the SEM observation process of the pretreated SEM sample Y in the second stage. Furthermore, to indicate SEM observation results from multiple SEM observations in different MaiML files, file B can be cited and used in respective MaiML files.

To indicate materials for a series of measurement/analysis processes, <materialTemplate> elements should include at least one <placeRef> element specified in 6.3.9. In that case, use the value for the <placeRef> element as the id attribute value for one of the <place> elements in the <pnml> elements. To indicate multiple <place> elements, indicate the <placeRef> elements in parallel.

6.3.7 Template for Measurement/Analysis Results: <resultTemplate>

To explicitly indicate of measurement/analysis result, use a < resultTemplate> element with a global element type. In this context, “results” refers to data output from a measurement/analysis process. For example, it refers to images output from an SEM observation process. To indicate the same result, the <resultTemplate> element should include the same <uuid> element.

The <resultTemplate> element includes a general purpose data container with a <property> element (refer to Tables 20 and 21) or a <content> element (refer to Tables 22 and 23) used to indicate measurement-related results. To indicate multiple results within one <resultTemplate> element, indicate the <property> or <content> elements in parallel.

The <resultTemplate> element is normally used as a measurement/analysis output, but it is also permissible to use it as an input within a series of measurement/analysis processes. However, if used as an input, it should preferably be converted to a <conditionTemplate> or <materialTemplate> element by means of an <instruction> element linked to a <transition> element.

To indicate results from a series of measurement/analysis processes, <resultTemplate> elements should include at least one <placeRef> element specified in 6.3.9. In that case, use the value for the <placeRef> element as the id attribute value for one of the <place> elements in the <pnml> elements. To indicate multiple <place> elements, indicate the <placeRef> elements in parallel.

6.3.8 Measurement/Analysis Operations: <instruction>

An <instruction> element with a global element type is used to indicate a specific measurement/analysis operation. For example, it could indicate an SEM observation process. To indicate the same result, the <instruction> element should include the same <uuid> element.

To indicate an operation in a series of measurement/analysis processes, <instruction> elements should include at least one <transitionRef> element specified in 6.3.10. In that case, the id attribute value for one of the

<transition> elements indicated in the <pnml> element is used as the <transitionRef> element value. To indicate multiple <transition> elements, indicate the <transitionRef> elements in parallel.

To indicate a <name> element, indicate the specific measurement/analysis operation with a namespace attached.

6.3.9 Material or Condition Reference for Measurement/Analysis Process <placeRef>

To explicitly indicate a condition, material, or results for a series of measurement/analysis processes, at least one <placeRef> element should be included as a child element of respective <materialTemplate> element, <conditionTemplate> element, or <resultTemplate> elements. In that case, the id attribute value of the corresponding <place> element for the <pnml> element indicated as a child element of the <method> element is referenced as the value for the <placeRef> element. If 2 or more <place> elements are included, indicate the <placeRef> elements with respective id attribute values in parallel.

Indication examples are described in 6.3.l to 6.3.3.

6.3.10 Operating Reference for Measurement/Analysis Process <transitionRef>

To explicitly indicate an operation in a series of measurement/analysis processes, at least one <transitionRef> element should be indicated as a child element of an <instruction> element. In that case, the id attribute value of the corresponding <transition> element for the <pnml> element indicated as a child element of the <method> element is referenced as the value for the <transitionRef> element. If 2 or more <transition> elements are included, indicate the <transitionRef> elements with respective id attribute values in parallel.

Indication examples are described in 6.3.1 to 6.3.3.

6.3.11 Referencing a Template with a Similar Measurement/Analysis Process: <templateRef>

The <templateRef> element is used to indicate a template of a similar measurement/analysis process. In this context, “template of a similar measurement/analysis process” refers to a template for a measurement/analysis process that can be indicated using similar <materialTemplate>, <conditionTemplate>, or <resultTemplate> elements and that has a <templateRef> element that somehow relates the measurement/analysis process being referenced to the measurement/analysis process referencing the process (refer to C.1).

Note: In this context, “somehow relates” refers to processes not connected by a process flow indicated with a <pnml> element, but that include many of the same template descendant elements.

If referencing a template for a similar measurement/analysis process, then indicate a <templateRef> element as a child element of the referenced template (<materialTemplate>, <conditionTemplate>, or <resultTemplate> element). Use the id attribute value for the referenced template as the ref attribute value for the <templateRef> element. Copy all the descendant elements from the referenced template to the referencing template, except the <uuid>, <placeRef>, and <templateRef> elements. Then overwrite the values for the copied elements by indicating descendant elements that replace the values or add to them. The priority order for values of the descendant elements of referencing templates is indicated in a) and b) below.

a) Values of descendant elements indicated in the referencing template

b) Values of descendant elements referenced by a <templateRef> element

If the referencing template includes templates referenced by the <templateRef> element that are indicated in parallel, then copy all the descendant elements from the referenced template in the same order as indicated in the <templateRef> element and overwrite the values by indicating descendant element values that replace or add values. Then the descendant elements of the referenced template are used to overwrite descendant element values that replace the values or add to them.

After the referencing template uses the <templateRef> element to copy the descendant elements from the referenced template in order to overwrite the descendant element values or add new descendant elements, the referencing template has a different UUID value than the referenced template.

Meanwhile, if the <materialTemplate>, <conditionTemplate>, or <resultTemplate> elements are the same, including the respective general purpose data containers, which are descendant elements, that is referred to as “the same measurement/analysis process template.” In that case, the same UUID value is indicated as for the <uuid> element value, so that the <templateRef> element can be used to reference the same template without having to indicate the descendant elements other than the <uuid> element.

6.4 Measurement/Analysis Results: <data>

6.4.1 <data> Element

Level 1 <data> elements are used to indicate results from executed measurements/analyses. Content for <data> elements is listed in Table 18. However, <data> elements are not included for files that only indicate measurement/analysis processes.

<data> elements include at least one <results> element specified in 6.4.2 as content. If any of the measurement/analysis processes indicated for the <protocol> element have a different <method> element or if results from executing the same <method> multiple times are indicated in the same file, then indicate a different <results> element.

To ensure the independent availability of data, it is recommended that all data generated from measurement/analysis processes be indicated. For example, if calibration data for a concentration measurement process is indicated in an MaiML file, even if only the calibration data is used for the next concentration

measurement, it is recommended that not only calibration data used for other measurement/analysis processes but also the measurement values used to generate the calibration data be indicated in a <data> element.

Table 18 Content of <data> Elements

Element	Descendant Element	Type	Description	Criterion
<data>	<results> 6.4.2	Global element type	Includes all materials, conditions, and results obtained from a series of measurement/analysis processes as content.	1 or more
	<material> 6.4.4	Referencing global element type	Used as a child element of a <results> element to indicate an instance of a measurement/analysis condition.	0 or more
	<condition> 6.4.5	Referencing global element type	Used as a child element of a <results> element, it indicates an instance of measurement/analysis results.	0 or more
	<result> 6.4.3	Referencing global element type	Used as a child element of a <results> element, it indicates an instance of measurement/analysis results.	0 or more
	<instanceRef> 6.4.6	Reference element type	Used as a child element of a <material>, <condition>, or <result> element, it references the id attribute of a separate <material>, <condition>, or <result> element output as an instance of a similar measurement/analysis process.	0 or more
Elements specified in this table should not be used to encrypt an entire element.				

6.4.2 Set of Measurement/Analysis Results: <results>

The <results> element is used to indicate the results from a series of measurement/analysis processes. This element includes <result> (6.4.3), <material> (6.4.4), and/or <condition> elements (6.4.5) as content, based on the <method> elements indicated below the <protocol> element.

If the measurement/analysis corresponding to an <instruction> element indicated as content for the <method> element is actually performed, then the time the <result>, <material>, or <condition> element content was obtained should be indicated as an <event> element specified in 6.5.4. Also, to indicate the life cycle of measurement/analysis processes, refer to 7.7.

6.4.3 Measurement/Analysis Results: <result>

The <result> element is used to indicate the results from a series of measurement/analysis processes. The element should be connected by using the id attribute for the <resultTemplate> element defined as content of the <protocol> element as the ref attribute value for the <result> element. Content for the element is indicated using a general purpose data container specified in 7.1.

If there was no change in the <value> element of a general purpose data container with the same key attribute in the content of connected <resultTemplate> elements, then that general purpose data container does not need to be indicated. To indicate general purpose data containers with the same key attribute, use the content of the <resultTemplate> element overwritten with the content indicated for the <result> element as the results obtained from the actual measurement/analysis process or the results used.

It is recommended that a general purpose data container with the same key attribute indicated in a <resultTemplate> element connected by a ref attribute be indicated as the general purpose data container indicated in the <result> element. On the other hand, it is also acceptable to indicate an additional general purpose data container with a new key attribute.

6.4.4 Specific Material for Measurement/Analysis: <material>

If a series of measurement/analysis processes is executed, a material is explicitly indicated by using a <material> element as content for the <results> element. In this context, “material” refers to a specific object, material, data, or other resource for a measurement/analysis process. The <material> element should be connected by using the id attribute for the <materialTemplate> element defined as content for the <protocol> element as the ref attribute value for the <material> element. Content for the <material> element is indicated using a general purpose data container specified in 7.1.

If there was no change in the <value> element of a general purpose data container with the same key attribute in the content of connected <materialTemplate> elements, then that general purpose data container does not need to be indicated. To indicate general purpose data containers with the same key attribute, use the content of the

<materialTemplate> element overwritten with the content indicated for the <material> element as the material used for or obtained from the actual measurement/analysis process.

It is recommended that a general purpose data container with the same key attribute indicated in a <materialTemplate> element connected by a ref attribute be indicated as the general purpose data container indicated in the <material> element. On the other hand, it is also acceptable to indicate an additional general purpose data container with a new key attribute.

6.4.5 Specific Condition for Measurement/Analysis: <condition>

If a series of measurement/analysis processes is executed, a condition is indicated by using the <condition> element as content for the <results> element. In this context, “condition” refers to a parameter or other setting for operations in measurement/analysis processes. The <condition> element should be connected by using the id attribute for the <conditionTemplate> element defined as content of the <protocol> element as the ref attribute value for the <condition> element. Content for the <condition> element is indicated using a general purpose data container specified in 7.1.

If there was no change in the <value> element of a general purpose data container with the same key attribute in the content of connected <conditionTemplate> elements, then that general purpose data container does not need to be indicated. To indicate general purpose data containers with the same key attribute, use the content of the <conditionTemplate> element overwritten with the content indicated for the <condition> element as the condition used for or obtained from the actual measurement/analysis process.

It is recommended that a general purpose data container with the same key attribute indicated in a <conditionTemplate> element connected by a ref attribute be indicated as the general purpose data container indicated in the <condition> element. On the other hand, it is also acceptable to indicate an additional general purpose data container with a new key attribute.

6.4.6 Referencing an Instance with a Similar Measurement/Analysis Process: <instanceRef>

The <instanceRef> element is used to indicate an instance of a similar measurement/analysis process. In this context, “instance of a similar measurement/analysis process” refers to an instance of a measurement/analysis process that can be indicated using the same type of <condition>, <material>, or <result> elements and that has an <instanceRef> element that somehow relates the measurement/analysis process being referenced to the measurement/analysis process referencing the process (refer to C.1).

Note: In this context, “somehow relates” refers to cases such as where the template referenced by the instance is connected by a process flow indicated with a <pnml> element or where the template referenced by

the instance is not connected by a process flow indicated with a <pnml> element, but includes many of the same descendant elements of the instance. For example, if measurements are performed with different types of instruments but have <material> elements that indicate roughly the same samples, <condition> elements that indicate similar conditions, and so on.

If using referenced instances from a similar measurement/analysis process, then indicate an <instanceRef> element as a child element of the instance being referenced (a <material>, <condition>, or <result> element that is a child element of a <results> element). Use the id attribute value for the referenced instance as the ref attribute value for the <instanceRef> element. In particular, if it is difficult to indicate the relationship between those similar measurement/analysis instances with different <uuid> element values by referencing the corresponding templates, then use an <instanceRef> element to indicate their relationship.

First, copy all the descendant element values from the template indicated by the instance ref attribute, except the <uuid>, <placeRef>, and <templateRef> elements (refer to 6.3.11). Then use all the descendant elements of the instance referenced by the <instanceRef>, except the <uuid> and <instanceRef> elements, to overwrite the instance values by replacing the values or adding to them. Lastly, indicate descendant elements for the referenced instance to overwrite its values by replacing the values or adding to them. The priority order for descendant element values of the referenced instance is indicated in a) to c) below.

a) Values of descendant elements indicated in the referenced instance
b) Values of descendant elements of instances referenced by an <instanceRef> element
c) Descendant elements of a template referenced by a ref attribute

If instances referenced by the <instanceRef> element are indicated in parallel in the instance being referenced, then copy the descendant elements from the referenced instance in the same order as indicated in the <instanceRef> element and then overwrite the descendant element values by replacing or adding to the values. Then the descendant elements of the referenced instance are used to overwrite descendant element values that replace the values or add to them.

After the referencing instance uses the <instanceRef> element to copy the descendant elements from the referenced instance in order to overwrite the descendant element values by replacing or adding new values, the instance will have a different UUID value than the referenced instance.

Meanwhile, if the <material>, <condition>, or <result> elements are the same including the descendant elements, then they are referred to as “the instance of the same measurement/analysis process.” In that case, the same UUID value is indicated as for the <uuid> element value, so that the <instanceRef> element can be used to reference the same instance without having to indicate the descendant elements other than the <uuid> element.

Also, if the <templateRef> element indicated in 6.3.11 is used, then the <instanceRef> element corresponding to the <templateRef> element should be used.

An example of using the <instanceRef> element is indicated in C.3.

6.5 Traceability of Measurement/Analysis Processes: <eventLog>

6.5.1 <eventLog> Element

To ensure data traceability, the <eventLog> elements described in Table 19 are indicated to show measurement/analysis log events for which <data> element content was obtained (refer to Table 18). <eventLog> elements have a global element type and at least one <log> element specified in 6.5.2.

Table 19 Content of <eventLog> Element

Element	Descendant Element	Type	Description	Criterion
<eventLog>	<log> 6.5.2	Referencing global element type	Indicates a set of log events for a series of measurement/analysis processes performed multiple times.	1 or more
	<trace> 6.5.3	Referencing global element type	Indicates log events for a series of processes during a single measurement/analysis.	1 or more
	<event> 6.5.4	Referencing global element type	This is used to indicate a log event of an individual operation defined in an <instruction> element for a <program> element for one series of measurement/analysis processes. It references the id attribute of <instruction> elements that indicate specific measurement/analysis operations.	1 or more
	<resultsRef> 6.5.5	Reference element type	Used as a child element of <event> elements to indicate operation output log events. It references the id attribute of <results> elements used to indicate all materials, conditions, or results for a single operation that generated a log event. An alternative method is to use a general purpose data container to specify the <uuid> element for <results> elements.	0 or more
	<creatorRef> 6.5.6	Reference element type	Used as a child element of a <log>, <trace>, or <event> element to indicate a set of series of measurement/analysis processes or log events for a series of measurement/analysis processes or operations. It references the id attribute of the <creator> element used to indicate the measuring/analytical instrument or software that generated a log event. An alternative method is to use a general purpose data container to specify the <uuid> element for <creator> elements.	0 or more
	<ownerRef> 6.5.7	Reference element type	Used as a child element of a <log>, <trace>, or <event> element to indicate a set of series of measurement/analysis processes or log events for a series of measurement/analysis processes or operations. It references the id attribute of the <owner> element used to indicate the measurement/analysis operator who generated a log event or the data owner. An alternative method is to use a general purpose data container to specify the <uuid> element for <owner> elements.	0 or more
Elements specified in this table should not be used to encrypt an entire element.				

The namespace declaration (xmlns) is used to define concept, lifecycle, and time prefixes used as attributes of <maiml> or <eventLog> elements. Definition methods are indicated in a) to c) below.

a) xmlns:concept="http://www.xes-standard.org/concept.xesext#"

b) xmlns:lifecycle="http://www.xes-standard.org/lifecycle.xesext#"

c) xmlns:time="http://www.xes-standard.org/time.xesext#"

6.5.2 Measurement/Analysis Log Event: <log>

The <log> element includes at least one <trace> element specified in 6.5.3 or multiple parallel <trace> elements if a series of measurement/analysis processes are performed multiple times. The <log> element is a referencing global element that corresponds to the <method> element in <protocol> element content and requires indicating <method> element id attributes as <log> element ref attributes.

6.5.3 Log Event of a Series of Processes for a Single Measurement/Analysis: <trace>

The <trace> element includes at least one <event> element specified in 6.5.4 and is used to indicate information about a series of measurement/analysis processes performed one time. The <trace> element is a referencing global element that corresponds to the <results> element in <data> element content. The id attribute for a corresponding <program> element should be indicated as a ref attribute of a <trace> element.

6.5.4 Log Event of a Measuring/Analysis Operation: <event>

The <event> element includes time-specific information about operations for a single series of measurement/analysis processes and should include at least one content corresponding to the <instruction> element. The referencing global type <event> element uses the id attribute of a corresponding <instruction> element as the ref attribute value for the <event> element. For details, refer to 7.7. The <content> element is used as a data structure specifically for measurement/analysis data and is not recommended for <eventLog> elements specified in 6.5 or for use in lower-level structures.

6.5.5 Log Event <resultsRef> Element that Refers to <results> Element

The <resultsRef> element can be indicated in a lower level than the <event> element to reference a set of measurement/analysis results indicated in <event> elements. It uses the <resultsRef> element ref attribute value as the id attribute value for <results> elements that include at least one <result>, <condition>, or <material> element output from the <instruction> element corresponding to the <event> element. A single <result> element can also be set to the value of a <value> element for a <event> element.

An example of using the element is indicated in 7.7.

6.5.6 Log Event <creatorRef> Element that Refers to <creator> Element

The <creatorRef> element can be indicated in a lower level than the <log>, <trace>, or <event> elements in

order to reference the measuring/analytical instrument or software that generated the measurement/analysis results indicated in a <log>, <trace>, or <event> element. The <creatorRef> element ref attribute value is used as the id attribute value for the <creator> element that generated the <result>, <condition>, or <material> element output from the <method>, <program>, or <instruction> element that corresponds to the <log>, <trace>, or <event> element.

An example of using the element is indicated in 7.7.

6.5.7 Log Event <ownerRef> Element that Refers to <owner> Element

The <ownerRef> element can be indicated in a lower level than <log>, <trace>, or <event> elements in order to reference the individual or group that generated the measurement/analysis results indicated in a <log>, <trace>, or <event> element. The <ownerRef> element ref attribute value is used as the id attribute value for the <owner> element (which indicates the person who performed the measurement/analysis or owns the data indicated in the MaiML file), where the owner is responsible for the <result>, <condition>, or <material> element output from the <method>, <program>, or <instruction> element that corresponds to the <log>, <trace>, or <event> element.

An example of using the element is indicated in 7.7.

7. How to Indicate Content for Elements that Indicate Structure

7.1 General Methods for Indicating Numeric, Text, and Other Information

7.1.1 <property> Element

Numeric values, text information, and other general purpose data or metadata are indicated using the <property> element indicated in Table 20. Within that context, the <EncryptedData> element is used for encryption specified in 7.3.

The content of that data is indicated as <value> element values for the <property> element. Data uncertainty is indicated as <uncertainty> element values. In addition, <description> elements with nested <property> and/or <content> element structures can also be indicated in lower levels.

Table 20 Content of <property> Elements

Element	Descendant Element	Type	Description	Criterion
<property>	<childUri>	xs:anyURI	If URI values are included in <value> elements when the content of <property> elements is encrypted, then all the URI values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<childHash>	xs:base64Binary	If hash values are included in <value> elements when the content of <property> elements is encrypted, then all hash values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<childUuid>	xs:string	If UUID values are included in <value> elements when the content of <property> elements is encrypted, then all the UUID values should be extracted and indicated before the corresponding <EncryptedData> element.	0 or more
	<EncryptedData> a)	xenc:EncryptedData	All content of <property> elements can be encrypted collectively. If encrypted, the elements are replaced by an <EncryptedData> element. Refer to 7.3.	0 or 1
	<description>	xs:string	Indicates the content of metadata, when this element is displayed by software, etc.	0 or 1
	<value>	Data type in Tables 25 or 26, or a space-delimited list type thereof (xs:list)	Indicates data content as a space-delimited list (Tables 25 and 26).	If a type in Table 25 (0 or 1) If a type in

				Table 26 (0 or more)
	<uncertainty>	General purpose data container[b)]	Indicates information for expressing the uncertainty of this element.	0 or more
	<property>	General purpose data container[b)]	Can be indicated as a structure below the general purpose data container that functions as the parent element, to indicate general purpose data or metadata, such as numeric values or text information included in measurement/analysis data.	0 or more

Table 20 Content of <property> Elements (continued)

Element	Descendant Element	Type	Description	Criterion
<property>	<content>	General purpose data container[b)]	Can be indicated as a structure below the general purpose data container that functions as the parent element, to indicate data with axes, such as numeric values or text information included in measurement/analysis data (vector data or tabular row/column data) or metadata.	0 or more
<value> elements express scalar quantities, words, etc., when indicated as an individual value. They express numeric vector quantities, word lists, and other information when indicated as space-delimited list. Note a) Tag used for encryption. (Refer to 7.3 for details.) Note b) As a general purpose data container, the <property> element includes content indicated in Table 20 and an attribute indicated in Table 21. The <content> element includes content indicated in Table 22 and an attribute indicated in Table 23. The <uncertainty> element includes the attributes and content indicated in Tables 20 to 23.				

Table 21 indicates attributes of the <property> element indicated in Table 20.

Table 21 Attributes of <property> Element

Element	Attribute	Type	Specified Data Values	Description	Criterion
<property>	xsi:type	Types in Tables 24 to 26	—	Indicates the data type for general purpose data containers.	1
	key	xs:QName	—	Specifies the general purpose data container name.	1
	formatString	xs:string	—	Indicates the format for displaying data. Used if the data type indicated in Table 25 or 26 is xs:dateTime, xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte. If the data type is xs:dateTime, use the xsd:dateTime format for XSD[a)]. If the data type is a numeric value type, use the format for respective numeric value types[b)].	0 or 1
	units	xs:string	—	Indicates the unit for displaying data. Used if the data type indicated in Table 25 or 26 is xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte.	0 or 1
	scaleFactor	xs:double	1	Specifies the conversion factor for converting to the data display unit specified by the units attribute. Used if the data type indicated in Table 25 or 26 is xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte.	0 or 1

To conform to a thesaurus that used namespace declarations, use an xmlns attribute to define namespaces and use prefixes to differentiate between data with a key attribute specified. For namespaces, use xmlns attributes with a prefix specified and declare the namespaces with the ancestor element for the key attribute.
Note: For example, to specify an AcceleratingVoltage value as the key attribute using the xxx prefix specified by the namespace, indicate key="xxx:AcceleratingVoltage."
Note a) In formatString, use the character string format "YYYY-MM-DDThh:mm:ss.sssTZD" to indicate XSD xsd:dateTime values in the ISO 8601 format. The "YYYY-MM-DDThh:mm:ss" portion cannot be omitted, including the number of digits, because it indicates the year, month, and day of the date value and the hour, minute, and second of the time value. Omit the ".sss" characters that indicate the decimal portion of the second value or indicate the precision level based on the number of "s" characters in the decimal portion. Also, omit the "TZD" characters used to specify the time zone or indicate a time zone specifier.
Note b) Use the "0," "." "E," or "e" characters as format character strings to indicate the number of decimal places in real numbers or use an exponent to indicate the number of significant digits in real numbers.
If xs:decimal, xs:double, or xs:float attributes are used to indicate real numbers, precision can be indicated by indicating real numbers in the form "integer portion.decimal portion" and then specifying the number of

decimal places. In that case, the integer portion is expressed with one zero, multiple digits are indicated, and the precision is indicated by the number of zeros.
For xs:double and xs:float attributes that indicate real numbers with a floating decimal point, the mantissa and exponent portions are combined in the form “<mantissa>e<exponent>” or “<mantissa>E<exponent>” to indicate the numbers. The mantissa can also be expressed as a combination of the integer portion and decimal portion, in the form “<integer portion>.<decimal portion>” to indicate the number of significant digits. In that case, the integer portion is expressed with one zero to indicate a single digit. Zeros can be used in the integer portion only to express zero as a real number. The decimal portion is expressed with zero or more zeros. Furthermore, the exponent portion is only expressed with integers. The number of zeros indicates the number of integer digits in the exponent portion.

7.1.2 <content> Element

Vector quantities, tabular row/column data, and other data with axes or metadata in measurement/analysis data, such as numeric values and text information, are indicated using the <content> element indicated in Table 22. Within that context, the <EncryptedData> element is used for encryption specified in 7.3.

The content of that data is indicated as <value> element values for the <content> element. Data uncertainty is indicated as <uncertainty> element values. In addition, <description> elements with nested <property> and/or <content> element structures can also be indicated in lower levels.

Table 22 Content of <content> Elements

Element	Descendant Element	Type	Description	Criterion
<content>	<childUri>	xs:anyURI	If URI values are included in <value> elements when the content of <content> elements is encrypted, then all the URI values should be extracted and indicated in front of the corresponding <EncryptedData> element.	0 or more
	<childHash>	xs:base64Binary	If hash values are included in <value> elements when the content of <content> elements is encrypted, then all hash values should be extracted and indicated in front of the corresponding <EncryptedData> element.	0 or more
	<childUuid>	xs:string	If UUID values are included in <value> elements when the content of <content> elements is encrypted, then all the UUID values should be extracted and indicated in front of the corresponding <EncryptedData> element.	0 or more
	<EncryptedData> a)	xenc:EncryptedData	All content of <property> elements can be encrypted collectively. If encrypted, the elements are replaced by an <EncryptedData> element. Refer to 7.3.	0 or 1
	<description>	xs:string	Indicates the content of metadata, when this element is displayed by software, etc.	0 or 1
	<value>	Data type in Table 26 (xs:list)	Indicates the content of multiple data values as a space-delimited list (Table 26).	0 or more
	<uncertainty>	General purpose data container b)	Indicates information for expressing the uncertainty of this element.	0 or more
	<property>	General purpose data container b)	Can be indicated as a structure below the general purpose data container that functions as the parent element, to indicate general purpose data or metadata, such as numeric values or text information included in measurement/analysis data.	0 or more
	<content>	General purpose data container b)	Can be indicated as a structure below the general purpose data container that functions as the parent element, to indicate data with axes, such as numeric values or text information included in measurement/analysis data (vector data or tabular row/column data) or metadata.	0 or more

<value> elements express scalar quantities, words, etc., when indicated as an individual value. They express numeric vector quantities, word lists, and other information when indicated as space-delimited list.
Note a) Tag used for encryption. (Refer to 7.3 for details.)
Note b) As a general purpose data container, the <property> element includes content indicated in Table 20 and an attribute indicated in Table 21. The <content> element includes content indicated in Table 22 and an attribute indicated in Table 23. The <uncertainty> element includes the attributes and content indicated in Tables 20 to 23.

Table 23 indicates the attributes for the <content> element indicated in Table 22. In this case, the axis attribute is specified for the <content> element to express large measurement/analysis data structures with a multidimensional or tabular structure.

In addition., a combination of identical key and id attributes is used to express a data series. To indicate the relationships between templates and data in large measurement/analysis data structures more explicitly, the id attributes of <content> elements in <materialTemplate>, <conditionTemplate>, and <resultTemplate> elements are referenced using the ref attributes in <content> elements included in <material>, <condition>, and <result> elements.

Table 23 Attributes of <content> Elements

Element	Attribute	Type	Description	Criterion
<content>	xsi:type	Type in Table 26	Indicates data types in Table 26 for general purpose data containers.	1
	key	xs:QName	Specifies the general purpose data container name.	1
	axis	xs:string	Indicates the abbreviated name for axes in vector data or tabular row/column data.	0 or 1
	size	xs:int	Indicates the number of items in vector data or tabular row/column data. The number should match the number of items listed in the <value> element.	0 or 1
	id	xs:ID	To use a <content> element defined as a template in <protocol> element content for referencing content of a <data> element, specify a unique character string from within the file in the content of the <protocol> element.	0 or 1
	ref	xs:IDREF	To use a <content> element defined as a template in <protocol> element content for referencing content of a <data> element, specify the id attribute value of the <protocol> element content in the <content> element of the <data> element.	0 or 1
	formatString	xs:string	Indicates the format for displaying data. Of the data types in Table 26, in case of xs:dateTime, xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte for data lists, the format for displaying data is indicated. If the data type is xs:dateTime, use the xsd:dateTime format for XSD[a)]. If the data type is a numeric value type, use the format for respective numeric value types[b)].	0 or 1
	units	xs:string	Indicates the unit for displaying data. Used if the Table 26 data type is xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte for data lists.	0 or 1
	scaleFactor	xs:double	Specifies the conversion factor for converting to the data display unit specified by the units attribute. Used to integerize values by multiplying them by a fixed multiple. Used if the Table 26 data type is xs:decimal, xs:double, xs:float, xs:long, xs:int, xs:short, xs:byte, xs:unsignedLong, xs:unsignedInt, xs:unsignedShort, or xs:unsignedByte for data lists.	0 or 1
To conform to a thesaurus that used namespace declarations, use an xmlns attribute to define namespaces and use prefixes to differentiate between data with a key attribute specified. For namespaces, use xmlns attributes with a prefix specified and declare the namespaces with the ancestor element for the key attribute. Note a) In formatString, use the character string format “YYYY-MM-DDThh:mm:ss.sssTZD” to indicate XSD xsd:dateTime values in ISO 8601 format. The “YYYY-MM-DDThh:mm:ss” portion cannot be omitted, including				

the number of digits, because it indicates the year, month, and day of the date value and the hour, minute, and second of the time value. Omit the ".sss" characters that indicate the decimal portion of the second value or indicate the precision level based on the number of "s" characters in the decimal portion. Also, omit the "TZD" characters used to specify the time zone or indicate a time zone specifier.
Note b) Use the "0," "." "E," or "e" characters as format character strings to indicate the number of decimal places in real numbers or use an exponent to indicate the number of significant digits in real numbers.
If xs:decimal, xs:double, or xs:float attributes are used to indicate real numbers, precision can be indicated by indicating real numbers in the form "integer portion.decimal portion" and then specifying the number of decimal places. In that case, the integer portion is expressed with one zero, multiple digits are indicated, and the precision is indicated by the number of zeros.
For xs:double and xs:float attributes that indicate real numbers with a floating decimal point, the mantissa and exponent portions are combined in the form "<mantissa>e<exponent>" or "<mantissa>E<exponent>" to indicate the numbers. The mantissa can also be expressed as a combination of the integer portion and decimal portion, in the form "<integer portion>.<decimal portion>" to indicate the number of significant digits. In that case, the integer portion is expressed with one zero to indicate a single digit. Zeros can be used in the integer portion only to express zero as a real number. The decimal portion is expressed with zero or more zeros. Furthermore, the exponent portion is only expressed with integers. The number of zeros indicates the number of integer digits in the exponent portion.

7.1.3 How to Indicate the Data Type for <property> and <content> Elements

In the MaiML data format, the MaiML data types indicated in Tables 24 to 26 as the xsi:type attribute used to indicate the data type of <property> and <content> elements. Table 24 lists types without a <value> element that are used as parent elements for <property> elements. Table 25 lists data types for values contained in a <value> element. Table 26 lists data types for space-delimited listed values. However, multiple <value> elements can be used to indicate large values, etc. In that case, <value> elements with the same data type are indicated in parallel.

Table 24 Data Type Indicated by a <property> Element xsi:type Attribute (With No <value> Element)

Attribute	Type	Data Type	Element Used	Description of Data	Attribute Included
xsi:type	propertyListType	—	property	Used as a parent element of other general purpose data containers to express data structures without including a <value> element.	—

Table 25 Data Type Indicated by a <property> Element xsi:type Attribute

Attribute	Type	Data Type	Element Used	Description of Data	Attribute Included
xsi:type	stringType	xs:string	property	Character string with space characters that are not replaced	—
	tokenType	xs:token	property	xs:normalizedString type character strings that do not include a space at the beginning or end and do not include multiple consecutive spaces.	—
	idType	xs:ID	property	Character string data with an ID type used as the data that can be referenced from other data within the same file.	—
	idRefType	xs:IDREF	property	Character string data with an IDREF type used to reference other data within the same file.	—
	qualifiedNameType	xs:QName	property	XML identifier name with a namespace prefix used for thesaurus definitions. Used to specify data to be referenced in a separate file or the same file.	—
	dateTimeType	xs:dateTime	property	Date and time	formatString
	decimalType	xs:decimal	property	Numeric values expressed in base-ten format	formatString units scaleFactor
	doubleType	xs:double	property	64-bit floating decimal real numbers	formatString units scaleFactor
	floatType	xs:float	property	32-bit floating decimal real numbers	formatString units scaleFactor
	intType	xs:int	property	Signed 32-bit integers	formatString units scaleFactor
	longType	xs:long	property	Signed 64-bit integers	formatString units scaleFactor
	shortType	xs:short	property	Signed 16-bit integers	formatString units scaleFactor
	byteType	xs:byte	property	Signed 8-bit integers	formatString units scaleFactor

Table 25 Data Type Indicated by a <property> Element xsi:type Attribute (continued)

Attribute	Type	Data Type	Element Used	Description of Data	Attribute Included
xsi:type	unsignedIntType	xs:unsignedInt	property	Unsigned 32-bit integers	formatString units scaleFactor
	unsignedLongType	xs:unsignedLong	property	Unsigned 64-bit integers	formatString units scaleFactor
	unsignedShortType	xs:unsignedShort	property	Unsigned 16-bit integers	formatString units scaleFactor
	unsignedByteType	xs:unsignedByte	property	Unsigned 8-bit integers	formatString units scaleFactor
	booleanType	xs:boolean	property	Logical operator type	—
	base64BinaryType	xs:base64Binary	property	Base-64 encoded binary information	—
	hexBinaryType	xs:hexBinary	property	Binary information expressed in hexadecimal format	—
	uriType	xs:anyURI	property	URI	—
	uuidType	xs:string	property	UUID	—
	languageType	xs:language	property	Character string used to indicate the language and locale (refer to JIS X 0412-2)	—
Assuming type including 0 or 1 <value> element.					

Table 26 Data Types (List Types) Indicated by a <property> or <content> Element xsi:type Attribute

Attribute	Type	Data Type	Element Used	Description of Data	Attribute Included
xsi:type	stringListType	xs:string	property	Type for lists of space-delimited character strings	—
	contentStringListType		content		
	idRefListType	xs:IDREF	property	Type for lists of space-delimited character strings with an IDREF type used to reference other data within the same file.	—
	contentIdRefListType		content		
	qualifiedNameListType	xs:QName	property	Type for lists of space-delimited XML identifier names with a namespace prefix used for thesaurus definitions. Used to reference data in a separate file or the same file.	—
	contentQualifiedNameListType		content		
	dateTimeListType	xs:dateTime	property	Date and time	formatString
	contentDateTimeListType		content		
	xxxListType [a)]	xxx [a)]	property	Type for space-delimited xxx type lists[a)]	formatString units scaleFactor
	contentXxxListType [b)]		content		
	yyyListType [c)]	yyy [c)]	property	Type for space-delimited yyy type lists[c)]	formatString units scaleFactor
	contentYyyListType [d)]		content		

Table 26 Data Types (List Types) Indicated by a <property> or <content> Element xsi:type Attribute (continued)

Attribute	Type	Data Type	Element Used	Description of Data	Attribute Included
xsi:type	zzzListType [e)]	zzz [e)]	property	Type for space-delimited zzz type lists[e)]	—
	contentZzzListType [f)]		content		
	stringEnumType [g)]	xs:string	property	Type for character strings with space characters not replaced and indicated using multiple <value> elements.	—
	contentStringEnumType [g)]		content		
Assuming type including zero or more <value> elements. Values for elements of this type are expressed using the space-delimited list type (xs:list). In that case, a succession of multiple space delimiter characters are replaced with a single space character and space characters included in data (list values) are treated as delimiter characters. Space-delimited lists can be indicated divided into multiple <value> elements. Of the data types indicated in Table 25, xxxType, yyyType, or zzzType types are respectively used to indicate the real number type, integer type, and unitless values, such as character string, logical, uri, and uuid values. Different attributes are applied to each type. Note a) The xxx type is for indicating real numbers with either the decimal, double, or float data type. Note b) Xxx represents either Decimal, Double, or Float. Note c) The yyy type is for indicating integer numbers with either the int, long, short, byte, unsignedInt, unsignedLong, unsignedShort, or unsignedByte data type. Note d) Yyy represents either Int, Long, Short, Byte, UnsignedInt, UnsignedLong, UnsignedShort, or UnsignedByt, and is to be replaced by them. Note e) The zzz type is for indicating boolean, base64Binary, hexBinary, uri, uuid, or language data types. Note f) Zzz represents either Boolean, Base64Binary, HexBinary, Uri, Uuid, or Language, and is to be replaced by them. Note g) The stringType type means the same thing as reintegrating multiple divided <value> elements into their original single <value> element. In contrast, the list types stringEnumType and contentStringEnumType mean a set of multiple character strings. Consequently, if integrated into a single <value> element, it functions as a set with only one character string and general purpose data containers with different values.					

7.2 How to Indicate Information for Preventing Data Tampering

In the MaiML data format, enveloped XML signatures are indicated using the <Signature> element.

7.3 How to Indicate Information for Encryption

The element tags and attributes indicated in Table 1 should not be encrypted in MaiML files. On the other hand, the <EncryptedData> element can be used to collectively encrypt all data in descendant elements of the global elements indicated in Table 6, except for <uuid> elements. Furthermore, the <EncryptedData> element can also be used to collectively encrypt all data indicated in general purpose data container content specified in Tables 20 and 22. If encrypted, the encryption method should conform to the XML encryption method specified in W3C recommendation xmlenc-core1, based on the method specified in Table 27.

Table 27 Encryption-Related Element Attributes

Element	Attribute	Type	Specified Attribute Values	Description	Criterion
<EncryptedData> a)	xmlns a)	xs:anyURI	http://www.w3.org/2001/04/xmlenc#	Indicates a namespace that specifies encryption.	0 or 1a)
Note a) If an xmlns attribute for a namespace that specifies encryption is to be added to an ancestor element such as an <maiml> element, the criterion for the xmlns attribute indicated in the <EncryptedData> element is 0. In that case, an xmlns attribute with a prefix, such as “xmlns:xenc” in an ancestor element, for example, and an element name with a prefix, such as “xenc:EncryptedData” should be used.					

If an encrypted portion includes any <insertion> elements specified in 7.4, then the <uri>, <hash>, or <uuid> element value for the encrypted <insertion> elements is indicated in parallel before the corresponding <EncryptedData> element, as <childUri>, <childHash>, or <childUuid> element values.

7.4 How to Cite External Files

To indicate the content of a different file in an MaiML file, an <insertion> element specified in Table 28 is used. In addition to other MaiML files, files configured with a different format can also be indicated as external files.

Table 28 Content of Elements Used to Specify an External File

Element	Child Element	Type	Description	Criterion
<insertion>	<uri>	xs:anyURI	Indicates URI values included in external files. To specify a relative path without specifying a protocol, specify a URI value with a relative path added based on the URI value in the MaiML file as a starting point.	1
	<hash>	xs:base64Binary	Includes an external file hash value specified in 7.9.2.	1
	<uuid>	xs:string	If the external file is in the MaiML data format, then this includes the <uuid> element value for the <document> element in the external file.	0 or 1
	<format>	xs:string	Uses a media type specified in JIS X 5810-1 to specify the format of the external file to be linked. The purpose is to ensure the uniqueness of the format[a)]. An example of the method used to specify that content is indicated in B.10.4.	0 or 1
If the external file is contained among multiple files combined in a ZIP file or the URI value for the external file exists in the same device, then indicate the file with the protocol “file:” omitted. In that case, specify the external file using a relative path starting from the current file that includes an <insertion> element. The method for specifying a relative path is described in a) to c) below. a) Specify the path using the characters “./” (may be omitted), indicating the folder containing the MaiML file and its subfolders. b) The “../” characters can be used to indicate the hierarchical level of a folder one level above or to connect path settings. c) To specify an external file on the network, specify the URI value for the absolute path, rather than the relative path. Note a) The uniqueness of the media type is ensured by “https://www.iana.org/assignments/media-types/media-types.xhtml.”				

7.5 How to Indicate the Uncertainty of Numeric, Text, and Other Information: <uncertainty>

The <uncertainty> element is used as a value that indicates the uncertainty of <value> element values included as content in <property> and <content> elements specified in 7.1. <uncertainty> elements can be indicated as child element of <property> or <content> elements including <value> elements.

<uncertainty> elements include the same content, attributes, and data types as the <property> and <content> elements specified in 7.1. They do not necessarily have the same data type as the parent element.

7.6 How to Indicate a Series of Measurement/Analysis Processes

Global <pnml> elements are used to model a series of measurement/analysis processes and display them as a Petri net. <pnml> elements include elements and attributes included in global elements. In addition, <place>, <transition>, and <arc> elements included as <pnml> element content are shown in Fig. 4. <place> and <transition> elements are simple element type elements that should include an id attribute. The <arc> element is a directed graph type element that should include a source and target attribute.

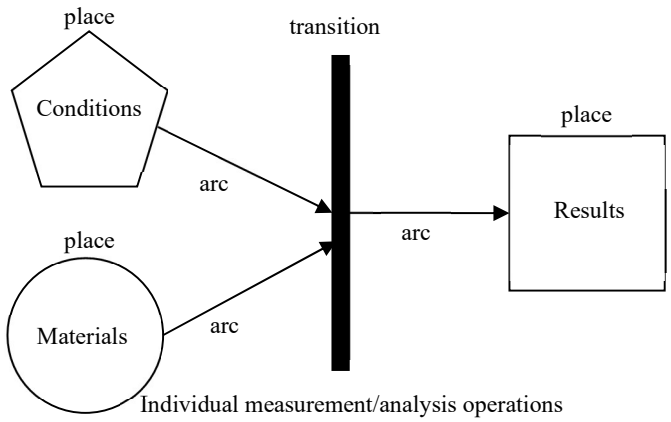
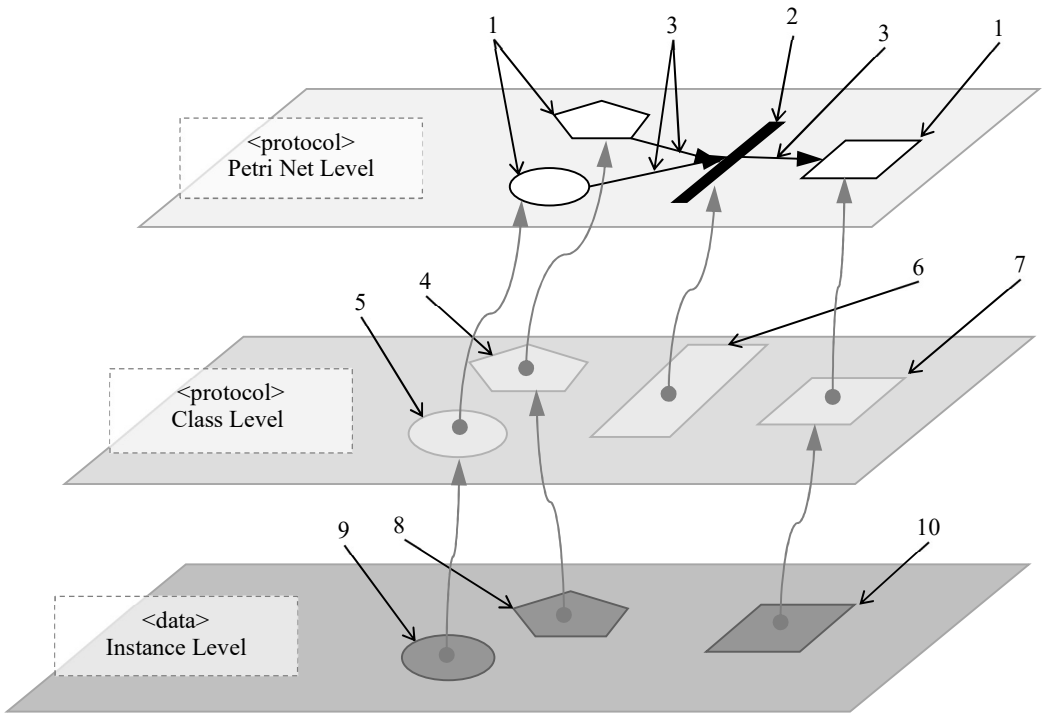


Fig. 4 Simple Petri Net Indicated by <pnml> Element

The <conditionTemplate> element used to indicate conditions, the <materialTemplate> element used to indicate materials, and the <resultTemplate> element used to indicate results are the three types of templates connected to one or multiple <place> elements to indicate they are elements for a series of measurement/analysis processes, as shown in Fig. 5. For that reason, the ref attributes of the <placeRef> elements, which are child elements of respective corresponding templates, are used to reference the id attribute included in the <place> element.



Definition of Symbols

1: <place> element
2: <transition> element
3: <arc> element
4: <conditionTemplate> element used to indicate conditions
5: <materialTemplate> element used to indicate materials
6: <instruction> element used to indicate individual measurement/analysis operations
7: <resultTemplate> element used to indicate results
8: <condition> element used to indicate conditions
9: <material> element used to indicate materials
10: <result> element used to indicate results

Fig. 5 Process Flow Indicated by <pnml> Element Included as Content of <protocol> Elements

The <transition> element is connected to <instruction> elements as content of a <program> element to indicate individual measurement/analysis operations. Therefore, it uses the ref attribute of the <transitionRef> element, which is a child element of the <instruction> element, to reference the id attribute of the <transition> element.

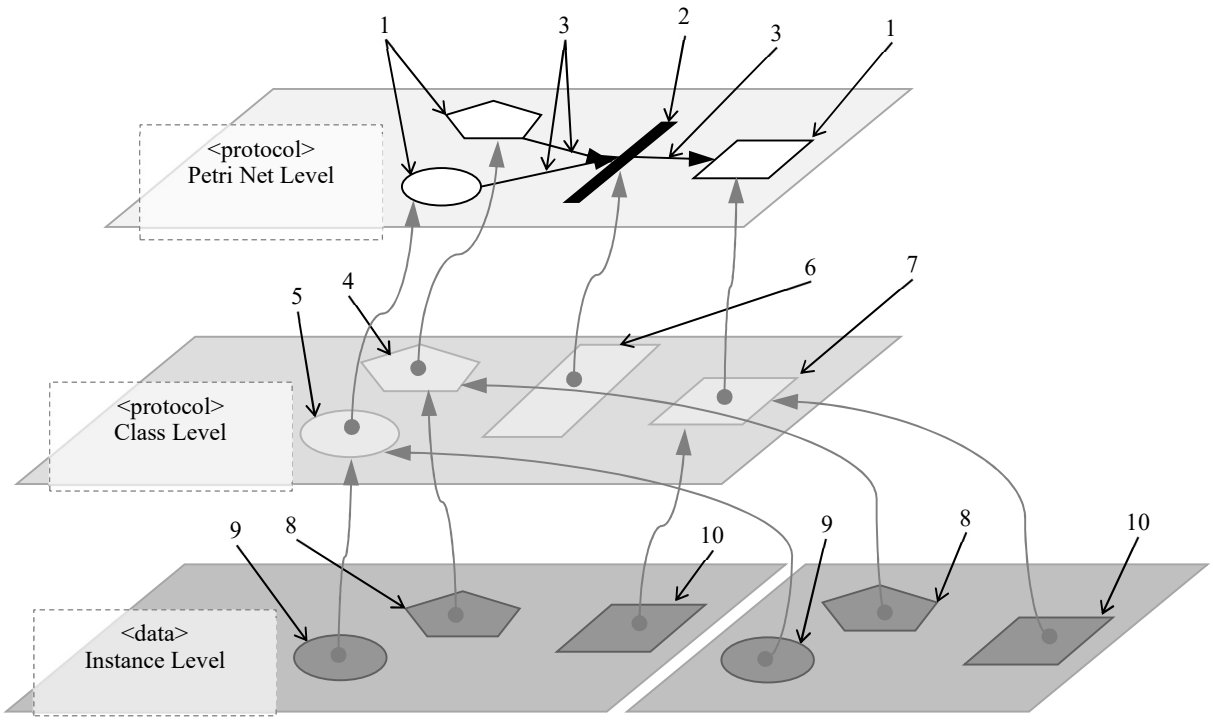
The <arc> element should include source and target attributes as xs:IDREF types. The source and target attributes should reference the id attribute of the <place> or <transition> element.

If <condition>, <material>, and <result> elements are used as content for a <data> element, the respective ref attributes should be used to reference the id attributes of the corresponding <conditionTemplate>, <materialTemplate>, and <resultTemplate> elements.

If the key attribute value of a descendant <property> or <content> element of the <condition> element is the same as the key attribute value of the descendant <property> or <content> element of the <conditionTemplate> element referenced by the ref attribute, then it is replaced by the content of the <property> or <content> element included in that <condition> element. In that case, it is only replaced if the hierarchical level of the descendant <property> or <content> element is also the same.

Similarly, the key attribute values are also replaced for <material> or <result> elements, just like the <condition> element, if the <property> or <content> element key attribute values are the same.

If a series of measurement/analysis processes indicated in a <protocol> element are executed multiple times and are indicated in the same MaiML file, then the content of the <condition>, <material>, or <result> element is indicated as content of the <results> element, as shown in Fig. 6.



Definition of Symbols

1: <place> element
2: <transition> element
3: <arc> element
4: <conditionTemplate> element used to indicate conditions
5: <materialTemplate> element used to indicate materials
6: <instruction> element used to indicate individual measurement/analysis operations
7: <resultTemplate> element used to indicate results
8: <condition> element used to indicate conditions
9: <material> element used to indicate materials
10:<result> element used to indicate results

Fig. 6 Links between <protocol> and < data> Elements

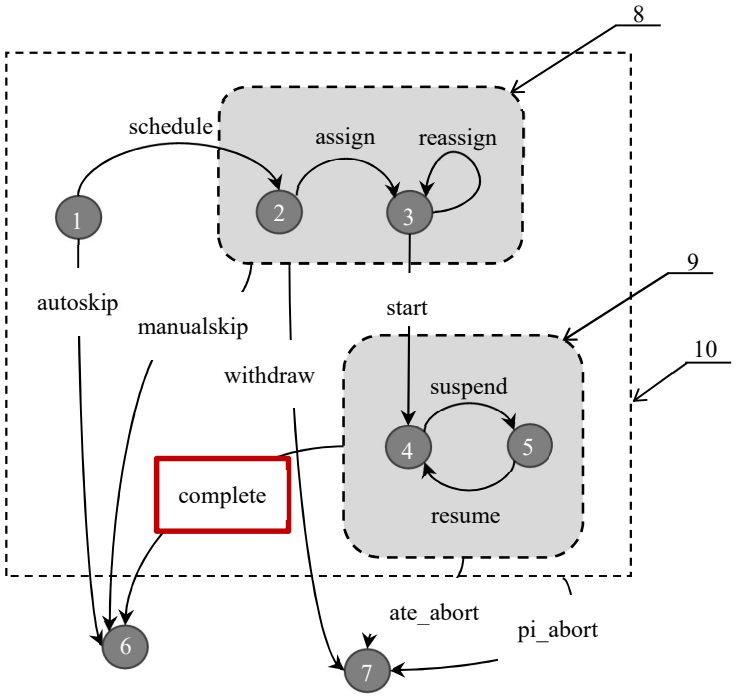
7.7 How to Indicate the Life Cycle of Measurement/Analysis Operations in Log Events

Measurement/analysis processes are indicated in Petri net levels as <pnml> elements according to the methods described in 7.6. In that case, measurement/analysis operations are indicated as <instruction> elements that reference <transition> elements, where measurement/analysis log events are indicated as content in <event> elements.

Measurement/analysis log events are indicated using <property> elements. Key attributes and data types specified by the XES Standard format are indicated, respectively, as the key attribute and xsi:type attribute for the <property> element. In that case, use the <value> element included in the <property> element to indicate the content indicated by the key attribute.

The model of transitions between measurement/analysis operating states shown in Fig. 7 corresponds to the life cycle of events indicated by the XES Standard format. In <event> element content, indicate the <property> element that includes a key attribute “lifecycle:transition” as a <value> element, in accordance with the state transitions shown in Fig. 7. To indicate measurement/analysis results as <data> elements, the <event> element should include a <property> element with “lifecycle:transition” as the key attribute and with “complete” as the

corresponding value.



Definition of Symbols

1: Initial state
2: Preparation state
3: Ready state
4: Action state
5: Sleep state
6: Finished state
7: Abnormal termination state
8: Preparation process
9: Action process
10: Processes during processing

The diagram above shows a model of transitions between measurement/analysis operation states if log events are indicated for measurement/analysis operations. The model conforms to the XES Standard format. The terms shown in the figure (schedule, assign, reassign, start, manualskip, autoskip, withdraw, suspend, resume, ate_abort, pi_abort, and complete) indicate the type of measurement/analysis operation state transition (refer to B.8). For example, the measurement/analysis operation “complete” indicates that the measurement/analysis process was completed normally.

The gray circled numbers indicate states with a measurement/analysis process and the arrows indicate the transitions from those states. Areas enclosed by a dashed line indicate metastates with multiple states.

The <property> element, which is one type of content included in <event> elements, includes a key attribute “lifecycle:transition” with a <value> element where status transitions like those shown here are indicated.

Fig. 7 Measurement/Analysis Operation Status Transition Model

In this case, <property> elements with a “concept:instance” or “time:timestamp” key attribute can be indicated in parallel as content of an <event> element. Depending on the measurement/analysis involved, if the <material>, <condition>, and <result> elements indicated in a level below a <results> element that is included in a <data> element were acquired at the same time, then indicate a <property> element with “concept:instance” specified as a key attribute. Include the <results> element UUID value as the <value> element in that <property> element.

Also depending on the measurement/analysis involved, if the <material>, <condition>, or <result> elements were acquired at different times, then indicate them respectively as different <event> elements. Include three <property> elements with key attributes “lifecycle:transition,” “concept:instance,” or “time:timestamp” in the respective <event> elements. For each of the three <property> elements, include the “complete” state transition that indicates the transition was completed, the UUID value of the corresponding element, and the time when the corresponding element was acquired as respective <value> element values.

The measurement/analysis operation state transition model indicated in Fig. 7 can also be used to indicate measurement/analysis operation log events as independent <event> elements. Using <content> elements as content of the <eventLog> element or content in lower levels is not recommended.

7.8 How to Indicate Information about Linking Files

7.8.1 How to Indicate File Links and Revisions

MaiML data format files can be linked to detect data tampering and specify the source of file modifications using the <chain> and <parent> elements specified in Table 29.

The content included respectively in <chain> and <parent> elements is listed in Table 30. <chain> and <parent> elements both include a global element type that can include a key attribute indicated in Table 31.

Table 29 Elements for Linking Files

Element	Type	Description	Criterion
<chain>	Global element type	Used to prevent data tampering using multiple files by linking MaiML files.	0 or more
<parent>	Global element type	Used to specify the source file if an MaiML file was modified.	0 or more

Table 30 Content of Elements for Linking Files

Element	Child Element	Type	Description	Criterion
<chain>	<uuid>	xs:string	If files are linked to detect data tampering, this specifies the <uuid> child element value for the <document> element included in Level 1 of the source file.	1
	<hash>	xs:base64Binary	If files are linked to detect data tampering, this specifies a digest value for the <Signature> child element for the <document> element included in Level 1 of the source file. If a <Signature> element is not specified, a file hash number is generated and used as the source, based on the method specified in 7.9.	1
	<chain>	Global element type	Content of <chain> elements can be indicated in nested structures.	0 or more
<parent>	<uuid>	xs:string	Specifies the <uuid> child element value for the <document> element included in Level 1 of the pre-modified file used as the source file.	1
	<hash>	xs:base64Binary	Specifies a digest value for the <Signature> child element value for the <document> element included in Level 1 of the pre-modified file used as the source file. If a <Signature> element is not specified, a hash number is generated and used for the source file, based on the method specified in 7.9.	1

	<parent>	Global element type	Content of <parent> elements can be indicated in nested structures.	0 or more

Table 31 Element Attributes for Linking Files

Element	Attribute	Type	Specified Value	Description	Criterion
<chain>	key	xs:string	chain	Used to indicate the relationship between files linked for detecting data tampering. The meaning of parameters used as values is indicated in B.10.1.	0 or 1
<parent>	key	xs:string	revised	Used to indicate the relationship between a modified file and its source file. The meaning of parameters used as values is indicated in B.10.2.	0 or 1

Indicated with nested <chain> elements if multiple files are connected in series to increase the probability of detecting data tampering. Specifically, the UUID values for directly connected files are indicated as <chain> element values. In addition, <chain> elements indicated in directly-connected files are indicated as child elements of that element.

Also, <chain> elements are indicated in parallel if multiple files not connected in series are used to increase the probability of detecting data tampering.

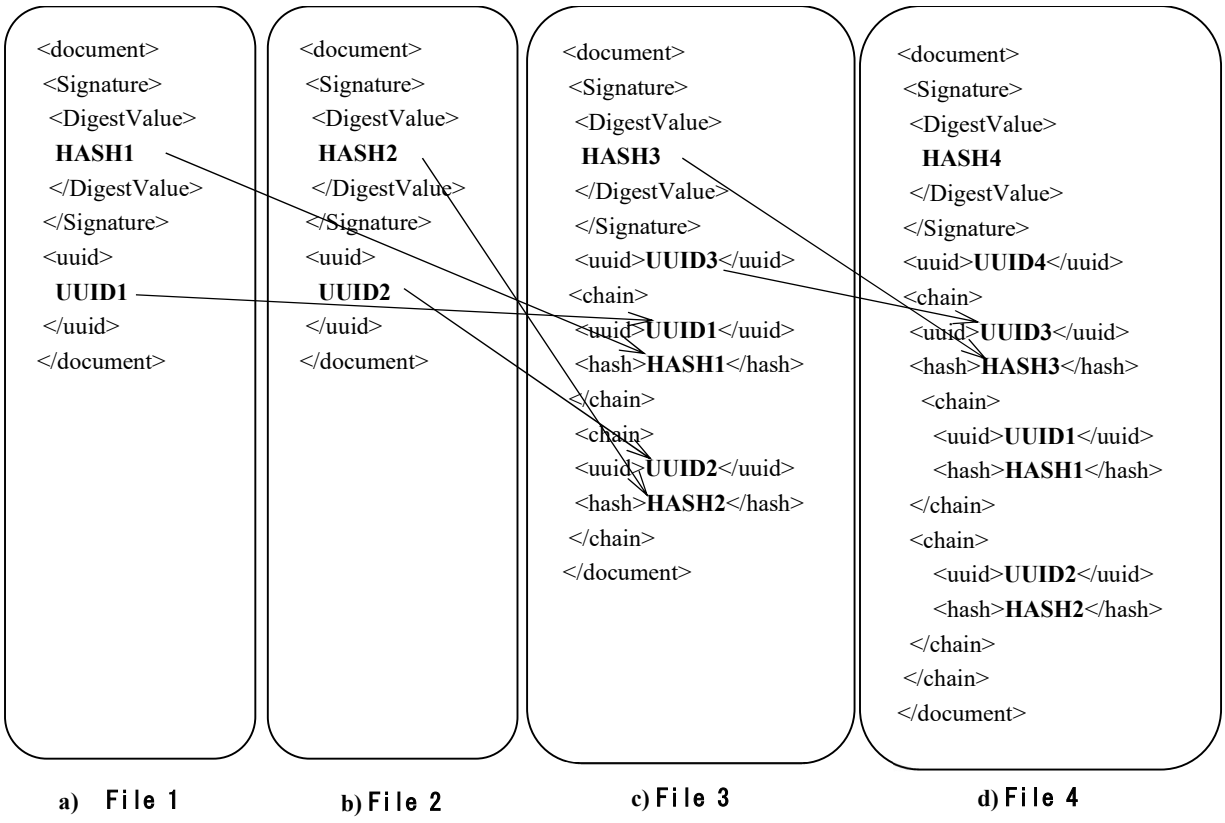
If a series of multiple consecutive files are used to indicate that a file was modified, then the <parent> elements are indicated nested. Specifically, the UUID values for directly connected files are indicated as <parent> element values. In addition, <parent> elements indicated in directly-connected files are indicated as child elements of that element.

If multiple files were modified as a newly merged file, then the <parent> elements are indicated in parallel.

7.8.2 Detecting Data Tampering Based on File Links

MaiML files use a <Signature> element as a child element of a <document> element specified in 6.2.1 to detect that a single file was tampered with.

Furthermore, data tampering in MaiML files can also be detected by using <chain> elements to link files to other MaiML files as shown in Fig. 8.



Note: If data tampering occurs in a) File 1, that results in different HASH1 values and requires changing the HASH1 value indicated in c) File 3. Changing the HASH1 value results in changing the hash value for c) File 3 (HASH3). That means d) File 4 also should be changed. Consequently, if a) File 1, c) File 3, and d) File 4 are all changed, then data tampering in a) File 1 cannot be detected.

Similarly, d) File 4 is connected to c) File 3 and is linked via c) File 3 to b) File 2. That is indicated in d) File 4 as child and grandchild elements of <chain> elements.

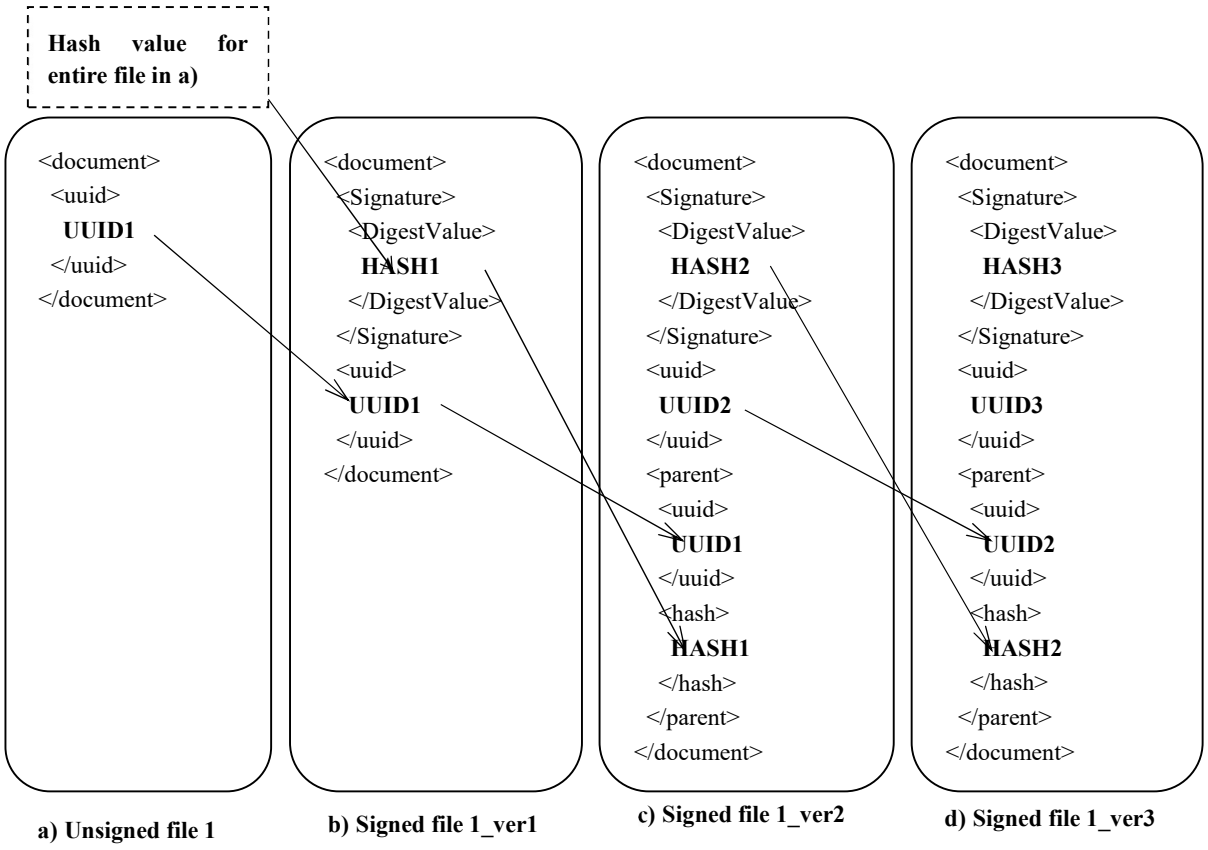
Indicating links between two files increases the probability of detecting data tampering.

Fig. 8 Using Linked Files to Detect Data Tampering

7.8.3 File Revisions

If the content of an MaiML file is changed, the digest value in the <Signature> elements indicated as a child

element of a <document> element specified in 6.2.1 and the <uuid> values used to ensure uniqueness should be changed. In addition, a <parent> element, used to indicate the source file of the revised file, should be included as a child element of a document> element specified in 6.2.1. The method for explicitly indicating a revised file is indicated in Fig. 9.



Note: c) Signed file 1_ver2, newly created by revising b) signed file 1_ver1, includes the UUID1 and HASH1 values from b) signed file 1_ver1 as content of a <parent> element. Furthermore, d) signed file 1_ver3, newly created by revising c) signed file 1_ver2, includes the UUID2 and HASH2 values from c) signed file 1_ver2 as content of a <parent> element.

Fig. 9 File Revisions

7.9 Hash Values

7.9.1 Hash Values for <Signature> Elements

The <Signature> element is compliant with XML signature requirements indicated in JIS X 5093 and ETSI TS 101 903. Furthermore, enveloped signatures are used in accordance with the format specified in JIS X 5093, with the <Signature> element indicated as child elements of the item being signed. <Signature> elements are indicated as a child element of a <document> element. To create a signature, a hash value generated from the unsigned file is used as a digest value before the <Signature> element is added.

7.9.2 Hash Values for External Files

<hash> elements specified in 7.4 are used to ensure the uniqueness of external files. <hash> element values are used as hash values for external files generated by the method specified by the method attribute. The content and attributes are indicated in Tables 32 and 33, respectively.

Table 32 Element Content Related to Hash Values

Element	Content	Type	Description	Criterion
<hash>	Element value only	xs:base64Binary	Indicates hash values from the external file, generated by the method specified by the method attribute.	1
Hash values are generated using a hash function specified by Federal Information Processing Standards Publication 180-2 (FIPS PUBS 180-2) and by NIST Special Publication 800-130 (SP 800-130).				

Table 33 Element Attributes Related to Hash Values

Element	Attribute	Type	Specified Value	Description	Criterion
<hash>	method	xs:string	SHA-256	Indicates the character string SHA-256, SHA-384, or SHA-512 as the method for generating hash values.	0 or 1
Hash values are generated using a hash function specified by Federal Information Processing Standards Publication 180-2 (FIPS PUBS 180-2) and by NIST Special Publication 800-130 (SP 800-130).					

7.10 Ensuring that Unique Global Elements are Identical and Unique

Unique global elements include a UUID value specified for ensuring the unique identity of a specified item, such as hardware, software, a person, or organization. Unique global elements used to identify the same person or organization include identical UUID values, whereas unique global elements that indicate different people or organizations should have different UUID values.

The UUID values used are either generated from a random number (version 4) or from content included in a

<name> or <uri> element (version 3 or 5), as defined in RFC 4122. However, to ensure the uniqueness of UUID values, UUID values generated by versions 3 and 5 should be generated from data with values guaranteed to be unique by means of a namespace specified by RFC 4122 (referred to as “namespace UUID” values).

References

The following are standards and other resources referenced by this standard.

[1] JIS Q 0030 Reference materials—Selected terms and definitions

[2] JIS Q 9000 Quality management systems—Fundamentals and vocabulary

[3] JIS X 0124 Representation of unit symbols for information interchange

[4] JIS X 4177-3 Document Schema Definition Languages (DSDL)—Part 3: Rule-based validation—Schematron

Note: Corresponding international standard: ISO/IEC 19757-1 Information technology—Document Schema Definition (DSDL)—Part 3: Rule-based validation—Schematron

Standard XML schema are specified as W3C Recommendation in XML Schema Part 0: Primer Second Edition (October 28, 2004), W3C XML Schema Part 1, XML Schema Part 1: Structures, W3C Recommendation (May 2, 2001), W3C XML Schema Part 2, XML Schema Part 2: Datatypes, and W3C Recommendation (May 2, 2001).

[5] JIS X 0412-2 Code for the representation of names of languages—Part 2: Alpha-3 code

[6] JIS Z 8000-1 Quantities and units—Part 1: General

[7] JIS Z 8000-2 Quantities and units—Part 2: Mathematics

[8] JIS Z 8000-3 Quantities and units—Part 3: Space and time

[9] JIS Z 8000-4 Quantities and units—Part 4: Mechanics

[10] JIS Z 8000-5 Quantities and units—Part 5: Thermodynamics

[11] JIS Z 8000-6 Quantities and units—Part 6: Electromagnetism

[12] JIS Z 8000-7 Quantities and units—Part 7: Light and radiation

[13] JIS Z 8000-8 Quantities and units—Part 8: Acoustics

[14] JIS Z 8000-9 Quantities and units—Part 9: Physical chemistry and molecular physics

[15] JIS Z 8000-10 Quantities and units—Part 10: Atomic and nuclear physics

[16] JIS Z 8000-11 Quantities and units—Part 11: Characteristic numbers

[17] JIS Z 8000-12 Quantities and units—Part 12: Condensed matter physics

The following are JIS standards that specify terminology related to measuring/analytical instruments, conditions, samples, etc.

[18] JIS Z 8103 Glossary of terms used in measurement

[19] JIS Z 8404-1 Measurement uncertainty—Part 1: Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty evaluation

[20] JIS Z 8404-2 Measurement uncertainty—Part 2: Measurement uncertainty for metrological applications—Repeated measurements and nested experiments

[21] JIS Z 8101-1 Statistics—Vocabulary and symbols —Part 1: General statistical terms and terms used in probability

Note: Applicable international standards: ISO 3534-1 Statistics—Vocabulary and symbols—Part 1: General

statistical terms and terms used in probability

[22] JIS Z 8101-2 Statistics—Vocabulary and symbols—Part 2: Applied statistics

Note: Applicable international standards: ISO 3534-2 Statistics—Vocabulary and symbols—Part 2: Applied statistics

[23] JIS K 0050 General rules for chemical analysis

[24] JIS K 0132 General rules for scanning electron microscopy

[25] JIS K 0211 Technical terms for analytical chemistry (General part)

[26] JIS K 0212 Technical terms for analytical chemistry (optical part)

[27] JIS K 0215 Technical terms for analytical chemistry (Analytical instrument part)

[28] JIS K 0147-1 Surface chemical analysis—Vocabulary—Part 1: General terms and terms used in spectroscopy

[29] JIS K 0147-2 Surface chemical analysis—Vocabulary—Part 2: Part 2: Terms used in scanning-probe microscopy

[30] JIS K 0199 Guideline for alignment procedure for identical location analysis between different microscopic measuring instruments

[31] JIS X 5810-2 Multipurpose Internet Mail Extensions (MIME)—Part 2: Media Types

Note: Compliant with IETF RFC 6838 Media Type Specifications and Registration Procedures.

The following are international standards/norms, recommendations, etc. referenced by this standard.

[32] IEEE Std 1849, IEEE Standard for eXtensible Event Stream (XES) for Achieving Interoperability in Event Logs and Event Streams

Note: Specified as a standard for event logs.

[33] IETF RFC 3986, Uniform Resource Identifier (URI): Generic Syntax

Note: Standard related to URIs.

[34] IETF RFC 4122, A Universally Unique IDentifier (UUID) URN Namespace (July 2005)

[35] ISO 8601-1:2019, Date and time—Representations for information interchange-Part 1: Basic rules

[36] W3C Recommendation xmlenc-core1 XML Encryption Syntax and Processing Version 1.1, 2013

Note: Available from https://www.w3.org/TR/xmlenc-core1/.

[37] W3C Recommendation xmlschema11-1 XML Schema Definition Language (XSD) 1.1, 2012

Note: Available from https://www.w3.org/TR/xmlschema11-1/.

[38] W3C Recommendation RDF 1.1 Concepts and Abstract Syntax

Note: Available from https://www.w3.org/TR/rdf11-concepts/.

Common Format for Measurement and Analysis Data
Commentary

This commentary is intended to explain requirements specified/indicated in the standard and is not part of the standard.

Send inquiries regarding this commentary to the Japanese Standards Association, which edited and published the commentary.

1. Intent of Establishing the Standard

In the materials field and other industrial fields with intense international competition, developing materials with higher added value due to functionally engineered properties can provide the key to competitiveness. In the industrial field of materials, it is becoming increasingly important to use a wide variety of measuring and analytical instruments to acquire comprehensive data about the materials themselves and the organizational and molecular structure of materials, and then engage in data-driven R&D for determining the conditions necessary for increasing material performance. Furthermore, due to advancements in digital transformations (DX), there are rapidly increasing needs for using AI to analyze data sets from multiple layers of R&D, including measurement and analysis data obtained from research and development, in order to accelerate the development of high-performance materials and components. In addition, an important challenge in industry is how to share expertise and experience, which was previously accumulated within individual researchers, among others within research and development workplaces.

To address that challenge, measurement/analysis data needs to be indicated in a form that enables reading and exchanging that data with broad applicability, extensibility, and data integrity. It is also important for the data to include not only measurement results but also measurement conditions, sample information, and historical information. That is essential for building a technical platform for measurement/analysis where measurement results from a wide variety of measuring/analytical instruments can be centralized in cyberspace for higher-order interdisciplinary and integrative analysis (composite cyber-physical system [CPS] for measurement/analysis).

This standard specifies requirements for a measurement/analysis data format based on XML (Extensible Markup Language) that provides general applicability, extensibility, and data integrity and that can be used for full sets of data, including measurement conditions and other information relevant to measurement results. Because establishing such a platform for composite CPS-based measurement/analysis, data utilization, and so on, requires the standardization of data formats for a variety of measuring/analytical instruments, this standard needed to be established as a JIS standard.

2. Background for Establishing the Standard

From basic research to product development, a large number of academic, R&D, and corporate institutions are involved in using measuring/analytical instruments for material analysis. Due to advancements from DX measures in recent years, measurement/analysis data is increasingly being treated as “big data” in combination with a wide variety of information that is dependent on the expertise and experience of specific personnel involved in research and development. That has generated a need in society for using AI to analyze multiple layers datasets in order to advance research and development. Given such background circumstances, the Japan Analytical Instruments Manufacturers' Association (JAIMA) drafted a proposed JIS standard for a common data format.

3. Components Included

a) Scope (Clause 1)

This standard specifies requirements for the structural portions of the data format that should be provided to (1) record acquired measurement/analysis data, measurement/analysis processes, sample information, pretreatment processes, and log events, (2) send/receive measurement/analysis data between different systems, and (3) indicate the design of and instructions for measurement/analysis processes.

b) Overview of Format (Clause 5)

The data format specified in this standard has been named the Measurement Analysis Instrument Markup Language (MaiML). The MaiML is compliant with XML and indicates the composition of data so that all inputs, processes, and outputs related to measurement/analysis processes performed using different measuring/analytical instruments and software (measurement/analysis data) can be shared in cyberspace for common use. The term for files written in the MaiML format was defined as “MaiML file.” A data composition was specified that enables all relevant information necessary for applicable measurement/analysis data to be included based on only the measurement/analysis included in an MaiML file shared in cyberspace. The ability to express everything relevant to a particular measurement/analysis is referred to as independent availability. The MaiML data format also offers the following features.

1) Data readability:

The overall structure is indicated as XML-compliant text, rather than binary code.

2) Use of specified file formats:

XML, PNML, XES, and other formats and conventions are used to ensure commonly available generic tools can be used when utilizing MaiML files.

3) Structuring of data:

All data and other information generated from various measuring/analytical instruments, software, or processes related to measurement/analysis can be comprehensively bundled as file units in cyberspace. MaiML files are structured so that measurement/analysis terminology, data types, and data values can be extracted as a set.

4) Modeled measurement/analysis processes and Petri nets:

Measurement/analysis processes are modeled and indicated as Petri nets, assuming the processes are discrete events, such as measurement/analysis or related operations.

5) Measurement/analysis terminology and namespaces:

To ensure MaiML can continue to be used after the combination, evolution, or advancement of measurements/analysis, the measurement/analysis terminology itself is not specified. On the other hand, to ensure that the individuals or groups that create MaiML files use terminology clearly, the individuals or groups that use the measurement/analysis terminology or other elements should use the designated namespace to indicate the terminology used.

6) Independent availability:

MaiML files enable all necessary information indicated in the file to be available using only data recorded in files and independently from the measuring/analytical instrument and software used for measurement/analysis. To ensure independent availability, specified files can be used linked to an external file or URI (uniform resource identifier).

7) Data uniqueness and preventing tampering:

To ensure data uniqueness, UUID (universally unique identifiers) can be used to uniquely identify specific data, even if the data is combined with any other data, such as in cyberspace. Electronic signatures or file links can be used to prevent data tampering.

8) Traceability:

The format enables tracing the history of when data was generated by indicating the data acquisition time, data owner, measuring/analytical instrument information, and so on.

c) Elements that Indicate Format Structure (Clause 6)

The overall structure of MaiML files, all the tags, elements, attributes, and types used within MaiML files are described, including how they relate respectively. The following paragraphs 1) to 5) describe the overall structure of MaiML files, the basic structures defined by the 4 types of tags, and how to configure code within each basic structure.

1) Overall structure of measurement/analysis data files:

MaiML files are configured in hierarchical levels from 0 to 4, which define the overall file composition. Level 0 indicates the range of MaiML files, from the beginning to the end. Level 1 defines the basic structure based on four types of tags: <document>, <protocol>, <data>, and <eventLog>. <document> layers are essential for ensuring the uniqueness of generated data. <protocol> layers indicate measurement/analysis processes and are essential for data reproducibility. They are the hierarchical level where multiple <program> layers are integrated. <data> layers are used to save results, conditions, and sample information when measurements/analyses are performed. These layers do not exist if only measurement/analysis conditions are saved. <eventLog> layers are specified by the XES format for reference purposes. They record log events of measurement/analysis-related actions in order to ensure the traceability of data.

2) Ensuring the uniqueness of files and measurements/analysis:

Methods for ensuring uniqueness and that no data tampering occurred include indicating UUID values and applying signatures.

3) Measurement/analysis processes:

Tags, elements, and attributes used within MaiML files to indicate measurement/analysis processes are listed and the method of modeling the series of measurement/analysis processes and indicating them as a Petri net is indicated. Methods for indicating multiple linked measurement/analysis processes and indicating templates for measurement/analysis processes are also indicated.

4) Measurement/analysis results:

The tags, elements, and attributes used to indicate measurement/analysis results are listed and the method for indicating them associated with measurement/analysis processes is indicated. The elements and methods used to indicate multiple results generated from using the same measurement/analysis processes to perform measurements/analyses multiple times are indicated.

5) Traceability of measurement/analysis processes:

The tags, elements, and attributes used to ensure the traceability of data are listed and the method of indicating measurement/analysis log events is indicated. The method for indicating log events from performing measurement/analysis processes one time, log events from performing a series of measurement/analysis processes, and log events from performing a series of measurement/analysis processes multiple times as a single set of log events is indicated.

d) How to Indicate Content for Elements that Indicate Structure (Clause 7)

To ensure data from a wide variety of measuring/analytical instruments can be indicated, a variety of data types are defined for translating values expressed as character strings according to the specified data type and processing them with a computer. Also, the type of data (name) can be specified using unique expressions that include a namespace. Examples are indicated of using the elements listed in Clause 3 c) of this commentary to indicate numeric data, text data, image data, and other information with data type and attribute information attached. The method for indicating a series of measurement/analysis processes modeled as a Petri net is indicated (Fig. 4). In addition, the method of indicating conditions, materials, and results associated to a specific <protocol> Petri net layer, <protocol> class layer, and a <data> instance layer is indicated (Fig. 5). The tags, elements, attributes, and data types used to indicate content of elements that indicate structure are described in paragraphs 1) to 10) below, including how they relate respectively.

1) General methods for indicating numeric, text, and other information:

Numeric values, text information, and other general-purpose data or metadata included in measurement/analysis data are indicated using the <property> element. Numeric values, text information, and other vector quantities, tabular row/column data, or other axis-based data or metadata are indicated using the <content> element.

2) Method for indicating information for preventing data tampering:

The <Signature> element is used to indicate enveloped type XML signatures applied to prevent data tampering in MaiML files.

3) Method for indicating information for encryption:

The method for indicating encryption information using an <EncryptedData> element is indicated for data and metadata other than <uuid> elements indicated in <property> and <content> elements, such as numeric and text information included in measurement/analysis data. The encryption method specified in this standard is based on the XML encryption method specified in W3C recommendation xmlenc-core1.

4) Method for citing external files:

In MaiML files, an <insertion> element for specifying external files is used to indicate the content of a different

file. In addition to other MaiML files, files configured using a different format can also be used as external files.

5) Method for indicating the uncertainty of numeric values, text information, etc.

The <uncertainty> element is included as content in <property> and <content> elements to indicate uncertainty values for the <value> element value included in respective elements. <uncertainty> elements can be indicated as child element of <property> or <content> elements including <value> elements.

6) Method for indicating a series of measurement/analysis processes:

<pnml> elements are used to model a series of measurement/analysis processes and display them as a Petri net diagram. Attributes are defined for <pnml> elements so they can be used to include <place>, <transition>, and <arc> elements and indicate the relationship between the three elements for conditions, materials, and results. Those elements can be used to indicate an entire series of measurement/analysis processes.

7) Method for indicating log events for the life cycle of measurement/analysis operations:

Measurement/analysis log events are indicated in the <eventLog> layer by linking them to measurement/analysis processes indicated in the <protocol> layer. Measurement/analysis log events are indicated using <property> elements. Key attributes and data types specified by the XES Standard format are indicated, respectively, as the key attribute and xsi:type attribute for the <property> element.

8) Method for indicating information about linked files:

In the MaiML data format, files can be linked to detect data tampering and specify the source of modified files using the <chain> and <parent> elements. The content included in content of <chain> and <parent> elements is listed in Table 30. <chain> and <parent> elements both include a global element type that can include a key attribute indicated in Table 31. If multiple files are connected in series to increase the probability of detecting data tampering, then <chain> elements are indicated nested. Specifically, the UUID values for directly connected files are indicated as <chain> element values. In addition, <chain> elements indicated in directly-connected files are indicated as child elements of that element. Also, <chain> elements are indicated in parallel if multiple files not connected in series are used to increase the probability of detecting data tampering. If a series of multiple consecutive files are used to indicate that a file was modified, then the <parent> elements are indicated nested. Specifically, the UUID values for directly connected files are indicated as <parent> element values, with the <parent> elements indicated in the directly connected files indicated as a child element of those elements. If multiple files were modified as a newly merged file, then the <parent> elements are indicated in parallel.

9) Hash values:

XML signatures specified in JIS X 5093 and ETSI TS 101 903 are used as <Signature> elements. Furthermore, enveloped signatures are used in accordance with the format specified in JIS X 5093, with the <Signature> element indicated as a child element of the item being signed. To create a signature, a hash value generated from the unsigned file, before the <Signature> element is added, is used as a digest value. A “SHA-256,” “SHA-384,” or “SHA-512” character string is indicated as hash values.

10) Ensuring that unique global elements are identical and unique:

Unique global elements include a UUID value specified for ensuring the unique identity of a specified item, such as hardware, software, a person, or organization. Unique global elements that indicate the same person or organization have identical UUID values, whereas unique global elements that indicate different people or

organizations are assigned different UUID values. The UUID values are either generated from random numbers (version 4) or from content included in a <name> element (version 3 or Version 5), as defined in RFC 4122.