MTConnect® Standard

Part 4.0 – Asset Information Model

Version 2.0.0

Prepared for: MTConnect Institute
Prepared from: `MTConnectSysMLModel.xml`
Prepared on: May 24, 2022

May 24, 2022

MTConnect Specification and Materials

The normative XMI is located at the following URL: `MTConnectSysMLModel.xml`

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1 Purpose of This Document

This document, *MTConnect Standard: Part 4.0 - Asset Information Model* of the MTConnect Standard, details information that is common to all types of *Assets*. Part 4.0 of the MTConnect Standard provide semantic models for entities that are used in the manufacturing process, but are not considered to be a piece of equipment. These entities are defined as *Assets*. These assets may be removed from a piece of equipment without detriment to the function of the equipment and can be associated with other pieces of equipment during their lifecycle. The data associated with these assets may be retrieved from multiple sources that are each responsible for providing their knowledge of the asset.

2 Terminology and Conventions

Refer to *MTConnect Standard Part 1.0 - Fundamentals* for a dictionary of terms, reserved language, and document conventions used in the MTConnect Standard.

2.1 MTConnect References

[MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Fundamentals*. Version 2.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Device Information Model*. Version 2.0.

[MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Observation Information Model*. Version 2.0.

[MTConnect Part 4.0] *MTConnect Standard: Part 4.0 - Asset Information Model*. Version 2.0.

3 Asset Information Model

The MTConnect Standard supports a simple distributed storage mechanism that allows applications and equipment to share and exchange complex information models in a similar way to a distributed data store. The *Asset Information Model* associates each `MTConnectAssets` entity with a unique identifier and allows for some predefined mechanisms to find, create, request, update, and delete these electronic documents in a way that provides for consistency across multiple pieces of equipment.

The protocol provides a limited mechanism of accessing *Assets* using the following properties: `assetId`, asset type (element name of asset root), and the piece of equipment associated with the asset. These access strategies will provide the following services and answer the following questions: What assets are from a particular piece of equipment? What are the assets of a particular type? What asset is stored for a given `assetId`?

Although these mechanisms are provided, an *agent* should not be considered a data store or a system of reference. The *agent* is providing an ephemeral storage capability that will temporarily manage the data for applications wishing to communicate and manage data as needed by the various processes. An application cannot rely on an *agent* for long term persistence or durability since the *agent* is only required to temporarily store the asset data and may require another system to provide the source data upon initialization. An *agent* is always providing the best-known equipment centric view of the data given the limitations of that piece of equipment.

The MTConnect Standard has two data item types to support change notification when an *Asset* is added, updated or removed. `AssetChanged` states the `assetId` of the *Asset* that has been added or updated. `AssetRemoved` states the `assetId` of the *Asset* that has been removed. See *MTConnect Standard: Part 3.0 - Observation Information Model* for more details.

3.1 Asset

abstract *Asset*.

It is used in the manufacturing process, but is not permanently associated with a single piece of equipment. It can be removed from the piece of equipment without compromising its function, and can be associated with other pieces of equipment during its lifecycle.

Note: See *Section B.1 - Assets Schema Diagrams* for XML schema.

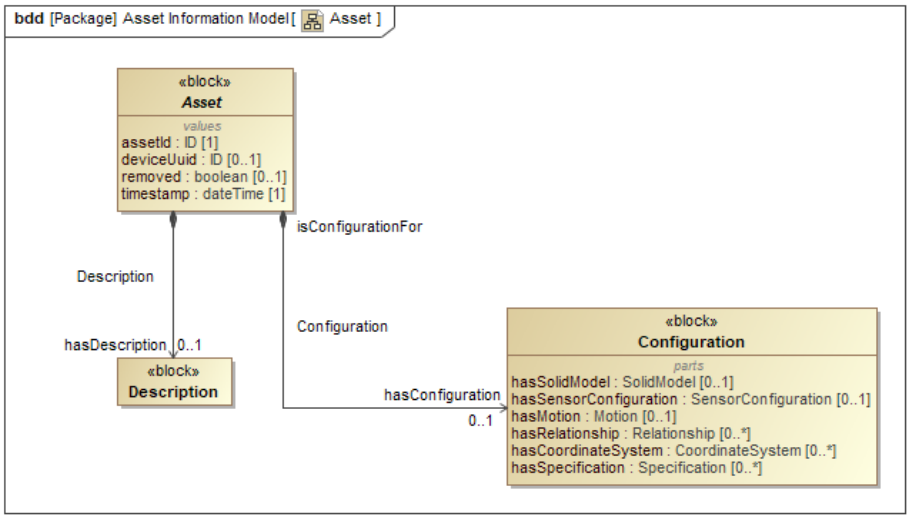

Figure 1: Asset

3.1.1 Value Properties of Asset

Table 1 lists the Value Properties of `Asset`.

Value Property name	Value Property type	Multiplicity
`assetId`	`ID`	1
`deviceUuid`	`ID`	0..1
`removed`	`boolean`	0..1
`timestamp`	`dateTime`	1

Table 1: Value Properties of Asset

Descriptions for Value Properties of `Asset`:

- `assetId`

  unique identifier for an `Asset`.

- `deviceUuid`

  associated piece of equipment's Universally Unique Identifier (UUID) that supplied the `Asset`'s data.

  It references to the `uuid` property of the `Device` defined in *MTConnect Standard: Part 2.0 - Device Information Model*.

- `removed`

  indicator that the `Asset` has been removed from the piece of equipment.

- `timestamp`

  time the `Asset` data was last modified.

3.1.2 Part Properties of Asset

Table 2 lists the Part Properties of `Asset`.

Part Property name	Multiplicity
`Description`	0..1
`Configuration`	0..1

Table 2: Part Properties of Asset

Descriptions for Part Properties of `Asset`:

- `Description`

  descriptive content.

  This can contain configuration information and manufacturer specific details.

- `Configuration`

  technical information about an entity describing its physical layout, functional characteristics, and relationships with other entities.

  See `Configuration` in *MTConnect Standard: Part 2.0 - Device Information Model*.

4 Cutting Tool Asset Information Model

There are two *information models* used to represent a cutting tool, `CuttingToolArchetype` and `CuttingTool`. The `CuttingToolArchetype` represents the static cutting tool geometries and nominal values as one would expect from a tool catalog and the `CuttingTool` represents the use or application of the tool on the shop floor with actual measured values and process data. In Version 1.3.0 of the MTConnect Standard it was decided to separate out these two concerns since not all pieces of equipment will have access to both sets of information. In this way, a generic definition of the cutting tool can coexist with a specific assembly *information model* with minimal redundancy of data.

MTConnect Standard will adopt the ISO 13399 structure when formulating the vocabulary for Cutting Tool geometries and structure to be represented in the `CuttingToolArchetype`. The nominal values provided in the `CuttingToolLifeCycle` section are only concerned with two aspects of the Cutting Tool; the Cutting Tool and the cutting item. The tool item, Adaptive Item, and Assembly Item will only be covered in the `CuttingToolDefinition` section of this document since this section contains the full ISO 13399 information about a Cutting Tool.

Figure 2: Cutting Tool Parts

The Figure 2 illustrates the parts of a Cutting Tool. The Cutting Tool is the aggregate of all the components and the cutting item is the part of the tool that removes the material from the workpiece. These are the primary focus of the MTConnect Standard.

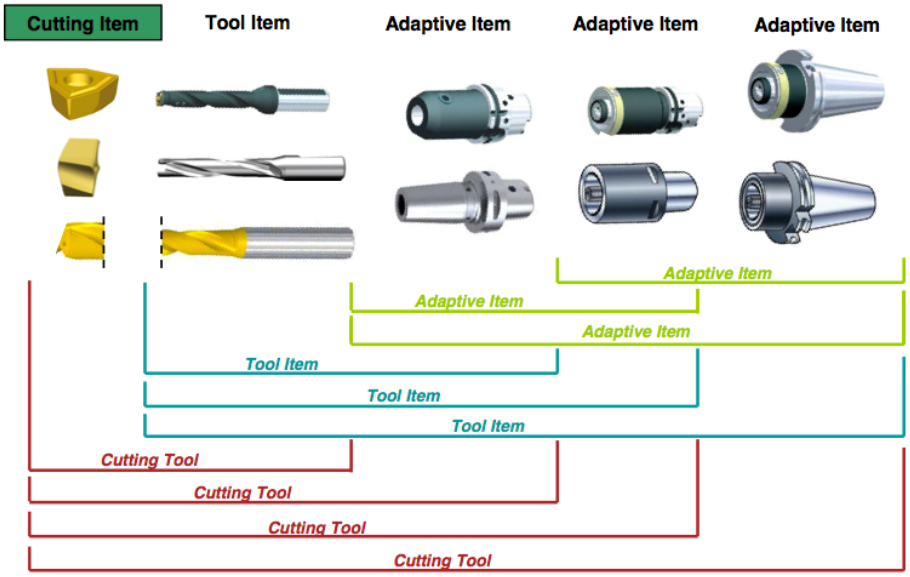

Figure 3: Cutting Tool Composition

Figure 3 provides another view of the composition of a Cutting Tool. The Adaptive Items and tool items will be used for measurements, but will not be modeled as separate entities. When we are referencing the Cutting Tool we are referring to the entirety of the assembly and when we provide data regarding the cutting item we are referencing each individual item as illustrated on the left of the previous diagram.

Figure 4 and Figure 5 further illustrates the components of the Cutting Tool. As we compose the tool item, cutting item, Adaptive Item, we get a Cutting Tool. The tool item, Adaptive Item, and Assembly Item will only be in the `CuttingToolDefinition` section that will contain the full ISO 13399 information. These figures also use the ISO 13399 codes for each of the measurements. These codes will be translated into the MTConnect Standard vocabulary as illustrated below. The measurements will have a maximum, minimum, and nominal value representing the tolerance of allowable values for this dimension.

The MTConnect Standard will not define the entire geometry of the Cutting Tool, but will provide the information necessary to use the tool in the manufacturing process. Additional information can be added to the definition of the Cutting Tool by means of schema extensions.

Additional diagrams will reference these dimensions by their codes that will be defined in the measurement tables. The codes are consistent with the codes used in ISO 13399 and have been standardized. MTConnect Standard will use the full text name for clarity in the *response documents*.

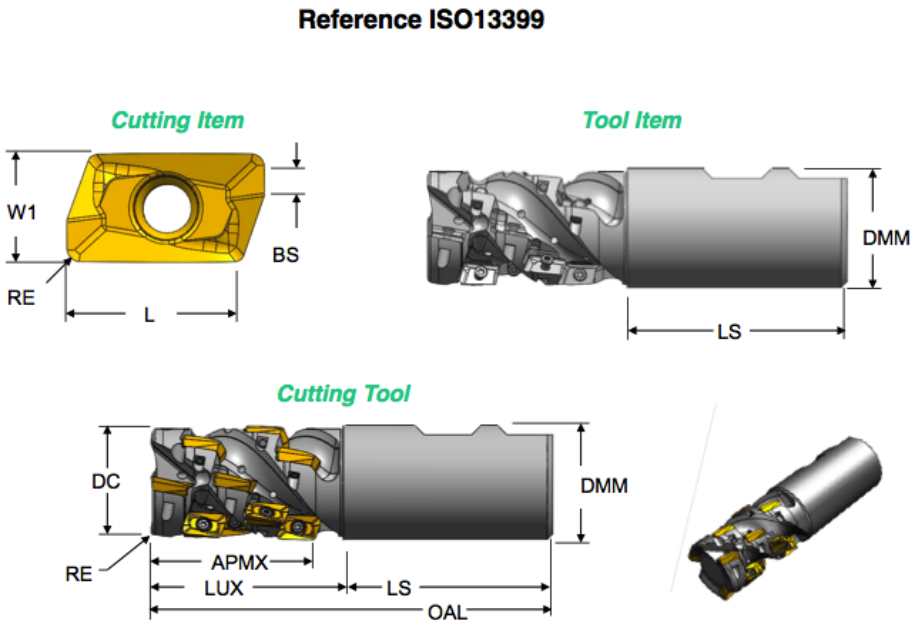

Figure 4: Cutting Tool, Tool Item, and Cutting Item

4.1 Cutting Tool

This section provides semantic information for the `CuttingTool` and `CuttingToolArchetype` models.

Note: See *Section B.2 - CuttingTool Schema Diagrams* for XML schema.

4.1.1 CuttingTool

`Asset` that physically removes the material from the workpiece by shear deformation.

4.1.1.1 Value Properties of CuttingTool

Table 3 lists the Value Properties of `CuttingTool`.

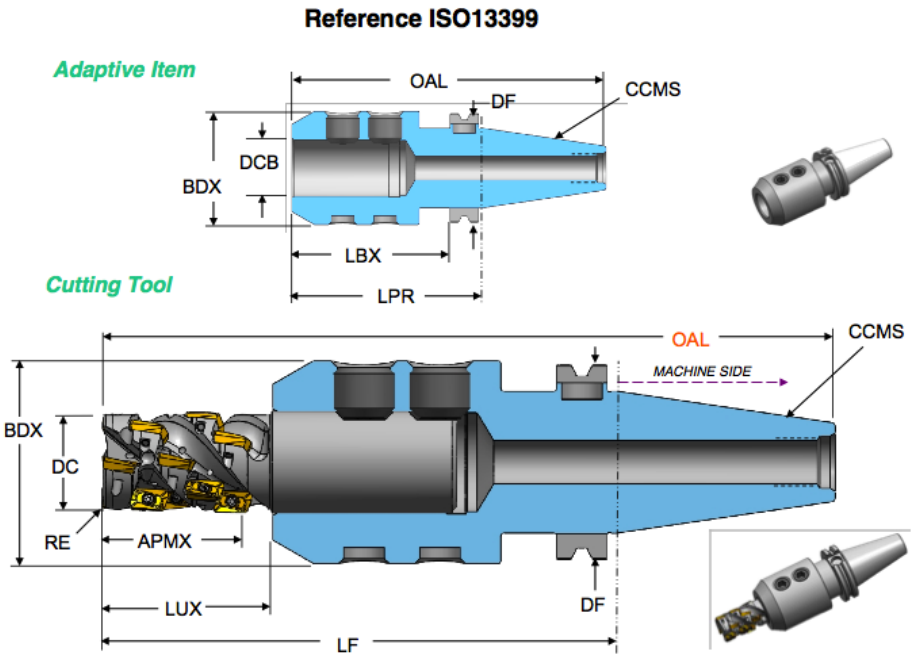

Figure 5: Cutting Tool, Tool Item, and Cutting Item 2

Value Property name	Value Property type	Multiplicity
`manufacturers`	`string`	0..*
`serialNumber`	`string`	1
`toolId`	`string`	1

Table 3: Value Properties of CuttingTool

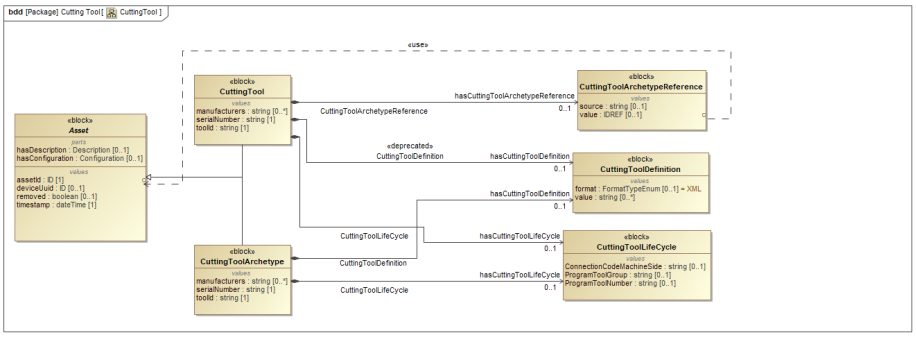

Figure 6: CuttingTool

Descriptions for Value Properties of CuttingTool:

- manufacturers

  manufacturers of the cutting tool.

  This will reference the tool item and adaptive items specifically. The cutting items manufacturers' will be a property of CuttingItem.

  Note: In Extensible Markup Language (XML), the representation **MUST** be a comma(,) delimited list of manufacturer names. See Figure 22.

- serialNumber

  unique identifier for this assembly.

- toolId

  identifier for a class of cutting tools.

4.1.1.2 Part Properties of CuttingTool

Table 4 lists the Part Properties of CuttingTool.

Part Property name	Multiplicity
CuttingToolLifeCycle	0..1
CuttingToolArchetypeReference	0..1
<<deprecated>> CuttingToolDefinition	0..1

Table 4: Part Properties of CuttingTool

Descriptions for Part Properties of CuttingTool:

- CuttingToolLifeCycle

  data regarding the application or use of the tool.

  This data is provided by various pieces of equipment (i.e. machine tool, presetter) and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured.

  See *Section 4.2.1 - CuttingToolLifeCycle*.

- CuttingToolArchetypeReference

  reference information about the assetId and/or the URL of the data source of CuttingToolArchetype.

- `CuttingToolDefinition`

  detailed structure of the cutting tool which is static during its lifecycle. *Ref ISO 13399*.

  DEPRECATED in *Version 1.3.0* for `CuttingTool`.

4.1.2 CuttingToolArchetype

`Asset` that describes the static cutting tool geometries and nominal values as one would expect from a tool catalog.

4.1.2.1 Value Properties of CuttingToolArchetype

Table 5 lists the Value Properties of `CuttingToolArchetype`.

Value Property name	Value Property type	Multiplicity
`manufacturers`	`string`	0..*
`serialNumber`	`string`	1
`toolId`	`string`	1

Table 5: Value Properties of CuttingToolArchetype

Descriptions for Value Properties of `CuttingToolArchetype`:

- `manufacturers`

  manufacturers of the cutting tool.

  This will reference the tool item and adaptive items specifically. The cutting items manufacturers' will be a property of `CuttingItem`.

  > Note: In XML, the representation will be a comma(,) delimited list of manufacturer names. See Figure 22.

- `serialNumber`

  unique identifier for this assembly.

- `toolId`

  identifier for a class of cutting tools.

4.1.2.2 Part Properties of CuttingToolArchetype

Table 6 lists the Part Properties of `CuttingToolArchetype`.

Part Property name	Multiplicity
`CuttingToolDefinition`	0..1
`CuttingToolLifeCycle`	0..1

Table 6: Part Properties of CuttingToolArchetype

Descriptions for Part Properties of `CuttingToolArchetype`:

- `CuttingToolDefinition`

  detailed structure of the cutting tool which is static during its lifecycle. *Ref ISO 13399*.

  See *Section 4.1.4 - CuttingToolDefinition*.

- `CuttingToolLifeCycle`

  data regarding the application or use of the tool.

  This data is provided by various pieces of equipment (i.e. machine tool, presetter) and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured.

  See *Section 4.2.1 - CuttingToolLifeCycle*.

4.1.3 CuttingToolArchetypeReference

reference information about the `assetId` and/or the URL of the data source of `CuttingToolArchetype`.

The value of `CuttingToolArchetypeReference` **MUST** be `IDREF`. See *Section 8.1.10 - IDREF*.

4.1.3.1 Value Properties of CuttingToolArchetypeReference

Table 7 lists the Value Properties of `CuttingToolArchetypeReference`.

Value Property name	Value Property type	Multiplicity
source	string	0..1

Table 7: Value Properties of CuttingToolArchetypeReference

Descriptions for Value Properties of CuttingToolArchetypeReference:

- source

  Uniform Resource Locator (URL) of the CuttingToolArchetype *information model*.

4.1.4 CuttingToolDefinition

detailed structure of the cutting tool which is static during its lifecycle. *Ref ISO 13399*.

The value of CuttingToolDefinition **MUST** be a list of string of size 0..*.

4.1.4.1 Value Properties of CuttingToolDefinition

Table 8 lists the Value Properties of CuttingToolDefinition.

Value Property name	Value Property type	Multiplicity
format	FormatTypeEnum	0..1

Table 8: Value Properties of CuttingToolDefinition

Descriptions for Value Properties of CuttingToolDefinition:

- format

  identifies the expected representation of the enclosed data.

  FormatTypeEnum Enumeration:

  - EXPRESS

    document will confirm to the ISO 10303 Part 21 standard.
  - TEXT

    document will be a text representation of the tool data.

- `UNDEFINED`
  document will be provided in an undefined format.
- `XML`
  default value for the definition. The content will be an XML document.

4.2 Cutting Tool Life Cycle

This section provides semantic information for the `CuttingToolLifeCycle` model.

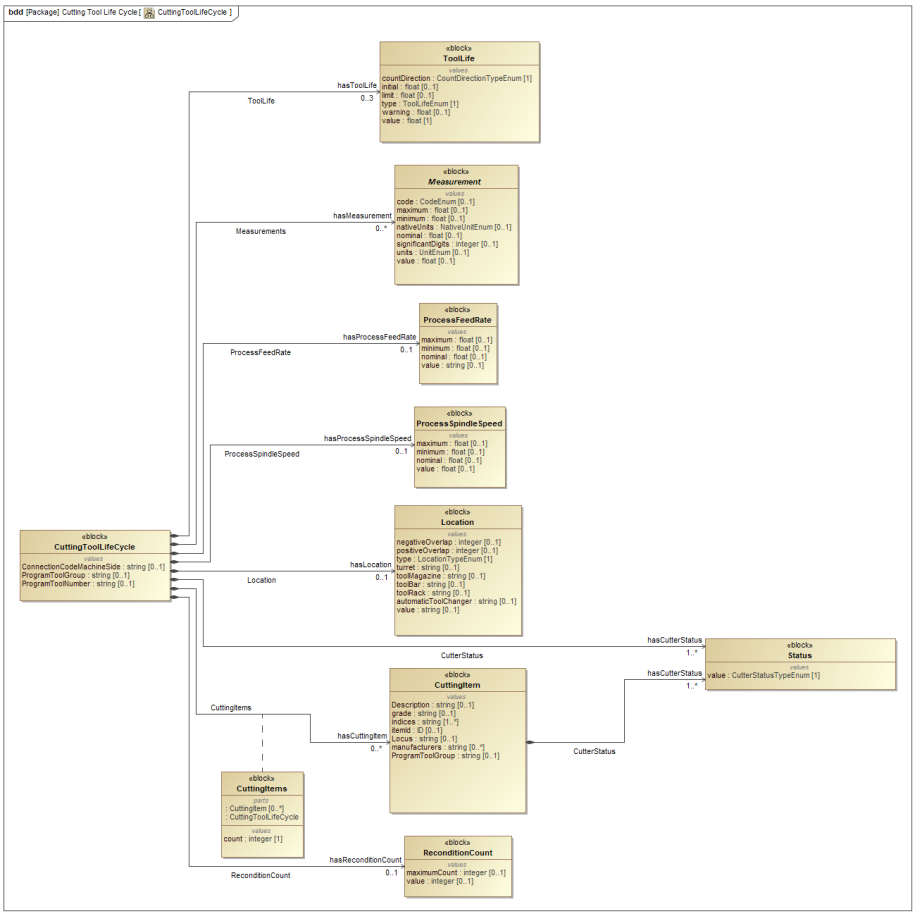

Figure 7: CuttingToolLifeCycle

Note: See *Section B.3 - CuttingToolLifeCycle Schema Diagrams* for XML schema.

4.2.1 CuttingToolLifeCycle

data regarding the application or use of the tool.

This data is provided by various pieces of equipment (i.e. machine tool, presetter) and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured.

4.2.1.1 Value Properties of CuttingToolLifeCycle

Table 9 lists the Value Properties of `CuttingToolLifeCycle`.

Value Property name	Value Property type	Multiplicity
`ConnectionCodeMachineSide`	`string`	0..1
`ProgramToolGroup`	`string`	0..1
`ProgramToolNumber`	`string`	0..1

Table 9: Value Properties of CuttingToolLifeCycle

Descriptions for Value Properties of `CuttingToolLifeCycle`:

- `ConnectionCodeMachineSide`

  identifier for the capability to connect any component of the cutting tool together, except Assembly Items, on the machine side. Code: `CCMS`

- `ProgramToolGroup`

  tool group this tool is assigned in the part program.

- `ProgramToolNumber`

  number of the tool as referenced in the part program.

4.2.1.2 Part Properties of CuttingToolLifeCycle

Table 10 lists the Part Properties of `CuttingToolLifeCycle`.

Part Property name	Multiplicity
ProcessFeedRate	0..1
ToolLife	0..3
ProcessSpindleSpeed	0..1
Status (organized by CutterStatus)	1..*
CuttingItem (organized by CuttingItems)	0..*
Measurement (organized by Measurements)	0..*
ReconditionCount	0..1
Location	0..1

Table 10: Part Properties of CuttingToolLifeCycle

Descriptions for Part Properties of CuttingToolLifeCycle:

- ProcessFeedRate

  constrained process feed rate for the tool in mm/s.

  The value **MAY** contain the nominal process target feed rate if available. If ProcessFeedRate is provided, at least one value of maximum, nominal, or minimum **MUST** be specified.

  See *Section 4.2.6 - ProcessFeedRate*.

- ToolLife

  cutting tool life as related to the assembly.

  See *Section 4.2.2 - ToolLife*.

- ProcessSpindleSpeed

  constrained process spindle speed for the tool in revolutions/minute.

  The value **MAY** contain the nominal process target spindle speed if available. If ProcessSpindleSpeed is provided, at least one value of maximum, nominal, or minimum **MUST** be specified.

  See *Section 4.2.5 - ProcessSpindleSpeed*.

- Status

  status of the cutting tool.

  CutterStatus provides the status of the assembly and *organize* one or more Status entities. See *Section 4.2.7 - Status*.

  The following combinations of Status entities **MUST NOT** occur for a CutterStatus:

  - NEW **MUST NOT** be used with USED, RECONDITIONED, or EXPIRED.
  - UNKNOWN **MUST NOT** be used with any other status.
  - ALLOCATED and UNALLOCATED **MUST NOT** be used together.
  - AVAILABLE and UNAVAILABLE **MUST NOT** be used together.
  - If the tool is EXPIRED, BROKEN, or NOT_REGISTERED it **MUST NOT** be AVAILABLE.

- CuttingItem

  part of of the tool that physically removes the material from the workpiece by shear deformation.

  CuttingItems groups one or more CuttingItem entities. See *Section 4.3.1 - CuttingItem* and *Section 4.3 - Cutting Item* for more detail.

- Measurement

  constrained scalar value associated with a cutting tool.

  Measurements groups one or more Measurement subtypes. See *Section 4.2.8 - Measurement*.

- ReconditionCount

  number of times the cutter has been reconditioned.

  See *Section 4.2.4 - ReconditionCount*.

- Location

  location of the pot or spindle the cutting tool currently resides in.

  If negativeOverlap or positiveOverlap is provided, the tool reserves additional locations on either side, otherwise if they are not given, no additional locations are required for this tool.

  If the pot occupies the first or last location, a rollover to the beginning or the end of the indexable values may occur. For example, if there are 64 pots and the tool is in pot 64 with a positiveOverlap of 1, the first pot **MAY** be occupied as well.

  See *Section 4.2.3 - Location* for more detail.

4.2.2 ToolLife

cutting tool life as related to the assembly.

ToolLife **MUST** be defined only for the CuttingToolLifeCycle of CuttingTool and **MUST NOT** be defined for the CuttingToolLifeCycle of CuttingToolArchetype.

The value of ToolLife **MUST** be float.

4.2.2.1 Value Properties of ToolLife

Table 11 lists the Value Properties of ToolLife.

Value Property name	Value Property type	Multiplicity
countDirection	CountDirectionTypeEnum	1
initial	float	0..1
limit	float	0..1
type	ToolLifeEnum	1
warning	float	0..1

Table 11: Value Properties of ToolLife

Descriptions for Value Properties of ToolLife:

- countDirection
  indicates if the tool life counts from zero to maximum or maximum to zero.
  CountDirectionTypeEnum Enumeration:
  - DOWN
    tool life counts down from the maximum to zero.
  - UP
    tool life counts up from zero to the maximum.
- initial
  initial life of the tool when it is new.
- limit
  end of life limit for the tool.
- type
  type of tool life being accumulated.
  ToolLifeEnum Enumeration:

  - `MINUTES`
    tool life measured in minutes.
    All units for minimum, maximum, and nominal **MUST** be provided in minutes.
  - `PART_COUNT`
    tool life measured in parts.
    All units for minimum, maximum, and nominal **MUST** be provided as the number of parts.
  - `WEAR`
    tool life measured in tool wear.
    Wear **MUST** be provided in millimeters as an offset to nominal. All units for minimum, maximum, and nominal **MUST** be given as millimeter offsets as well. The standard will only consider dimensional wear at this time.

- `warning`
  point at which a tool life warning will be raised.

4.2.3 Location

location of the pot or spindle the cutting tool currently resides in.

If `negativeOverlap` or `positiveOverlap` is provided, the tool reserves additional locations on either side, otherwise if they are not given, no additional locations are required for this tool.

If the pot occupies the first or last location, a rollover to the beginning or the end of the indexable values may occur. For example, if there are 64 pots and the tool is in pot 64 with a `positiveOverlap` of 1, the first pot **MAY** be occupied as well.

`Location` **MUST** be defined only for the `CuttingToolLifeCycle` of `CuttingTool` and **MUST NOT** be defined for the `CuttingToolLifeCycle` of `CuttingToolArchetype`.

The value of `Location` **MUST** be `string`.

4.2.3.1 Value Properties of Location

Table 12 lists the Value Properties of `Location`.

Value Property name	Value Property type	Multiplicity
negativeOverlap	integer	0..1
positiveOverlap	integer	0..1
type	LocationTypeEnum	1
turret	string	0..1
toolMagazine	string	0..1
toolBar	string	0..1
toolRack	string	0..1
automaticToolChanger	string	0..1

Table 12: Value Properties of Location

Descriptions for Value Properties of Location:

- negativeOverlap

  number of locations at lower index values from this location.

- positiveOverlap

  number of locations at higher index value from this location.

- type

  type of location being identified.

  When a POT or STATION type is used, value of Location **MUST** be a numeric value.

  LocationTypeEnum Enumeration:

  - CRIB

    location with regard to a tool crib.

  - END_EFFECTOR

    location associated with an end effector.

  - EXPIRED_POT

    location for a tool that is no longer usable and is awaiting removal from a tool magazine or turret.

  - POT

    number of the pot in the tool handling system.

  - REMOVAL_POT

    location for a tool removed from a tool magazine or turret awaiting transfer to a location outside of the piece of equipment.

353 – RETURN_POT
354 location for a tool removed from a *spindle* or turret and awaiting return to a
355 tool magazine.
356 – SPINDLE
357 location associated with a *spindle*.
358 – STAGING_POT
359 location for a tool awaiting transfer to a tool magazine or turret from outside
360 of the piece of equipment.
361 – STATION
362 tool location in a horizontal turning machine.
363 – TRANSFER_POT
364 location for a tool awaiting transfer from a tool magazine to spindle or a turret.

365 • turret
366 turret associated with a tool.

367 • toolMagazine
368 tool magazine associated with a tool.

369 • toolBar
370 tool bar associated with a tool.

371 • toolRack
372 tool rack associated with a tool.

373 • automaticToolChanger
374 automatic tool changer associated with a tool.

375 4.2.4 ReconditionCount

376 number of times the cutter has been reconditioned.

377 ReconditionCount **MUST** be defined only for the CuttingToolLifeCycle of
378 CuttingTool and **MUST NOT** be defined for the CuttingToolLifeCycle of
379 CuttingToolArchetype.

380 The value of ReconditionCount **MUST** be integer.

4.2.4.1 Value Properties of ReconditionCount

Table 13 lists the Value Properties of `ReconditionCount`.

Value Property name	Value Property type	Multiplicity
`maximumCount`	`integer`	0..1

Table 13: Value Properties of ReconditionCount

Descriptions for Value Properties of `ReconditionCount`:

- `maximumCount`
  maximum number of times the tool may be reconditioned.

4.2.5 ProcessSpindleSpeed

constrained process spindle speed for the tool in revolutions/minute.

The `value` **MAY** contain the nominal process target spindle speed if available. If `ProcessSpindleSpeed` is provided, at least one value of `maximum`, `nominal`, or `minimum` **MUST** be specified.

The value of `ProcessSpindleSpeed` **MUST** be `float`.

4.2.5.1 Value Properties of ProcessSpindleSpeed

Table 14 lists the Value Properties of `ProcessSpindleSpeed`.

Value Property name	Value Property type	Multiplicity
`maximum`	`float`	0..1
`minimum`	`float`	0..1
`nominal`	`float`	0..1

Table 14: Value Properties of ProcessSpindleSpeed

Descriptions for Value Properties of `ProcessSpindleSpeed`:

- `maximum`
  upper bound for the tool's target spindle speed.

- `minimum`

  lower bound for the tools spindle speed.

- `nominal`

  nominal speed the tool is designed to operate at.

4.2.6 ProcessFeedRate

constrained process feed rate for the tool in mm/s.

The `value` **MAY** contain the nominal process target feed rate if available. If `ProcessFeedRate` is provided, at least one value of `maximum`, `nominal`, or `minimum` **MUST** be specified.

The value of `ProcessFeedRate` **MUST** be `string`.

4.2.6.1 Value Properties of ProcessFeedRate

Table 15 lists the Value Properties of `ProcessFeedRate`.

Value Property name	Value Property type	Multiplicity
`maximum`	`float`	0..1
`minimum`	`float`	0..1
`nominal`	`float`	0..1

Table 15: Value Properties of ProcessFeedRate

Descriptions for Value Properties of `ProcessFeedRate`:

- `maximum`

  upper bound for the tool's process target feedrate.

- `minimum`

  lower bound for the tool's feedrate.

- `nominal`

  nominal feedrate the tool is designed to operate at.

4.2.7 Status

status of the cutting tool.

`CutterStatusTypeEnum` Enumeration:

- `ALLOCATED`
  tool is has been committed to a piece of equipment for use and is not available for use in any other piece of equipment.
- `AVAILABLE`
  tool is available for use.
  If this is not present, the tool is currently not ready to be used.
- `BROKEN`
  premature tool failure.
- `EXPIRED`
  tool has reached the end of its useful life.
- `MEASURED`
  tool has been measured.
- `NEW`
  new tool that has not been used or first use.
  Marks the start of the tool history.
- `NOT_REGISTERED`
  tool cannot be used until it is entered into the system.
- `RECONDITIONED`
  tool has been reconditioned.
- `UNALLOCATED`
  tool has not been committed to a process and can be allocated.
- `UNAVAILABLE`
  tool is unavailable for use in metal removal.
- `UNKNOWN`
  tool is an indeterminate state. This is the default value.

- `USED`

  tool is in process and has remaining tool life.

4.2.8 Measurement

constrained scalar value associated with a cutting tool.

A `Measurement` is specific to the tool management policy at a particular shop. The tool zero reference point or gauge line will be different depending on the particular implementation and will be assumed to be consistent within the shop. MTConnect Standard does not standardize the manufacturing process or the definition of the zero point.

The value of `Measurement` **MUST** be `float`.

4.2.8.1 Value Properties of Measurement

Table 16 lists the Value Properties of `Measurement`.

Value Property name	Value Property type	Multiplicity
`code`	`CodeEnum`	0..1
`maximum`	`float`	0..1
`minimum`	`float`	0..1
`nativeUnits`	`NativeUnitEnum`	0..1
`nominal`	`float`	0..1
`significantDigits`	`integer`	0..1
`units`	`UnitEnum`	0..1

Table 16: Value Properties of Measurement

Descriptions for Value Properties of `Measurement`:

- `code`

  shop specific code for the measurement.

  ISO 13399 codes **MAY** be used for these codes as well.

  See *Section 4.4 - Cutting Tool Measurement Subtypes* and *Section 4.5 - Cutting Item Measurement Subtypes* for details on `Measurement` types and their respective `code` values.

- `maximum`

  maximum value for the measurement.

- `minimum`

  minimum value for the measurement.

- `nativeUnits`

  units the measurement was originally recorded in. See *MTConnect Standard: Part 2.0 - Device Information Model* for the complete list of `nativeUnits`.

  The value of `nativeUnits` **MUST** be one of the `NativeUnitEnum` enumeration.

- `nominal`

  as advertised value for the measurement.

- `significantDigits`

  number of significant digits in the reported value.

- `units`

  units for the measurements. See *MTConnect Standard: Part 2.0 - Device Information Model* for the complete list of `units`.

  The value of `units` **MUST** be one of the `UnitEnum` enumeration.

4.3 Cutting Item

A `CuttingItem` is the portion of the tool that physically removes the material from the workpiece by shear deformation. The cutting item can be either a single piece of material attached to the `CuttingTool` or it can be one or more separate pieces of material attached to the `CuttingTool` using a permanent or removable attachment. A `CuttingItem` can be comprised of one or more cutting edges. Cutting items include: replaceable inserts, brazed tips and the cutting portions of solid `CuttingTools`.

MTConnect Standard considers `CuttingItems` as part of the `CuttingTool`. A `CuttingItems` **MUST NOT** exist in MTConnect unless it is attached to a `CuttingTool`. Some of the measurements, such as `FunctionalLength`, **MUST** be made with reference to the entire `CuttingTool` to be meaningful.

Note: See *Section B.4 - CuttingItem Schema Diagrams* for XML schema.

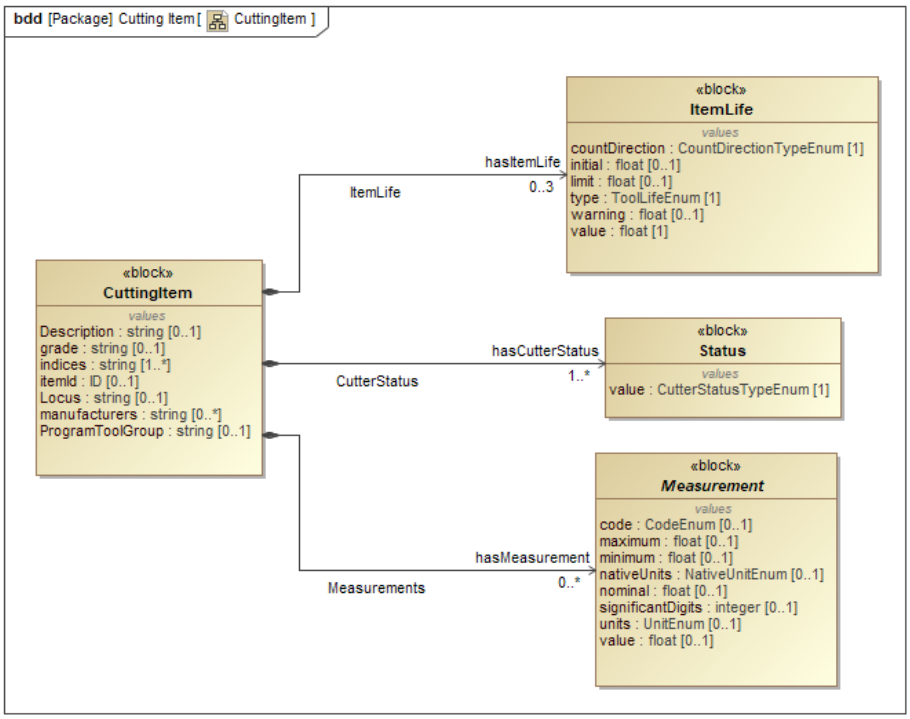

Figure 8: CuttingItem

4.3.1 CuttingItem

part of of the tool that physically removes the material from the workpiece by shear deformation.

4.3.1.1 Value Properties of CuttingItem

Table 17 lists the Value Properties of `CuttingItem`.

Value Property name	Value Property type	Multiplicity
`Description`	`string`	0..1
`grade`	`string`	0..1
`indices`	`string`	1..*
`itemId`	`ID`	0..1
`Locus`	`string`	0..1
`manufacturers`	`string`	0..*
`ProgramToolGroup`	`string`	0..1

Table 17: Value Properties of CuttingItem

Descriptions for Value Properties of `CuttingItem`:

- `Description`

  free-form description of the cutting item.

- `grade`

  material composition for this cutting item.

- `indices`

  number or numbers representing the individual cutting item or items on the tool.

  Indices **SHOULD** start numbering with the inserts or `CuttingItem` furthest from the gauge line and increasing in value as the items get closer to the gauge line. Items at the same distance **MAY** be arbitrarily numbered.

  > Note: In XML, the representation **MUST** be a single number ("1") or a comma separated set of individual elements ("1,2,3,4"), or as a inclusive range of values as in ("1-10") or any combination of ranges and numbers as in "1-4,6-10,22". There **MUST NOT** be spaces or non-integer values in the text representation.

- `itemId`

  manufacturer identifier of this cutting item.

- `Locus`

  free form description of the location on the cutting tool.

  For clarity, the words `FLUTE`, `INSERT`, and `CARTRIDGE` **SHOULD** be used to assist in noting the location of a `CuttingItem`. `Locus` **MAY** be any free form string, but **SHOULD** adhere to the following rules:

  - The location numbering **SHOULD** start at the furthest `CuttingItem` and work it's way back to the `CuttingItem` closest to the gauge line.
  - Flutes **SHOULD** be identified as such using the word `FLUTE`:. For example: `FLUTE`: 1, `INSERT`: 2 - would indicate the first flute and the second furthest insert from the end of the tool on that flute.
  - Other designations such as `CARTRIDGE` **MAY** be included, but should be identified using upper case and followed by a colon (:).

- `manufacturers`

  manufacturers of the cutting item.

  This will reference the tool item and adaptive items specifically. The cutting items manufacturers' will be a property of `CuttingItem`.

Note: In XML, the representation **MUST** be a comma(,) delimited list of manufacturer names. See Figure 34.

- `ProgramToolGroup`

  tool group this item is assigned in the part program.

4.3.1.2 Part Properties of CuttingItem

Table 18 lists the Part Properties of `CuttingItem`.

Part Property name	Multiplicity
`Status` (organized by `CutterStatus`)	1..*
`ItemLife`	0..3
`Measurement` (organized by `Measurements`)	0..*

Table 18: Part Properties of CuttingItem

Descriptions for Part Properties of `CuttingItem`:

- `Status`

  status of the cutting tool.

  `CutterStatus` provides the status of the assembly and *organize* one or more `Status` entities. See *Section 4.2.7 - Status*.

  The following combinations of `Status` entities **MUST NOT** occur for a `CutterStatus`:

  - `NEW` **MUST NOT** be used with `USED`, `RECONDITIONED`, or `EXPIRED`.
  - `UNKNOWN` **MUST NOT** be used with any other status.
  - `ALLOCATED` and `UNALLOCATED` **MUST NOT** be used together.
  - `AVAILABLE` and `UNAVAILABLE` **MUST NOT** be used together.
  - If the tool is `EXPIRED`, `BROKEN`, or `NOT_REGISTERED` it **MUST NOT** be `AVAILABLE`.

  `CutterStatus` **MUST** be defined only for the `CuttingToolLifeCycle` of `CuttingTool` and **MUST NOT** be defined for the `CuttingToolLifeCycle` of `CuttingToolArchetype`.

- `ItemLife`

  life of a `CuttingItem`.

  See *Section 4.3.3 - ItemLife*.

- `Measurement`

  constrained scalar value associated with a cutting tool.

  `Measurements` groups one or more `Measurement` subtypes. See *Section 4.2.8 - Measurement*.

4.3.2 CuttingItems

`CuttingItems` groups one or more `CuttingItem` entities. See *Section 4.3.1 - CuttingItem* and *Section 4.3 - Cutting Item* for more detail.

4.3.2.1 Value Properties of CuttingItems

Table 19 lists the Value Properties of `CuttingItems`.

Value Property name	Value Property type	Multiplicity
`count`	`integer`	1

Table 19: Value Properties of CuttingItems

Descriptions for Value Properties of `CuttingItems`:

- `count`

  number of `CuttingItem` organized by `CuttingItems`.

4.3.3 ItemLife

life of a `CuttingItem`.

The value of `ItemLife` **MUST** be `float`.

4.3.3.1 Value Properties of ItemLife

Table 20 lists the Value Properties of `ItemLife`.

Value Property name	Value Property type	Multiplicity
countDirection	CountDirectionTypeEnum	1
initial	float	0..1
limit	float	0..1
type	ToolLifeEnum	1
warning	float	0..1

Table 20: Value Properties of ItemLife

Descriptions for Value Properties of ItemLife:

- countDirection

  indicates if the item life counts from zero to maximum or maximum to zero.

  The value of countDirection **MUST** be one of the CountDirectionTypeEnum enumeration.

- initial

  initial life of the item when it is new.

- limit

  end of life limit for this item.

- type

  type of item life being accumulated.

  The value of type **MUST** be one of the ToolLifeEnum enumeration.

- warning

  point at which a item life warning will be raised.

4.4 Cutting Tool Measurement Subtypes

This section lists the Measurement subtypes for CuttingTool.

These Measurement subtypes for CuttingTool are specific to the entire assembly and **MUST NOT** be used for the Measurement pertaining to a CuttingItem. Figure 9 and Figure 10 will be used to reference the assembly specific Measurement subtypes.

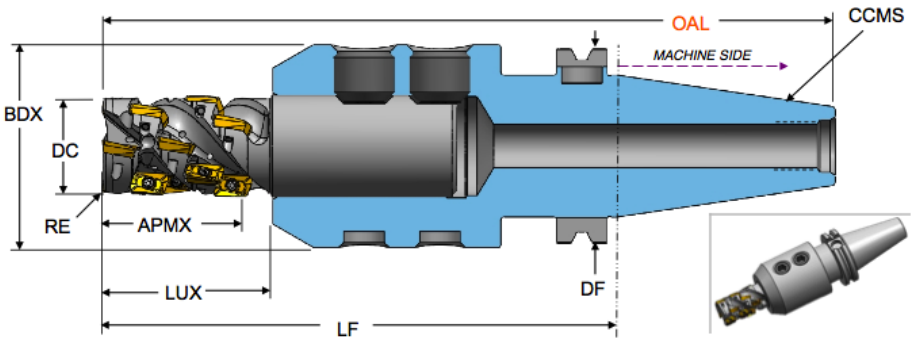

Figure 9: Cutting Tool Measurement 1

4.4.1 BodyDiameterMax

largest diameter of the body of a tool item.

The `code` of `BodyDiameterMax` **MUST** be `BDX`.

The `units` of `BodyDiameterMax` **MUST** be `MILLIMETER`.

4.4.2 BodyLengthMax

distance measured along the X axis from that point of the item closest to the workpiece, including the cutting item for a tool item but excluding a protruding locking mechanism for an adaptive item, to either the front of the flange on a flanged body or the beginning of the connection interface feature on the machine side for cylindrical or prismatic shanks.

The `code` of `BodyLengthMax` **MUST** be `LBX`.

The `units` of `BodyLengthMax` **MUST** be `MILLIMETER`.

4.4.3 DepthOfCutMax

maximum engagement of the cutting edge or edges with the workpiece measured perpendicular to the feed motion.

The `code` of `DepthOfCutMax` **MUST** be `APMX`.

The `units` of `DepthOfCutMax` **MUST** be `MILLIMETER`.

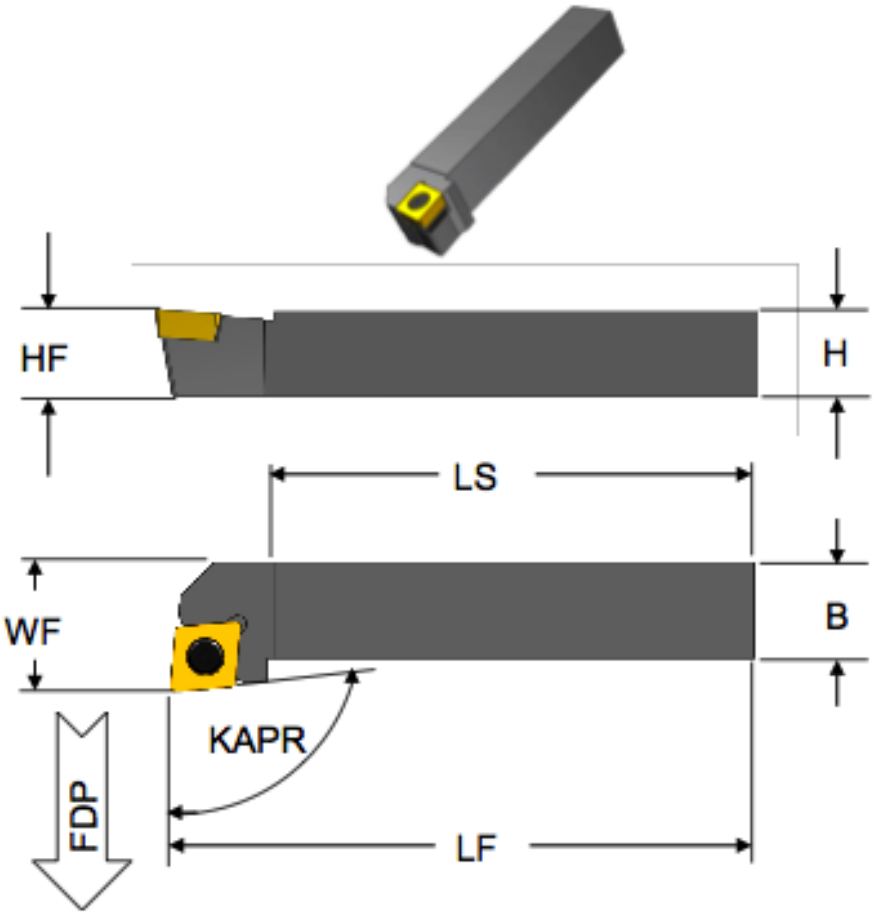

Figure 10: Cutting Tool Measurement 2

607 4.4.4 CuttingDiameterMax

608 maximum diameter of a circle on which the defined point Pk of each of the master inserts
609 is located on a tool item.

610 The normal of the machined peripheral surface points towards the axis of the cutting tool.

611 The `code` of `CuttingDiameterMax` **MUST** be `DC`.

612 The `units` of `CuttingDiameterMax` **MUST** be `MILLIMETER`.

4.4.5 FlangeDiameterMax

dimension between two parallel tangents on the outside edge of a flange.

The `code` of `FlangeDiameterMax` **MUST** be `DF`.

The `units` of `FlangeDiameterMax` **MUST** be `MILLIMETER`.

4.4.6 OverallToolLength

largest length dimension of the cutting tool including the master insert where applicable.

The `code` of `OverallToolLength` **MUST** be `OAL`.

The `units` of `OverallToolLength` **MUST** be `MILLIMETER`.

4.4.7 ShankDiameter

dimension of the diameter of a cylindrical portion of a tool item or an adaptive item that can participate in a connection.

The `code` of `ShankDiameter` **MUST** be `DMM`.

The `units` of `ShankDiameter` **MUST** be `MILLIMETER`.

4.4.8 ShankHeight

dimension of the height of the shank.

The `code` of `ShankHeight` **MUST** be `H`.

The `units` of `ShankHeight` **MUST** be `MILLIMETER`.

4.4.9 ShankLength

dimension of the length of the shank.

The `code` of `ShankLength` **MUST** be `LS`.

The `units` of `ShankLength` **MUST** be `MILLIMETER`.

4.4.10 UsableLengthMax

maximum length of a cutting tool that can be used in a particular cutting operation including the non-cutting portions of the tool.

The `code` of `UsableLengthMax` **MUST** be `LUX`.

The `units` of `UsableLengthMax` **MUST** be `MILLIMETER`.

4.4.11 ProtrudingLength

dimension from the yz-plane to the furthest point of the tool item or adaptive item measured in the -X direction.

The `code` of `ProtrudingLength` **MUST** be `LPR`.

The `units` of `ProtrudingLength` **MUST** be `MILLIMETER`.

4.4.12 FunctionalLength

distance from the gauge plane or from the end of the shank to the furthest point on the tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool.

The `CuttingTool` functional length will be the length of the entire tool, not a single cutting item. Each `CuttingItem` can have an independent `FunctionalLength` represented in its measurements.

The `code` of `FunctionalLength` **MUST** be `LF`.

The `units` of `FunctionalLength` **MUST** be `MILLIMETER`.

4.4.13 Weight

total weight of the cutting tool in grams.

The force exerted by the mass of the cutting tool.

The `code` of `Weight` **MUST** be `WT`.

The `units` of `Weight` **MUST** be `GRAM`.

4.5 Cutting Item Measurement Subtypes

This section lists the `Measurement` subtypes for `CuttingItem`.

These `Measurement` subtypes for `CuttingItem` are specific to an individual `CuttingItem` and **MUST NOT** be used for the `Measurement` pertaining to an assembly. Figures below will be used to for reference for the `CuttingItem` specific `Measurement` types.

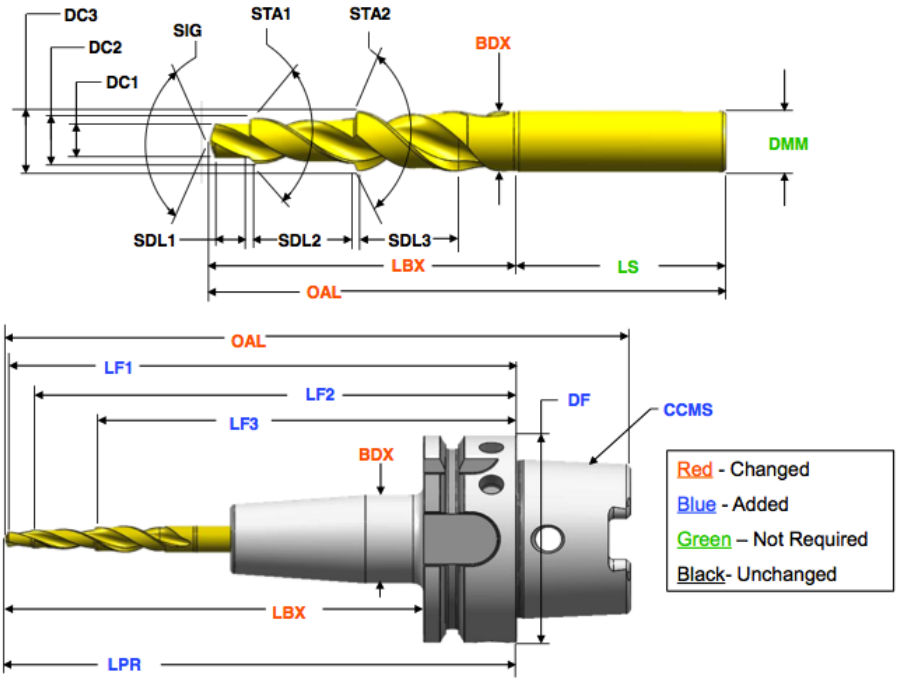

Figure 11: Cutting Tool

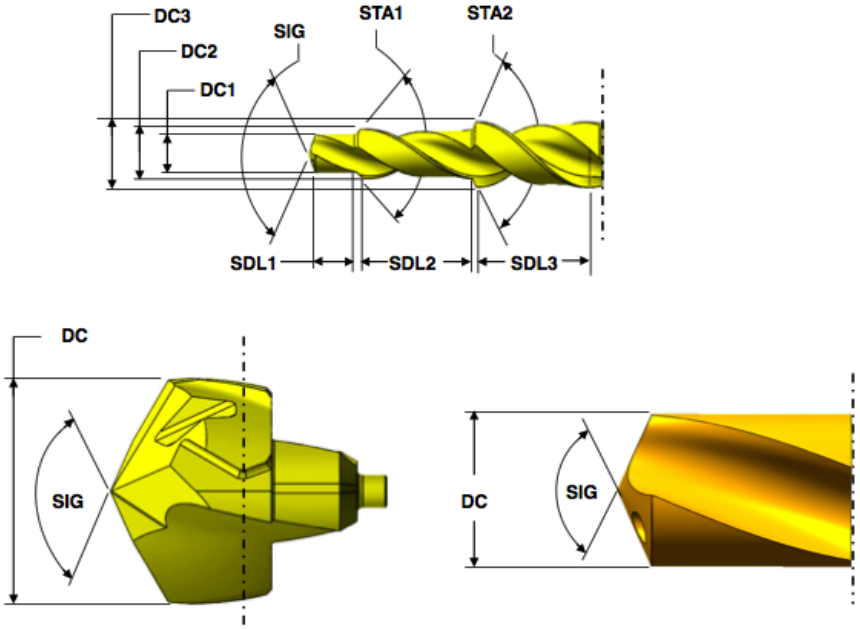

Figure 12: Cutting Item

664 4.5.1 FunctionalLength

665 distance from the gauge plane or from the end of the shank of the cutting tool, if a gauge
666 plane does not exist, to the cutting reference point determined by the main function of the
667 tool.

668 This measurement will be with reference to the cutting tool and **MUST NOT** exist without
669 a cutting tool.

670 The `code` of `FunctionalLength` **MUST** be `LFx`.

671 The `units` of `FunctionalLength` **MUST** be `MILLIMETER`.

672 4.5.2 CuttingReferencePoint

673 theoretical sharp point of the cutting tool from which the major functional dimensions are
674 taken.

675 The `code` of `CuttingReferencePoint` **MUST** be `CRP`.

676 The `units` of `CuttingReferencePoint` **MUST** be `MILLIMETER`.

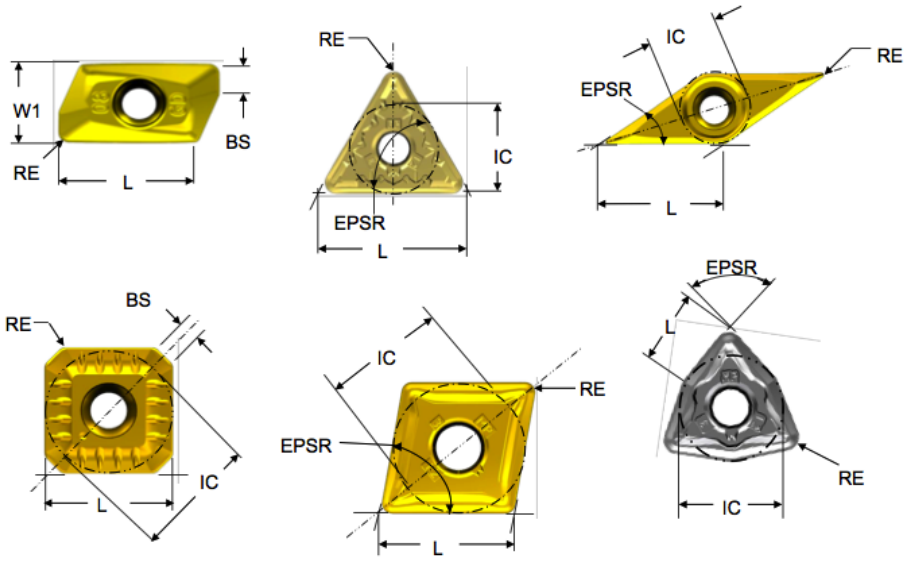

Figure 13: Cutting Item Measurement

677 4.5.3 CuttingEdgeLength

678 theoretical length of the cutting edge of a cutting item over sharp corners.

679 The `code` of `CuttingEdgeLength` **MUST** be `L`.

680 The `units` of `CuttingEdgeLength` **MUST** be `MILLIMETER`.

681 4.5.4 DriveAngle

682 angle between the driving mechanism locator on a tool item and the main cutting edge.

683 The `code` of `DriveAngle` **MUST** be `DRVA`.

684 The `units` of `DriveAngle` **MUST** be `DEGREE`.

685 4.5.5 FlangeDiameter

686 dimension between two parallel tangents on the outside edge of a flange.

687 The `code` of `FlangeDiameter` **MUST** be `DF`.

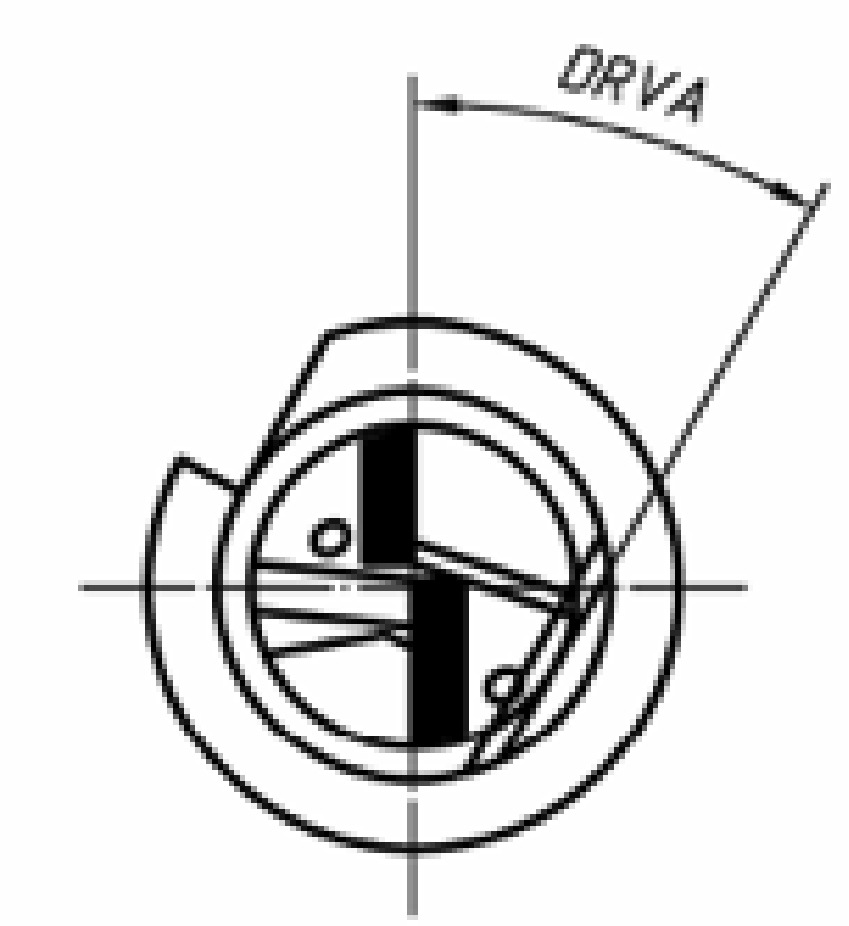

Figure 14: Cutting Item Drive Angle

688 The `units` of `FlangeDiameter` **MUST** be `MILLIMETER`.

689 4.5.6 FunctionalWidth

690 distance between the cutting reference point and the rear backing surface of a turning tool
691 or the axis of a boring bar.

692 The `code` of `FunctionalWidth` **MUST** be `WF`.

693 The `units` of `FunctionalWidth` **MUST** be `MILLIMETER`.

4.5.7 IncribedCircleDiameter

diameter of a circle to which all edges of a equilateral and round regular insert are tangential.

The `code` of `IncribedCircleDiameter` **MUST** be `IC`.

The `units` of `IncribedCircleDiameter` **MUST** be `MILLIMETER`.

4.5.8 PointAngle

angle between the major cutting edge and the same cutting edge rotated by 180 degrees about the tool axis.

The `code` of `PointAngle` **MUST** be `SIG`.

The `units` of `PointAngle` **MUST** be `DEGREE`.

4.5.9 ToolCuttingEdgeAngle

angle between the tool cutting edge plane and the tool feed plane measured in a plane parallel the xy-plane.

The `code` of `ToolCuttingEdgeAngle` **MUST** be `KAPR`.

The `units` of `ToolCuttingEdgeAngle` **MUST** be `DEGREE`.

4.5.10 ToolLeadAngle

angle between the tool cutting edge plane and a plane perpendicular to the tool feed plane measured in a plane parallel the xy-plane.

The `code` of `ToolLeadAngle` **MUST** be `PSIR`.

The `units` of `ToolLeadAngle` **MUST** be `DEGREE`.

4.5.11 ToolOrientation

angle of the tool with respect to the workpiece for a given process.

The value is application specific.

The `code` is `N/A` for `ToolOrientation`.

The `units` of `ToolOrientation` **MUST** be `DEGREE`.

4.5.12 StepDiameterLength

length of a portion of a stepped tool that is related to a corresponding cutting diameter measured from the cutting reference point of that cutting diameter to the point on the next cutting edge at which the diameter starts to change.

The `code` of `StepDiameterLength` **MUST** be `SDLx`.

The `units` of `StepDiameterLength` **MUST** be `MILLIMETER`.

4.5.13 StepIncludedAngle

angle between a major edge on a step of a stepped tool and the same cutting edge rotated 180 degrees about its tool axis.

The `code` of `StepIncludedAngle` **MUST** be `STAx`.

The `units` of `StepIncludedAngle` **MUST** be `DEGREE`.

4.5.14 WiperEdgeLength

measure of the length of a wiper edge of a cutting item.

The `code` of `WiperEdgeLength` **MUST** be `BS`.

The `units` of `WiperEdgeLength` **MUST** be `MILLIMETER`.

4.5.15 CuttingDiameter

diameter of a circle on which the defined point Pk located on this cutting tool.

The normal of the machined peripheral surface points towards the axis of the cutting tool.

The `code` of `CuttingDiameter` **MUST** be `DCx`.

The `units` of `CuttingDiameter` **MUST** be `MILLIMETER`.

4.5.16 CuttingHeight

distance from the basal plane of the tool item to the cutting point.

The `code` of `CuttingHeight` **MUST** be `HF`.

The `units` of `CuttingHeight` **MUST** be `MILLIMETER`.

4.5.17 CornerRadius

nominal radius of a rounded corner measured in the X Y-plane.

The `code` of `CornerRadius` **MUST** be `RE`.

The `units` of `CornerRadius` **MUST** be `MILLIMETER`.

4.5.18 Weight

total weight of the cutting tool in grams.

The force exerted by the mass of the cutting tool.

The `code` of `Weight` **MUST** be `WT`.

The `units` of `Weight` **MUST** be `GRAM`.

4.5.19 ChamferFlatLength

flat length of a chamfer.

The `code` of `ChamferFlatLength` **MUST** be `BCH`.

The `units` of `ChamferFlatLength` **MUST** be `MILLIMETER`.

4.5.20 ChamferWidth

width of the chamfer.

The `code` of `ChamferWidth` **MUST** be `CHW`.

The `units` of `ChamferWidth` **MUST** be `MILLIMETER`.

4.5.21 InsertWidth

W1 is used for the insert width when an inscribed circle diameter is not practical.

The `code` of `InsertWidth` **MUST** be `W1`.

The `units` of `InsertWidth` **MUST** be `MILLIMETER`.

5 Files Asset Information Model

Manufacturing processes require various documents, programs, setup sheets, and digital media available at the device for a given process. The File and FileArchetype Assets provide a mechanism to communicate specific "Files" that are relevant to a process where the media is located on a server and represented by a Universal Resource Locator (URL).

The FileArchetype contains metadata common to all File Assets for a certain purpose. The File Asset references the file specific to a given device or set of devices. The File Asset does not hold the contents of the file, it contains a reference to the location (URL) used to access the information. The metadata associated with the File provides semantic information about the representation (mime-type) and the application associated with the File. The application of the file is an extensible controlled vocabulary with common manufacturing uses provided.

5.1 Files

This section provides semantic information for the File model.

Note: See *Section B.7 - File Schema Diagrams* for XML schema.

5.1.1 AbstractFile

abstract Asset that contains the common properties of the File and FileArchetype types.

5.1.1.1 Value Properties of AbstractFile

Table 21 lists the Value Properties of AbstractFile.

Value Property name	Value Property type	Multiplicity
name	string	1
mediaType	string	1
applicationCategory	ApplicationCategoryEnum	1
applicationType	ApplicationTypeEnum	1

Table 21: Value Properties of AbstractFile

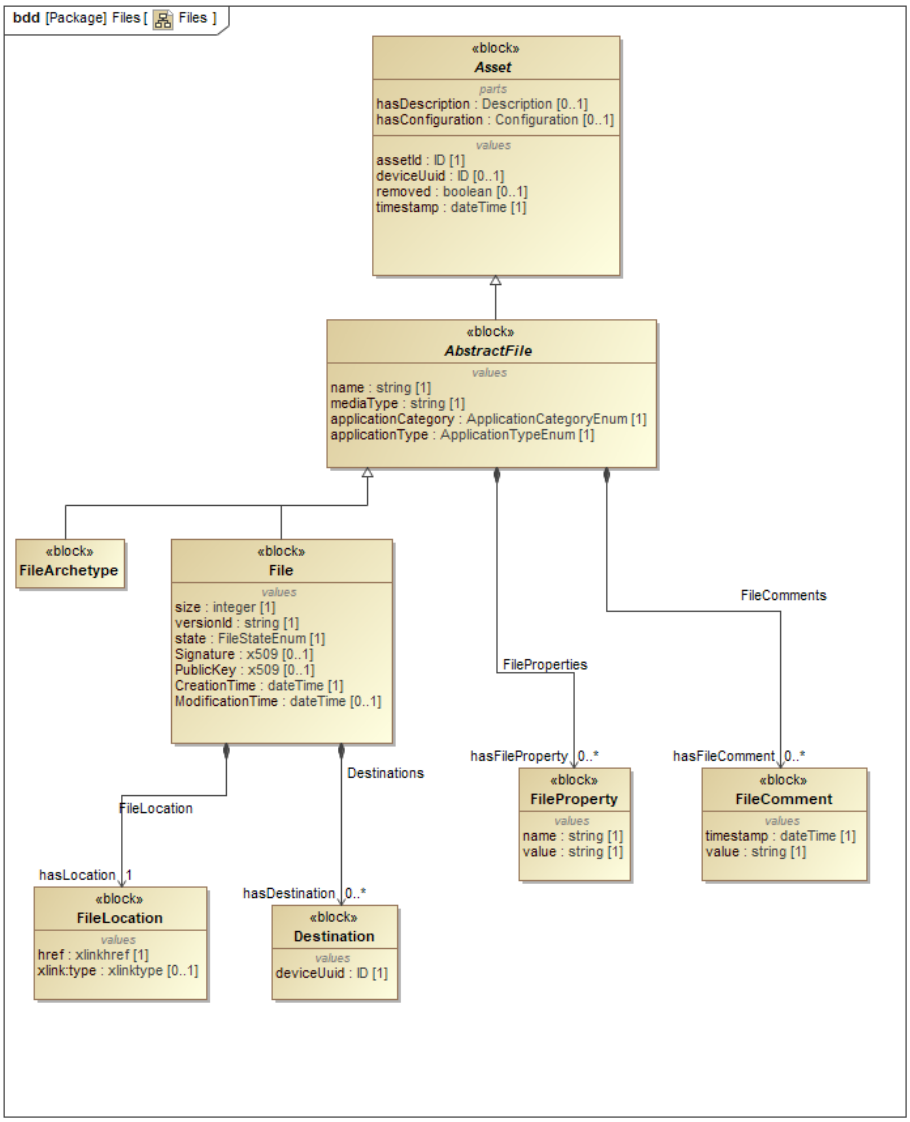

Figure 15: Files

Descriptions for Value Properties of `AbstractFile`:

- `name`
  name of the file.
- `mediaType`
  mime type of the file.
- `applicationCategory`
  category of application that will use this file.
  `ApplicationCategoryEnum` Enumeration:
  - `ASSEMBLY`
    files regarding the fully assembled product.
  - `DEVICE`
    device related files.
  - `HANDLING`
    files relating to the handling of material.
  - `INSPECTION`
    files related to the quality inspection.
  - `MAINTENANCE`
    files relating to equipment maintenance.
  - `PART`
    files relating to a part.
  - `PROCESS`
    files related to the manufacturing process.
  - `SETUP`
    files related to the setup of a process.
- `applicationType`
  type of application that will use this file.
  `ApplicationTypeEnum` Enumeration:
  - `DATA`
    generic data.
  - `DESIGN`
    computer aided design files or drawings.

816 – DOCUMENTATION
817 documentation regarding a category of file.
818 – INSTRUCTIONS
819 user instructions regarding the execution of a task.
820 – LOG
821 data related to the history of a machine or process.
822 – PRODUCTION_PROGRAM
823 machine instructions to perform a process.

824 5.1.1.2 Part Properties of AbstractFile

825 *Table 22* lists the Part Properties of AbstractFile.

Part Property name	Multiplicity
FileProperty (organized by FileProperties)	0..*
FileComment (organized by FileComments)	0..*

Table 22: Part Properties of AbstractFile

826 Descriptions for Part Properties of AbstractFile:

827 • FileProperty
828 key-value pair providing additional metadata about a File.
829 FileProperties groups one or more FileProperty entities for a File. See
830 *Section 5.1.4 - FileProperty*.

831 • FileComment
832 remark or interpretation for human interpretation associated with a File or FileArchetype.
833 FileComments groups one or more FileComment entities for a File. See
834 *Section 5.1.5 - FileComment*.

835 5.1.2 File

836 AbstractFile type that provides information about the File instance and its URL.

837 5.1.2.1 Value Properties of File

838 *Table 23* lists the Value Properties of File.

Value Property name	Value Property type	Multiplicity
size	integer	1
versionId	string	1
state	FileStateEnum	1
Signature	x509	0..1
PublicKey	x509	0..1
CreationTime	dateTime	1
ModificationTime	dateTime	0..1

Table 23: Value Properties of File

Descriptions for Value Properties of File:

- size
  size of the file in bytes.
- versionId
  version identifier of the file.
- state
  state of the file.
  FileStateEnum Enumeration:
  - EXPERIMENTAL
    used for processes other than production or otherwise defined.
  - PRODUCTION
    used for production processes.
  - REVISION
    content is modified from PRODUCTION or EXPERIMENTAL.
- Signature
  secure hash of the file.
- PublicKey
  public key used to verify the signature.
- CreationTime
  time the file was created.
- ModificationTime
  time the file was modified.

5.1.2.2 Part Properties of File

Table 24 lists the Part Properties of `File`.

Part Property name	Multiplicity
`FileLocation`	1
`Destination` (organized by `Destinations`)	0..*

Table 24: Part Properties of File

Descriptions for Part Properties of `File`:

- `FileLocation`

  URL reference to the file location.

  See *Section 5.1.6 - FileLocation*.

- `Destination`

  reference to the target `Device` for this `File`.

  `Destinations` groups one or more `Destination` entities. See *Section 5.1.7 - Destination*.

5.1.3 FileArchetype

`AbstractFile` type that provides information common to all versions of a file.

5.1.4 FileProperty

key-value pair providing additional metadata about a `File`.

The value of `FileProperty` **MUST** be `string`.

5.1.4.1 Value Properties of FileProperty

Table 25 lists the Value Properties of `FileProperty`.

Value Property name	Value Property type	Multiplicity
name	string	1

Table 25: Value Properties of FileProperty

Descriptions for Value Properties of FileProperty:

- name
  name of the FileProperty.

5.1.5 FileComment

remark or interpretation for human interpretation associated with a File or FileArchetype.

The value of FileComment **MUST** be string.

5.1.5.1 Value Properties of FileComment

Table 26 lists the Value Properties of FileComment.

Value Property name	Value Property type	Multiplicity
timestamp	dateTime	1

Table 26: Value Properties of FileComment

Descriptions for Value Properties of FileComment:

- timestamp
  time the comment was made.

5.1.6 FileLocation

URL reference to the file location.

5.1.6.1 Value Properties of FileLocation

Table 27 lists the Value Properties of FileLocation.

Value Property name	Value Property type	Multiplicity
href	xlinkhref	1
xlink:type	xlinktype	0..1

Table 27: Value Properties of FileLocation

Descriptions for Value Properties of FileLocation:

- href
  URL reference to the file.
  href is of type xlink:href from the W3C XLink specification.
- xlink:type
  type of href for the xlink href type.
  MUST be locator referring to a URL .

5.1.7 Destination

reference to the target Device for this File.

5.1.7.1 Value Properties of Destination

Table 28 lists the Value Properties of Destination.

Value Property name	Value Property type	Multiplicity
deviceUuid	ID	1

Table 28: Value Properties of Destination

Descriptions for Value Properties of Destination:

- deviceUuid
  uuid of the target device or application.

6 Raw Material Asset Information Model

Raw material represents the source of material for immediate use and sources of material that may or may not be used during the manufacturing process.

The `RawMaterial Asset` holds the references to the content stored in the actual `RawMaterial` container or derived about the `RawMaterial` by the system during operation.

6.1 Raw Material

This section provides semantic information for the `RawMaterial` model.

Note: See *Section B.8 - RawMaterial Schema Diagrams* for XML schema.

6.1.1 RawMaterial

`Asset` that represents raw material.

6.1.1.1 Value Properties of RawMaterial

Table 29 lists the Value Properties of `RawMaterial`.

Value Property name	Value Property type	Multiplicity
name	string	0..1
containerType	string	0..1
processKind	string	0..1
serialNumber	string	0..1
HasMaterial	boolean	0..1
Form	FormEnum	1
ManufacturingDate	dateTime	0..1
FirstUseDate	dateTime	0..1
LastUseDate	dateTime	0..1
InitialVolume	CUBIC_MILLIMETER	0..1
InitialDimension	MILLIMETER	0..3
InitialQuantity	integer	0..1
CurrentVolume	CUBIC_MILLIMETER	0..1
CurrentDimension	MILLIMETER	0..3
CurrentQuantity	integer	0..1

Table 29: Value Properties of RawMaterial

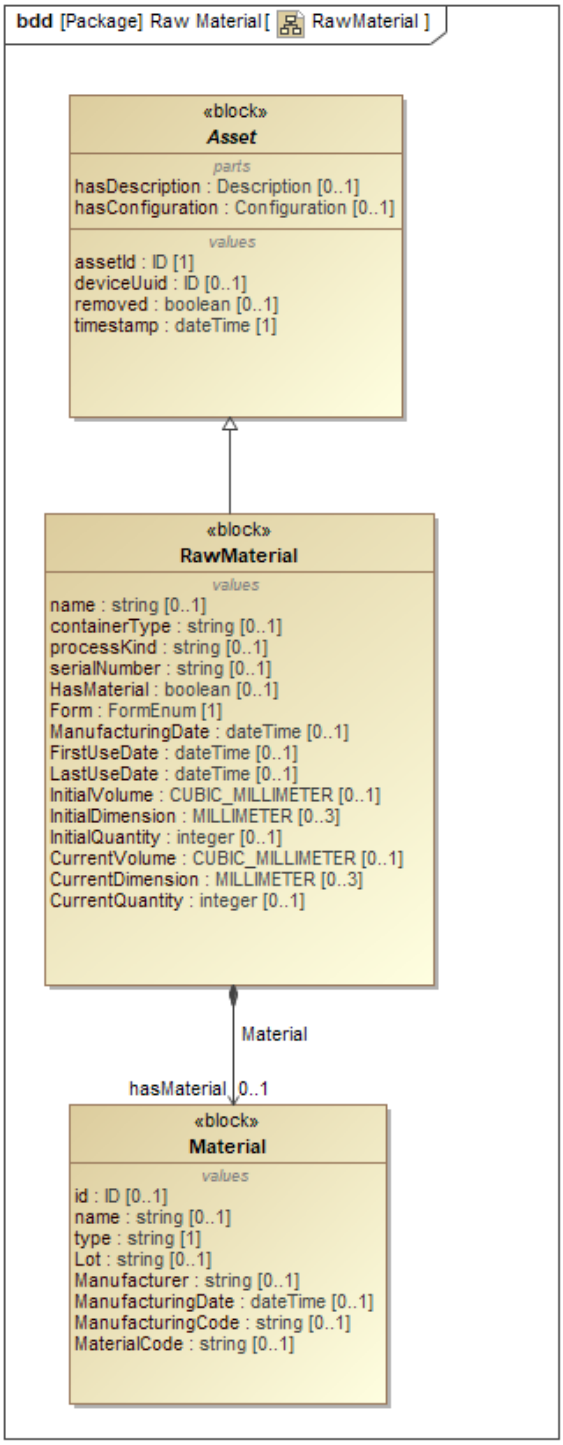

Figure 16: RawMaterial

Descriptions for Value Properties of RawMaterial:

- name

  name of the raw material.

  Examples: Container1 and AcrylicContainer.

- containerType

  type of container holding the raw material.

  Examples: Pallet, Canister, Cartridge, Tank, Bin, Roll, and Spool.

- processKind

  ISO process type supported by this raw material.

  Examples include: VAT_POLYMERIZATION, BINDER_JETTING, MATERIAL_EXTRUSION, MATERIAL_JETTING, SHEET_LAMINATION, POWDER_BED_FUSION and DIRECTED_ENERGY_DEPOSITION.

- serialNumber

  serial number of the raw material.

- HasMaterial

  Material has existing usable volume.

- Form

  form of the raw material.

  FormEnum Enumeration:

  - BAR
  - BLOCK
  - CASTING
  - FILAMENT
  - GAS
  - GEL
  - LIQUID
  - POWDER
  - SHEET

- ManufacturingDate

  date the raw material was created.

- `FirstUseDate`
  date raw material was first used.
- `LastUseDate`
  date raw material was last used.
- `InitialVolume`
  amount of material initially placed in raw material when manufactured.
- `InitialDimension`
  dimension of material initially placed in raw material when manufactured.
- `InitialQuantity`
  quantity of material initially placed in raw material when manufactured.
- `CurrentVolume`
  amount of material currently in raw material.
- `CurrentDimension`
  dimension of material currently in raw material.
- `CurrentQuantity`
  quantity of material currently in raw material.

6.1.1.2 Part Properties of RawMaterial

Table 30 lists the Part Properties of `RawMaterial`.

Part Property name	Multiplicity
`Material`	0..1

Table 30: Part Properties of RawMaterial

Descriptions for Part Properties of `RawMaterial`:

- `Material`
  material used as the `RawMaterial`.
  See *Section 6.1.2 - Material*.

6.1.2 Material

material used as the RawMaterial.

6.1.2.1 Value Properties of Material

Table 31 lists the Value Properties of Material.

Value Property name	Value Property type	Multiplicity
id	ID	0..1
name	string	0..1
type	string	1
Lot	string	0..1
Manufacturer	string	0..1
ManufacturingDate	dateTime	0..1
ManufacturingCode	string	0..1
MaterialCode	string	0..1

Table 31: Value Properties of Material

Descriptions for Value Properties of Material:

- id
  unique identifier for the material.
- name
  name of the material.
  Examples: ULTM9085, ABS, 4140.
- type
  type of material.
  Examples: Metal, Polymer, Wood, 4140, Recycled, Prestine and Used.
- Lot
  manufacturer's lot code of the material.
- Manufacturer
  name of the material manufacturer.

- `ManufacturingDate`

  manufacturing date of the material from the material manufacturer.

- `ManufacturingCode`

  lot code of the raw feed stock for the material, from the feed stock manufacturer.

- `MaterialCode`

  American Society for Testing and Materials (ASTM) standard code that the material complies with.

7 QIF Asset Information Model

The Quality Information Framework (QIF) is an American National Standards Institute (ANSI) accredited standard developed by the Digital Metrology Standards Consortium (DMSC) standards development organization. The DMSC is an A-liaison to the International Standards Organization (ISO) Technical Committee (TC) 184. QIF addresses the needs of the metrology community to have a semantic information model for the exchange of metrology data throughout the verification lifecycle from product design to execution, analysis, and reporting.

The MTConnect QIF *Asset Information Model* provides a wrapper around a QIF document (i.e., a dataset conforming to the QIF Information model) in its native XML representation. The MTConnect standard does not alter or extend the QIF standard and regards the QIF standard as a passthrough.

Information about the QIF standards is at the following location: https://qifstandards.org

7.1 QIF

This section provides semantic information for the `QIFDocumentWrapper` model.

> Note: See *Section B.9 - QIFDocumentWrapper Schema Diagrams* for XML schema.

7.1.1 QIFDocument

QIF Document as given by the QIF standard.

7.1.2 QIFDocumentWrapper

`Asset` that carries the QIF Document.

7.1.2.1 Value Properties of QIFDocumentWrapper

Table 32 lists the Value Properties of `QIFDocumentWrapper`.

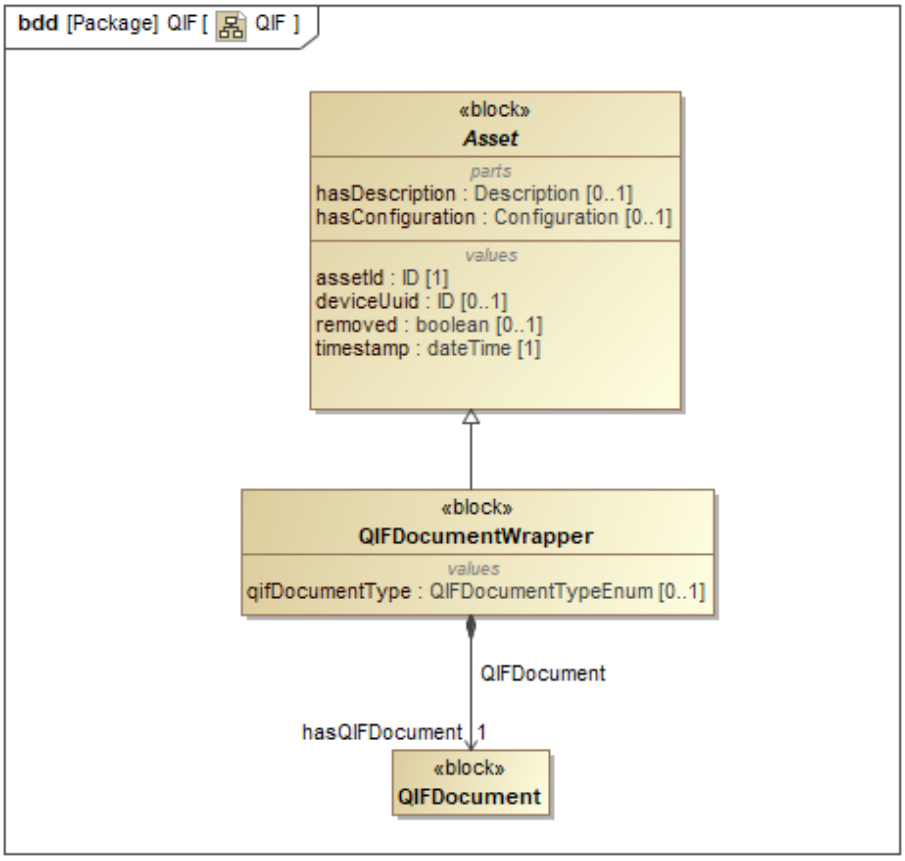

Figure 17: QIFDocumentWrapper

Value Property name	Value Property type	Multiplicity
qifDocumentType	QIFDocumentTypeEnum	0..1

Table 32: Value Properties of QIFDocumentWrapper

Descriptions for Value Properties of QIFDocumentWrapper:

- qifDocumentType

  contained QIF Document type as defined in the QIF Standard.

  QIFDocumentTypeEnum Enumeration:

  - MEASUREMENT_RESOURCE
  - PLAN
  - PRODUCT
  - RESULTS

- RULES
- STATISTICS

7.1.2.2 Part Properties of QIFDocumentWrapper

Table 33 lists the Part Properties of QIFDocumentWrapper.

Part Property name	Multiplicity
QIFDocument	1

Table 33: Part Properties of QIFDocumentWrapper

Descriptions for Part Properties of QIFDocumentWrapper:

- QIFDocument

  QIF Document as given by the QIF standard.

8 Profile

MTConnect Profile is a *profile* that extends the Systems Modeling Language (SysML) metamodel for the MTConnect domain using additional data types and *stereotypes*.

8.1 DataTypes

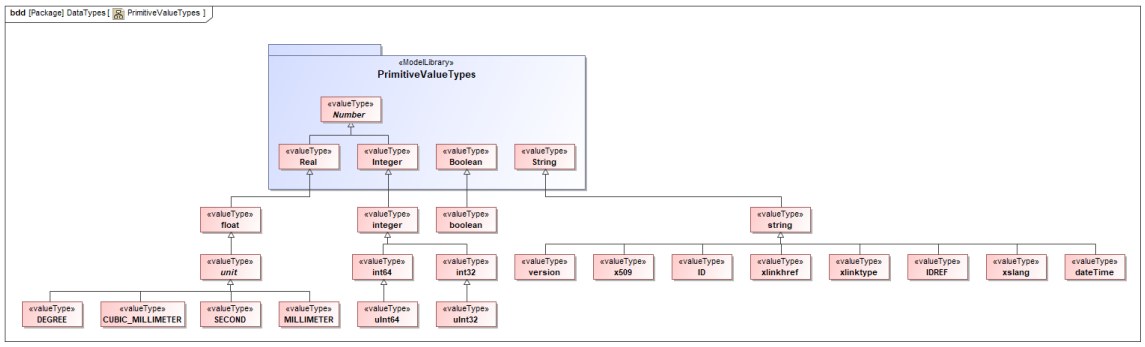

Figure 18: DataTypes

8.1.1 boolean

primitive type.

8.1.2 ID

string that represents an identifier (ID).

8.1.3 string

primitive type.

8.1.4 float

primitive type.

8.1.5 dateTime

string that represents timestamp in ISO 8601 format.

8.1.6 integer

primitive type.

8.1.7 xlinktype

string that represents the type of an XLink element. See `https://www.w3.org/TR/xlink11/`.

8.1.8 xslang

string that represents a language tag. See `http://www.ietf.org/rfc/rfc4646.txt`.

8.1.9 SECOND

float that represents time in seconds.

8.1.10 IDREF

string that represents a reference to an `ID`.

8.1.11 xlinkhref

string that represents the locator attribute of an XLink element. See `https://www.w3.org/TR/xlink11/`.

8.1.12 x509

string that represents an `x509` data block. *Ref ISO/IEC 9594-8:2020*.

8.1.13 int32

32-bit integer.

8.1.14 int64

64-bit integer.

8.1.15 version

series of four numeric values, separated by a decimal point, representing a *major*, *minor*, and *revision* number of the MTConnect Standard and the revision number of a specific *schema*.

8.1.16 uInt32

32-bit unsigned integer.

8.1.17 uInt64

64-bit unsigned integer.

8.2 Stereotypes

8.2.1 organizer

element that *organizes* other elements of a type.

8.2.2 deprecated

element that has been deprecated.

8.2.3 extensible

enumeration that can be extended.

8.2.4 informative

element that is descriptive and non-normative.

8.2.5 valueType

extends SysML `<<ValueType>>` to include `Class` as a value type.

8.2.6 normative

element that has been added to the standard.

8.2.7 observes

association in which a *Component* makes *Observations* about an observable *DataItem*.

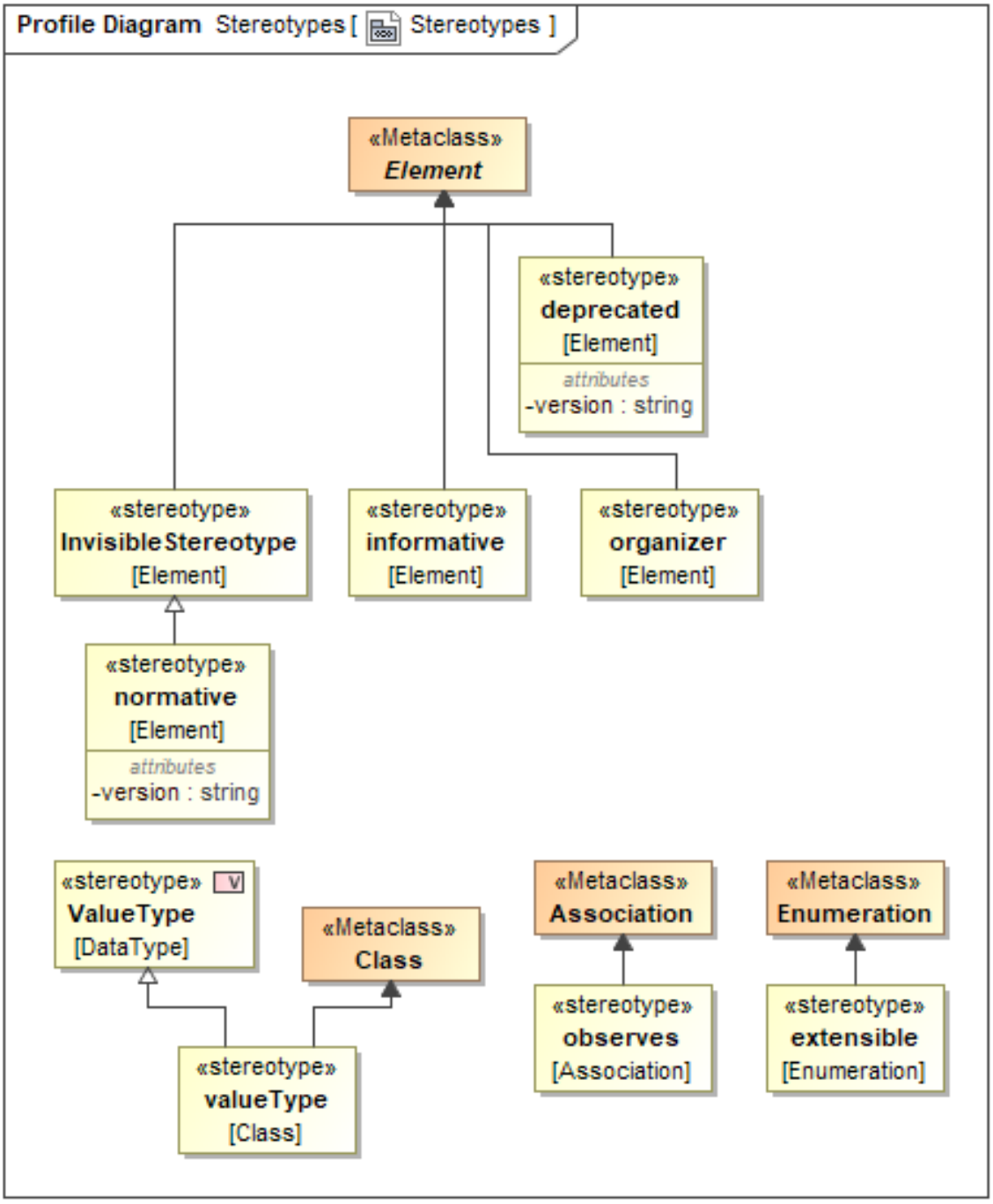

Figure 19: Stereotypes

Appendices

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New York, 1984.

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IEEE STD 1451.4-1994, Standard for a Smart Transducer Interface for Sensors and Actuators – Mixed-Mode Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats, IEEE Instrumentation and Measurement Society, TC-9, The Institute of Electrical and Electronics Engineers, Inc., New York, N.Y. 10016, SH95225, December 15, 2004.

B XML Schema Diagrams

B.1 Assets Schema Diagrams

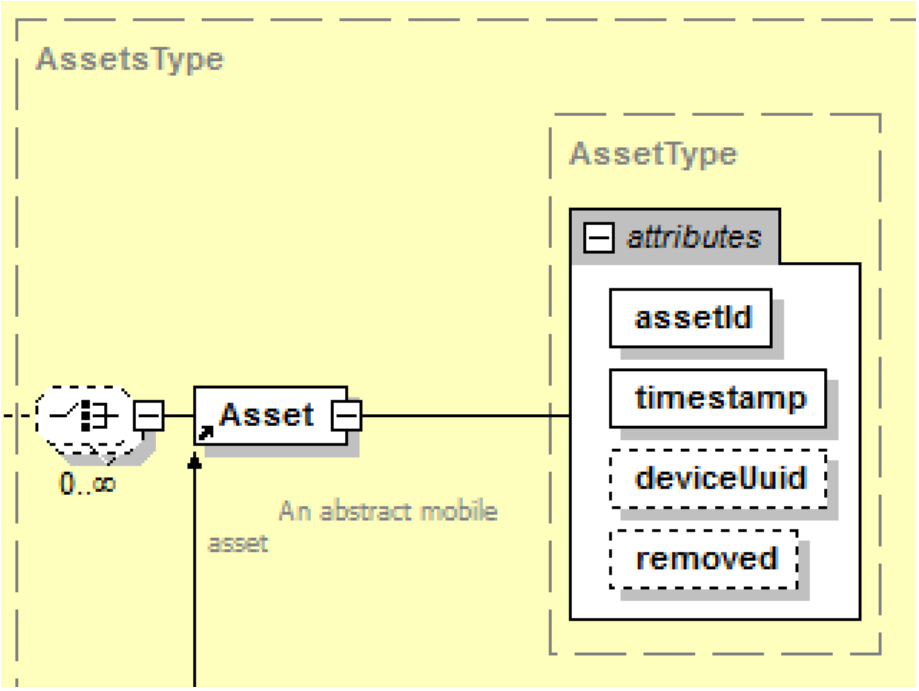


Figure 20: Asset Schema

B.2 CuttingTool Schema Diagrams

B.3 CuttingToolLifeCycle Schema Diagrams

B.4 CuttingItem Schema Diagrams

B.5 ISO 13399 Diagrams

B.5.1 Measurement Diagrams

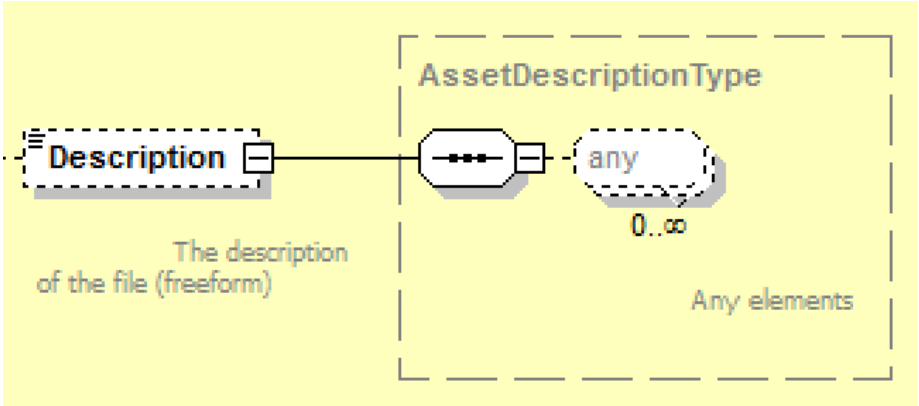


Figure 21: Description Schema

B.6 Cutting Tool Examples

B.6.1 Shell Mill

Example 1: Example for Indexable Insert Measurements

```
1  <?xml version="1.0" encoding="UTF-8"?>
2  <MTConnectAssets
3  xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
4  xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
5  xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
6  xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
7  http://mtconnect.org/schemas/MTConnectAssets\textunderscore 1.2.xsd"
       >
8    <Header creationTime="2011-05-11T13:55:22"
9    assetBufferSize="1024" sender="localhost"
10   assetCount="2" version="1.2" instanceId="1234"/>
11   <Assets>
12   <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240"
13   timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
14   manufacturers="KMT,Parlec">
15     <CuttingToolLifeCycle>
16     <CutterStatus><Status>NEW</Status></CutterStatus>
17     <ProcessSpindleSpeed maximum="13300"
18     nominal="605">10000</ProcessSpindleSpeed>
19     <ProcessFeedRate
20     nominal="9.22">9.22</ProcessSpindleSpeed>
21     <ConnectionCodeMachineSide>CV50
22     </ConnectionCodeMachineSide>
23     <Measurements>
24       <BodyDiameterMax code="BDX">73.25
25       </BodyDiameterMax>
26       <OverallToolLength nominal="222.25"
27         minimum="221.996" maximum="222.504"
```

```
        code="OAL">222.25</OverallToolLength>
      <UsableLengthMax code="LUX" nominal="82.55">82.55
      </UsableLengthMax>
      <CuttingDiameterMax code="DC" nominal="76.2"
        maximum="76.213" minimum="76.187">76.2
      </CuttingDiameterMax>
      <BodyLengthMax code="LF" nominal="120.65"
        maximum="120.904" minimum="120.404">120.65
      </BodyLengthMax>
      <DepthOfCutMax code="APMX"
      nominal="60.96">60.95</DepthOfCutMax>
      <FlangeDiameterMax code="DF"
        nominal="98.425">98.425</FlangeDiameterMax>
    </Measurements>
    <CuttingItems count="24">
      <CuttingItem indices="1-24" itemId="SDET43PDER8GB"
        manufacturers="KMT" grade="KC725M">
        <Measurements>
          <CuttingEdgeLength code="L" nominal="12.7"
            minimum="12.675" maximum="12.725">12.7
          </CuttingEdgeLength>
          <WiperEdgeLength code="BS" nominal=
          "2.56">2.56</WiperEdgeLength>
          <IncribedCircleDiameter code="IC"
            nominal="12.7">12.7
          </IncribedCircleDiameter>
          <CornerRadius code="RE" nominal="0.8">
            0.8</CornerRadius>
        </Measurements>
      </CuttingItem>
    </CuttingItems>
  </CuttingToolLifeCycle>
</CuttingTool>
</Assets>
</MTConnectAssets>
```

B.6.2 Step Drill

Example 2: Example for Step Mill Side View

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\textunderscore␣1.2.xsd"
   >
  <Header creationTime="2011-05-
␣␣11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"
     />
  <Assets>
    <CuttingTool serialNumber="1␣" toolId="B732A08500HP"
    timestamp="2011-05-11T13:55:22" assetId="B732A08500HP␣"
    manufacturers="KMT,Parlec">
      <Description>
        Step Drill - KMT, B732A08500HP Grade KC7315
        Adapter - Parlec, C50-M12SF300-6
      </Description>
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <ProcessSpindleSpeed nominal="5893">5893</
     ProcessSpindleSpeed>
        <ProcessFeedRate nominal="2.5">2.5</ProcessFeedRate>
        <ConnectionCodeMachineSide>CV50 Taper</
           ConnectionCodeMachineSide>
        <Measurements>
          <BodyDiameterMax code="BDX">31.8</BodyDiameterMax>
          <BodyLengthMax code="LBX" nominal="120.825" maximum="
             126.325"
          minimum="115.325">120.825</BodyLengthMax>
          <ProtrudingLength code="LPR" nominal="155.75" maximum="
             161.25"
          minimum="150.26">155.75</ProtrudingLength>
          <FlangeDiameterMax code="DF"
          nominal="98.425">98.425</FlangeDiameterMax>
          <OverallToolLength nominal="257.35" minimum="251.85"
          maximum="262.85" code="OAL">257.35</OverallToolLength>
        </Measurements>
        <CuttingItems count="2">
          <CuttingItem indices="1" manufacturers="KMT" grade="KC7315
             ">>
            <Measurements>
              <CuttingDiameter code="DC1" nominal="8.5" maximum="
     8.521"
              minimum="8.506">8.5135</CuttingDiameter>
              <StepIncludedAngle code="STA1" nominal="90" maximum="
                 91"
```

```
                minimum="89">90</StepIncludedAngle>
                <FunctionalLength code="LF1" nominal="154.286"
                minimum="148.786"
                maximum="159.786">154.286</FunctionalLength>
                <StepDiameterLength code="SDL1"
                nominal="9">9</StepDiameterLength>
                <PointAngle code="SIG" nominal="135" minimum="133"
                maximum="137">135</PointAngle>
              </Measurements>
            </CuttingItem>
            <CuttingItem indices="2" manufacturers="KMT" grade="KC7315
                ">>
              <Measurements>
                <CuttingDiameter code="DC2" nominal="12" maximum="
      12.011"
                minimum="12">12</CuttingDiameter>
                <FunctionalLength code="LF2" nominal="122.493"
                maximum="127.993"
                minimum="116.993">122.493</FunctionalLength>
                <StepDiameterLength code="SDL2"
                nominal="9">9</StepDiameterLength>
              </Measurements>
            </CuttingItem>
          </CuttingItems>
        </CuttingToolLifeCycle>
      </CuttingTool>
    </Assets>
</MTConnectAssets>
```

B.6.3 Shell Mill with Individual Loci

Example 3: Example for Shell Mill with Explicate Loci

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\textunderscore␣1.2.xsd"
    >
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"
     />
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240"
    timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
    manufacturers="KMT,Parlec">
      <Description>Keyway: 55 degrees</Description>
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <Measurements>
          <UsableLengthMax code="LUX"
          nominal="82.55">82.55</UsableLengthMax>
          <CuttingDiameterMax code="DC" nominal="76.2" maximum="
             76.213"
          minimum="76.187">76.2</CuttingDiameterMax>
          <DepthOfCutMax code="APMX" nominal="60.96">60.95</
             DepthOfCutMax>
        </Measurements>
        <CuttingItems count="24">
          <CuttingItem indices="1" itemId="SDET43PDER8GB"
          manufacturers="KMT">
            <Locus>FLUTE: 1, ROW: 1</Locus>
            <Measurements>
             <DriveAngle code="DRVA" nominal="55">55</DriveAngle>
           </Measurements>
          </CuttingItem>
          <CuttingItem indices="2-24" itemId="SDET43PDER8GB"
          manufacturers="KMT">
            <Locus>FLUTE: 2-4, ROW: 1; FLUTE: 1-4, ROW 2-6</Locus>
          </CuttingItem>
        </CuttingItems>
      </CuttingToolLifeCycle>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
```

B.6.4 Drill with Individual Loci

Example 4: Example for Step Drill with Explicate Loci

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\textunderscore␣1.2.xsd"
   >
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"
     />
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSEM0781LD"
    timestamp="2011-05-11T13:55:22" assetId="KSEM0781LD.1"
       manufacturers="KMT">
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <ConnectionCodeMachineSide>HSK63A</ConnectionCodeMachineSide
     >
        <Measurements>
          <BodyDiameterMax code="BDX">52.75</BodyDiameterMax>
          <OverallToolLength nominal="172.29"
          code="OAL">172.29</OverallToolLength>
          <UsableLengthMax code="LUX" nominal="49">49</
             UsableLengthMax>
          <FlangeDiameterMax code="DF"
          nominal="62.94">62.94</FlangeDiameterMax>
        </Measurements>
        <CuttingItems count="3">
          <CuttingItem indices="1" itemId="KSEM0781LD" manufacturers
             ="KMT"
          grade="KC7015">
            <Locus>FLUTE: 1, ROW: 1</Locus>
            <Measurements>
         <FunctionalLength code="LF1" nominal="154.42">154.42</
    FunctionalLength>
          <CuttingDiameter code="DC1" nominal="19.844">19.844</
             CuttingDiameter>
          <PointAngle code="SIG" nominal="140">140</PointAngle>
          <ToolCuttingEdgeAngle code="KAPR1" nominal="45">45</
             ToolCuttingEdgeAngle>
          <StepDiameterLength code="SLD1" nominal="39.8">39.8</
             StepDiameterLength>
            </Measurements>
          </CuttingItem>
          <CuttingItem indices="2-3" itemId="TPMT-21.52-FP"
          manufacturers="KMT" grade="KCM15">
            <Locus>FLUTE: 1-2, ROW: 2</Locus>
            <Measurements>
```

```
39          <FunctionalLength code="LF2" nominal="112.9">119.2</
      FunctionalLength>
40          <CuttingDiameter code="DC2" nominal="31">31</
               CuttingDiameter>
41             </Measurements>
42           </CuttingItem>
43         </CuttingItems>
44       </CuttingToolLifeCycle>
45     </CuttingTool>
46   </Assets>
47 </MTConnectAssets>
```

B.6.5 Shell Mill with Different Inserts on First Row

Example 5: Example for Shell Mill with Different Inserts on First Row

```
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
http://mtconnect.org/schemas/MTConnectAssets\textunderscore␣1.2.xsd"
   >
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
  sender="localhost" assetCount="2" version="1.2" instanceId="1234"
     />
  <Assets>
    <CuttingTool serialNumber="1" toolId="XXX" timestamp="2011-05-11
    T13:55:22"
    assetId="XXX.1" manufacturers="KMT">
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
        <Measurements>
          <DepthOfCutMax code="APMX" nominal="47.8">47.8</
    DepthOfCutMax>
          <CuttingDiameterMax code="DC"
          nominal="50.8">50.8</CuttingDiameterMax>
          <UsableLengthMax code="LUX"
          nominal="78.74">78.74</UsableLengthMax>
        </Measurements>
        <CuttingItems count="9">
          <CuttingItem indices="1-3" itemId="EDPT180564PDER-LD"
          manufacturers="KMT">
            <Locus>FLUTE: 1-3, ROW: 1</Locus>
            <Measurements>
              <CornerRadius code="RE" nominal="6.25">6.35</
    CornerRadius>
            </Measurements>
          </CuttingItem>
          <CuttingItem indices="4-9" itemId="EDPT180508PDER-LD"
          manufacturers="KMT">
            <Locus>FLANGE: 1-4, ROW: 2-3</Locus>
          </CuttingItem>
        </CuttingItems>
      </CuttingToolLifeCycle>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
```

B.7 File Schema Diagrams

B.8 RawMaterial Schema Diagrams

B.9 QIFDocumentWrapper Schema Diagrams

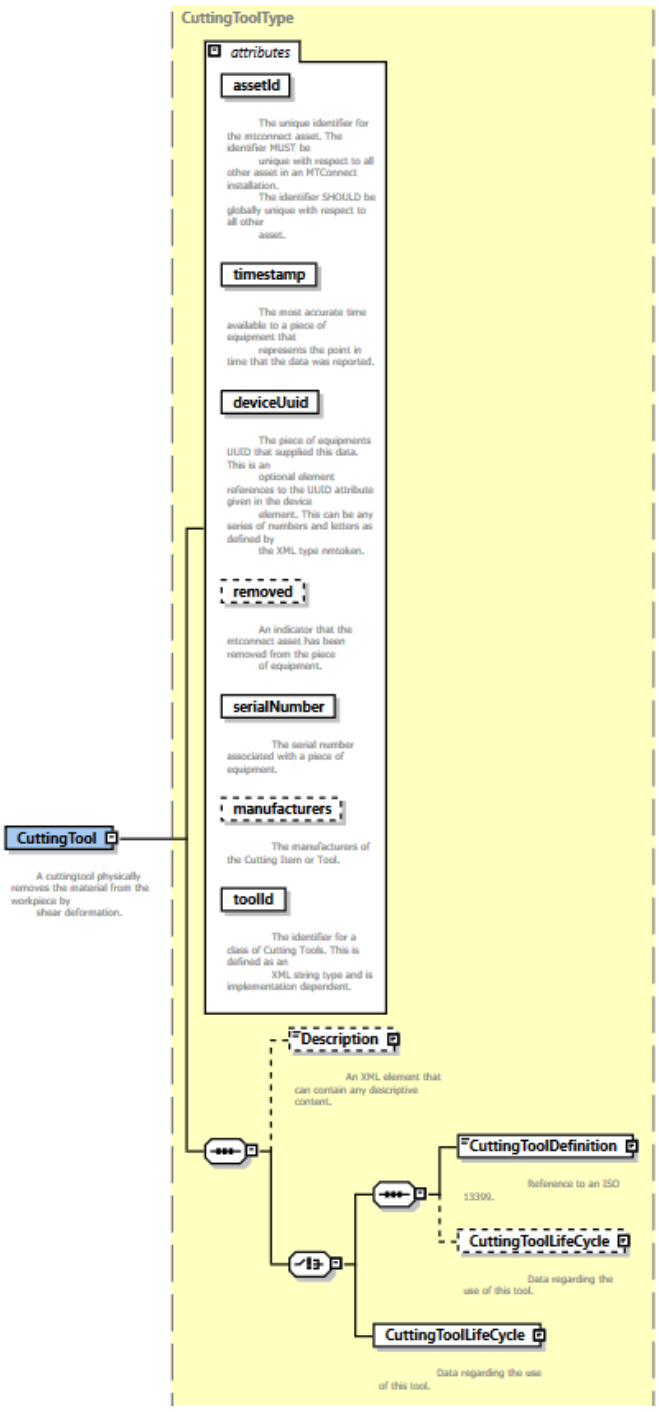


Figure 22: CuttingTool Schema

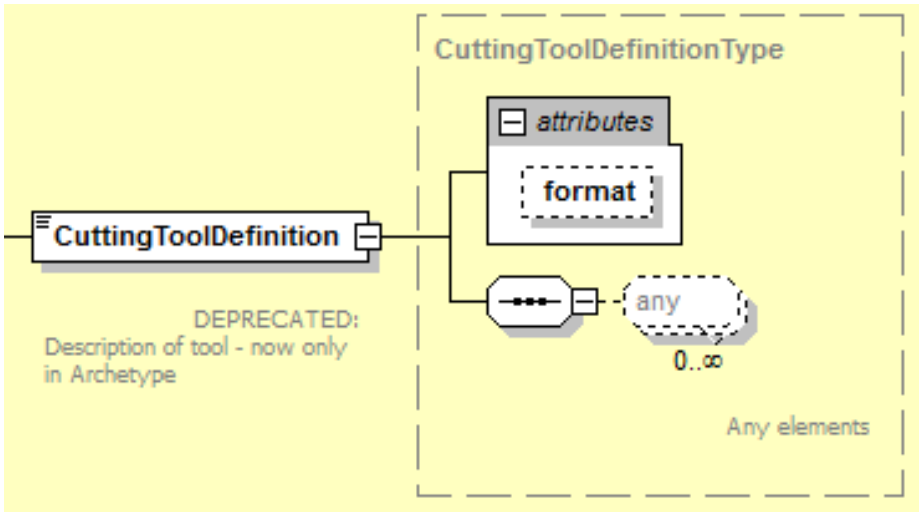


Figure 23: CuttingToolDefinition Schema

Figure 24: CuttingToolArchetypeReference Schema

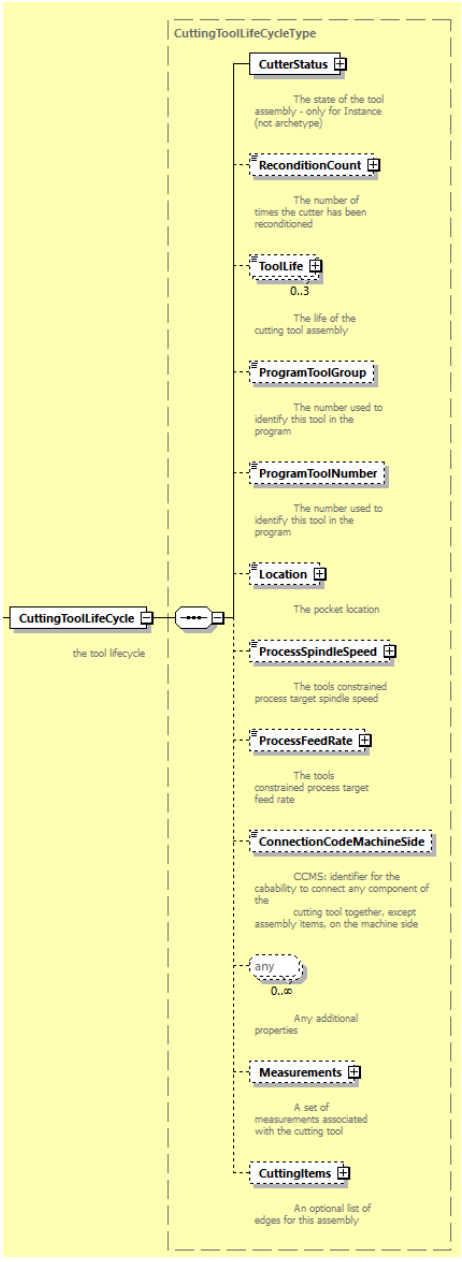


Figure 25: CuttingToolLifeCycle Schema

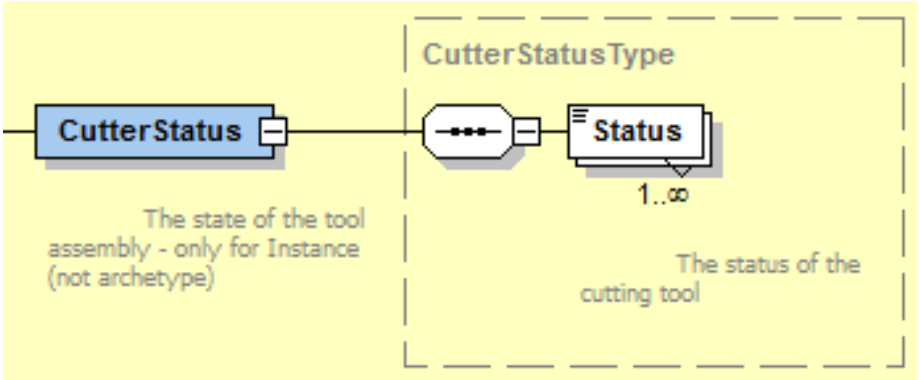


Figure 26: CutterStatus Schema

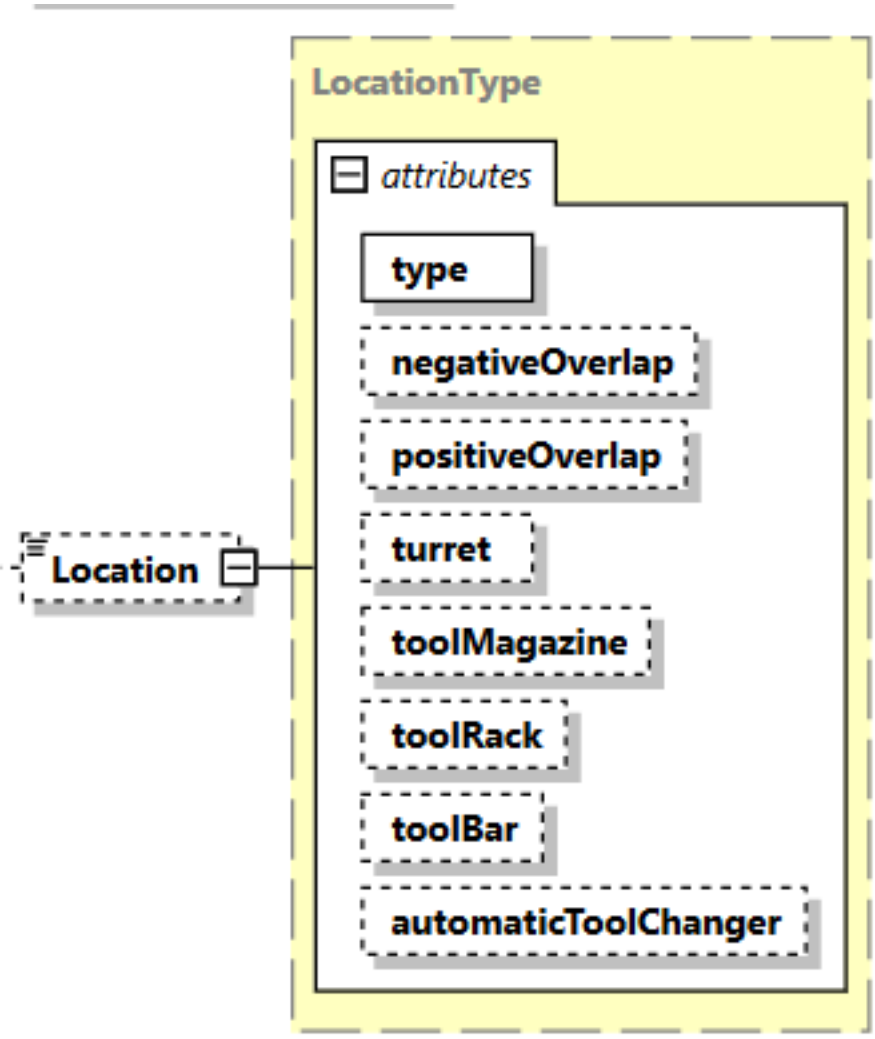


Figure 27: Location Schema

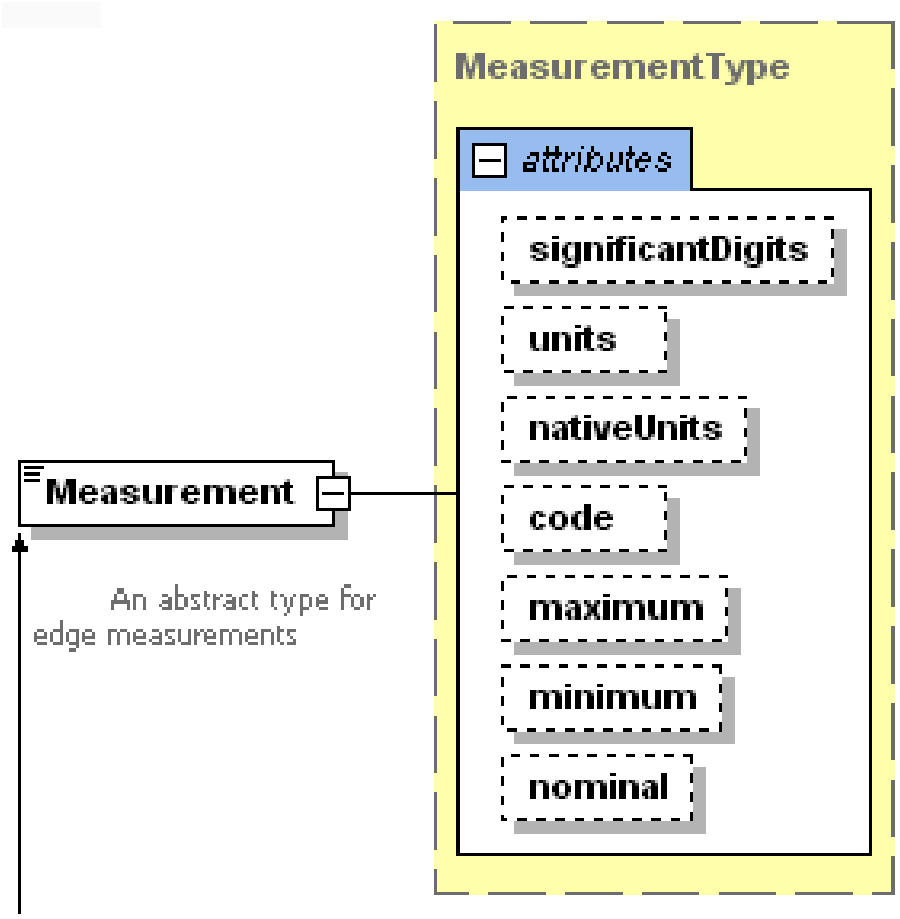


Figure 28: Measurement Schema

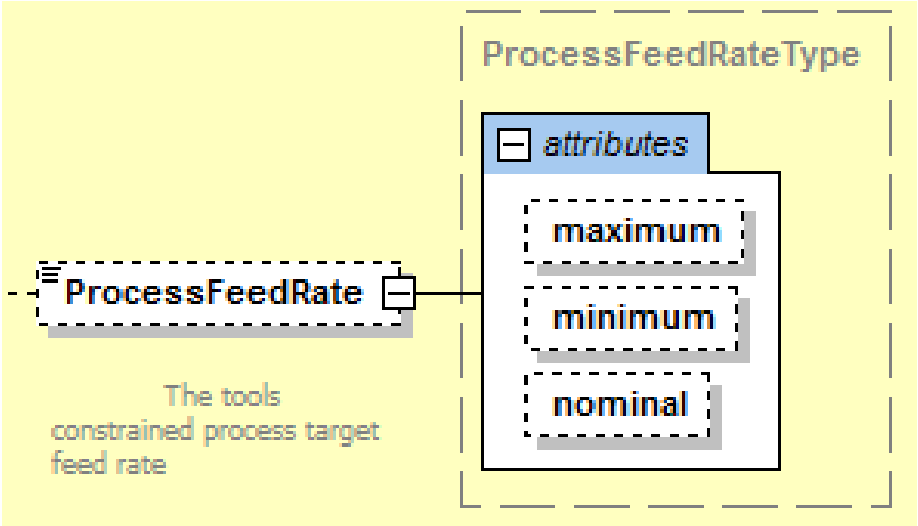


Figure 29: ProcessFeedRate Schema

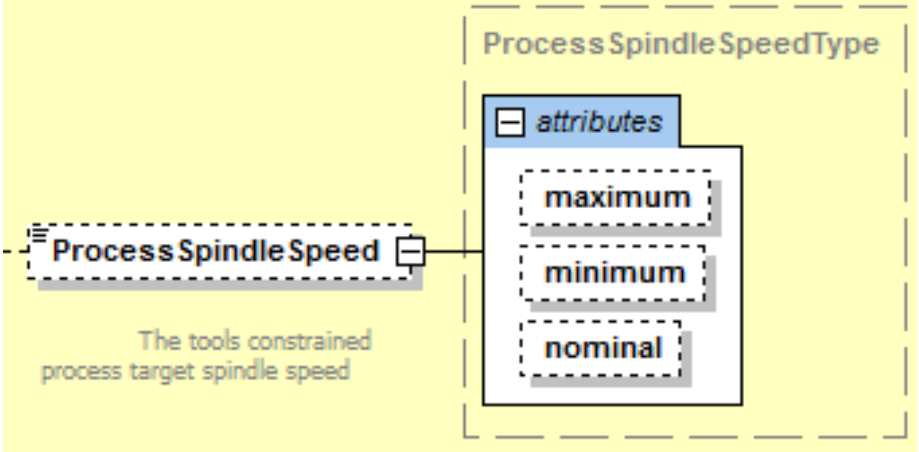


Figure 30: ProcessSpindleSpeed Schema

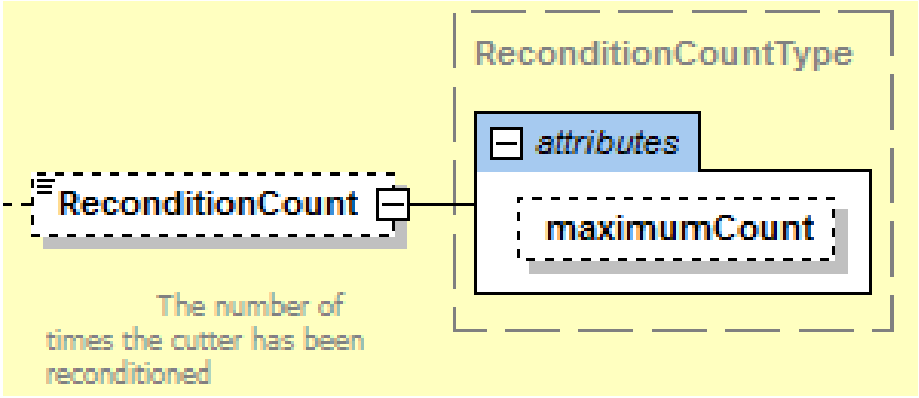


Figure 31: ReconditionCount Schema

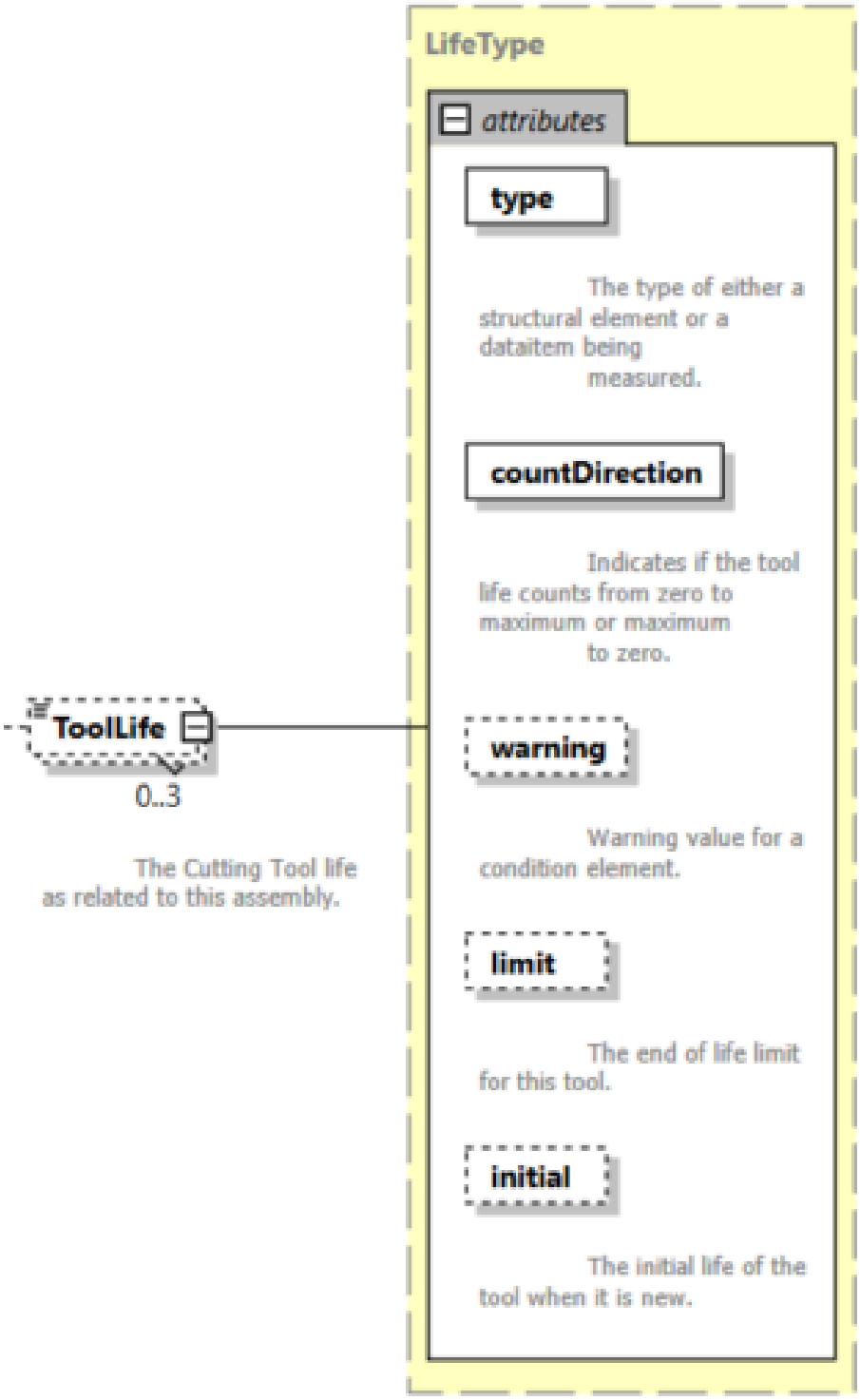


Figure 32: ToolLife Schema

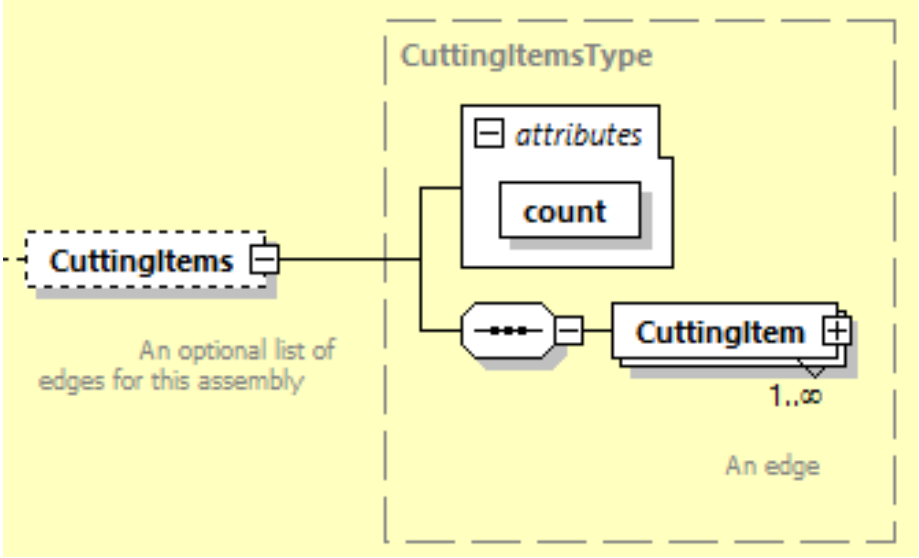


Figure 33: CuttingItems Schema

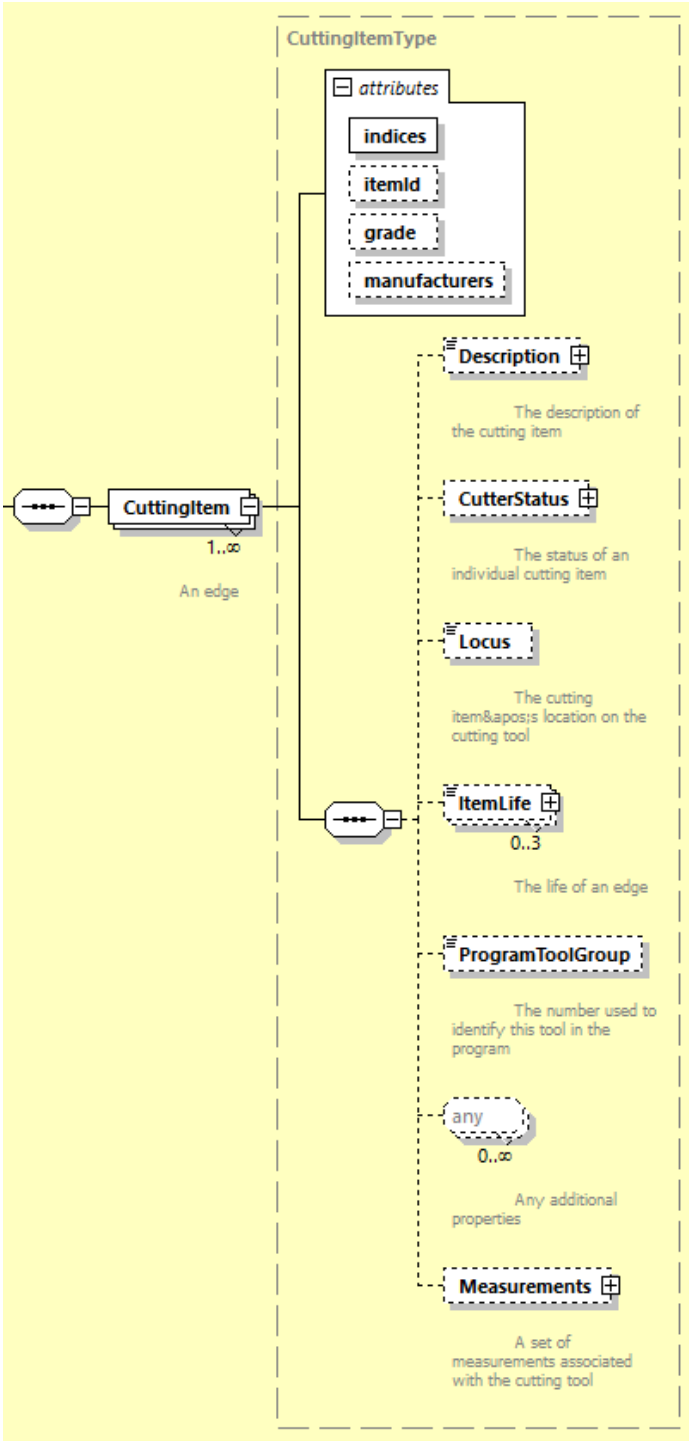


Figure 34: CuttingItem Schema

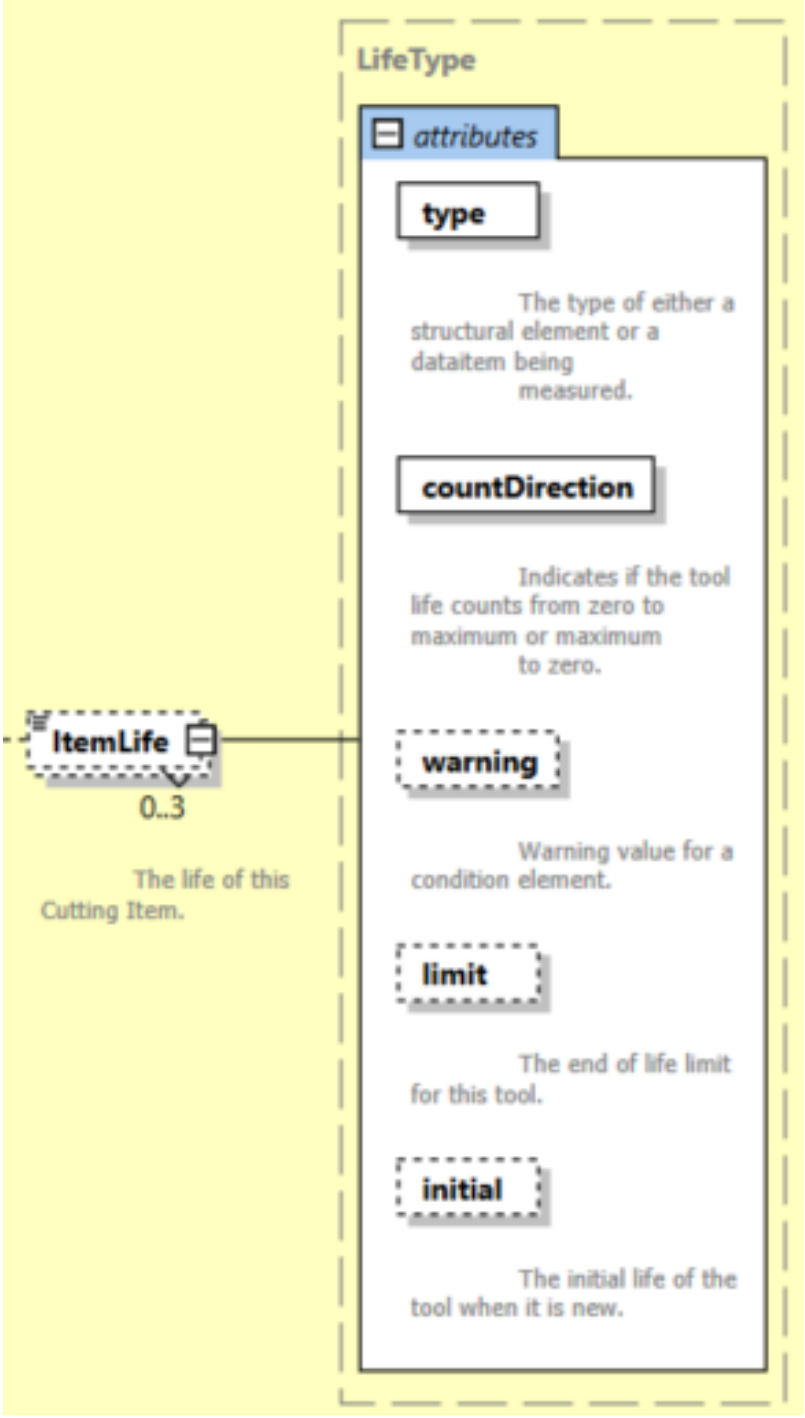


Figure 35: ItemLife Schema

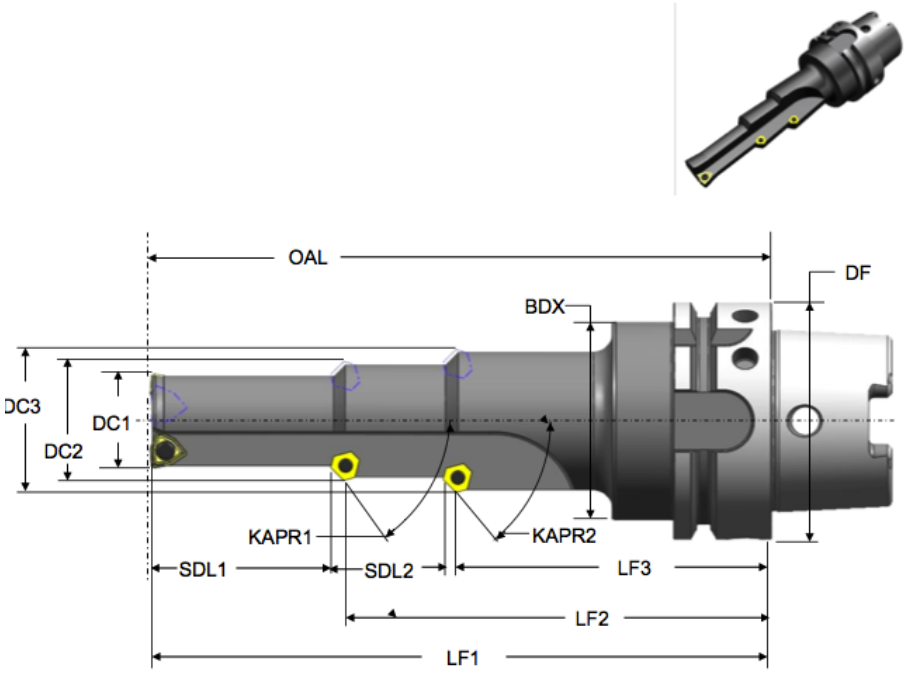


Figure 36: Cutting Tool Measurement 3

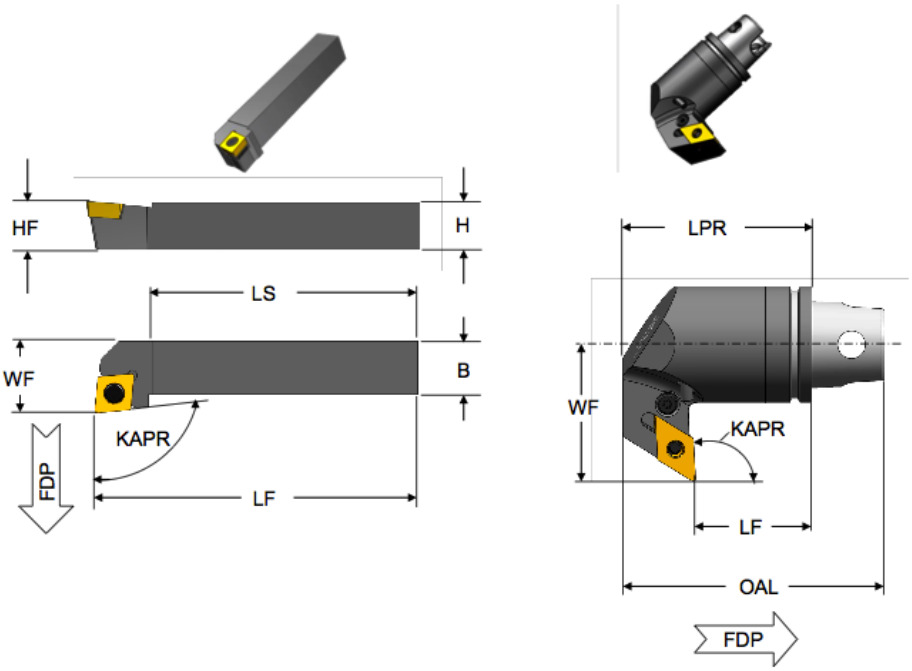


Figure 37: Cutting Tool Measurement 4

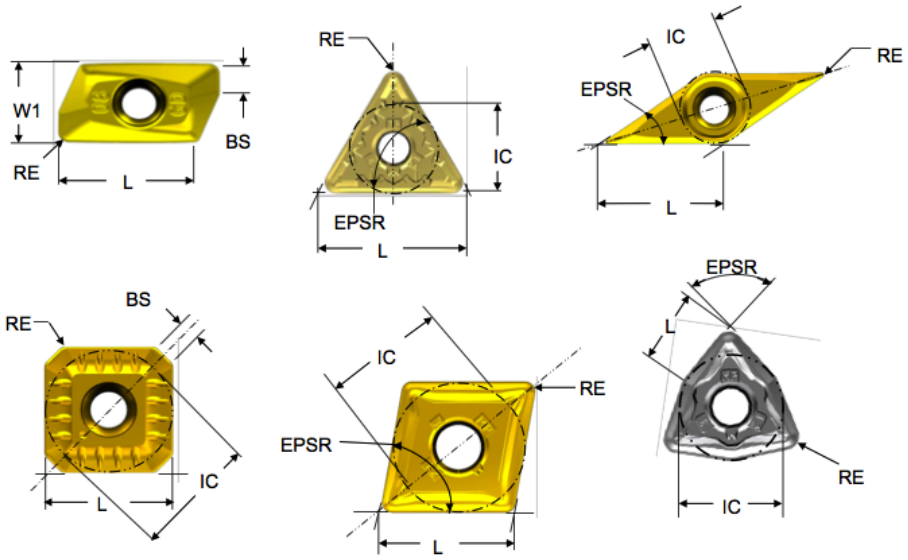


Figure 38: Cutting Tool Measurement 5

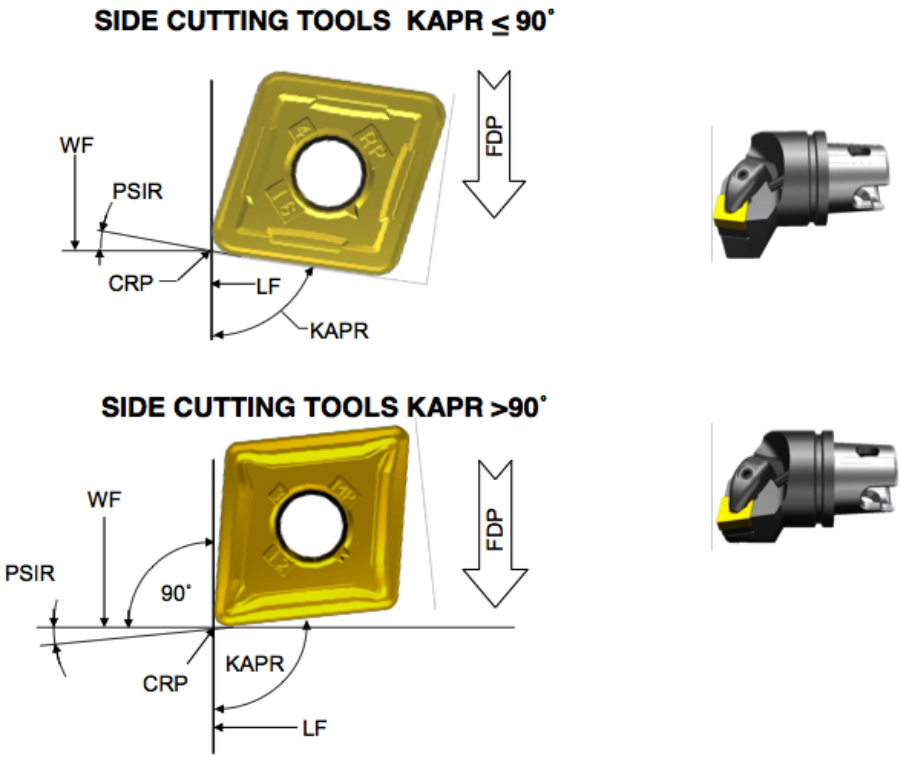


Figure 39: Cutting Tool Measurement 6

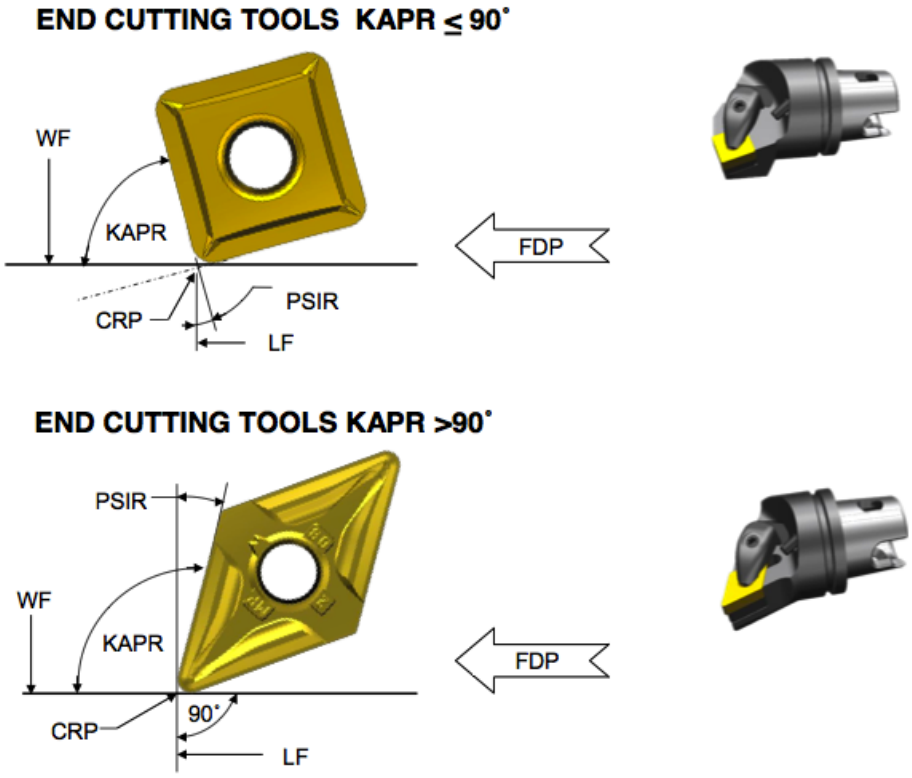


Figure 40: Cutting Tool Measurement 7

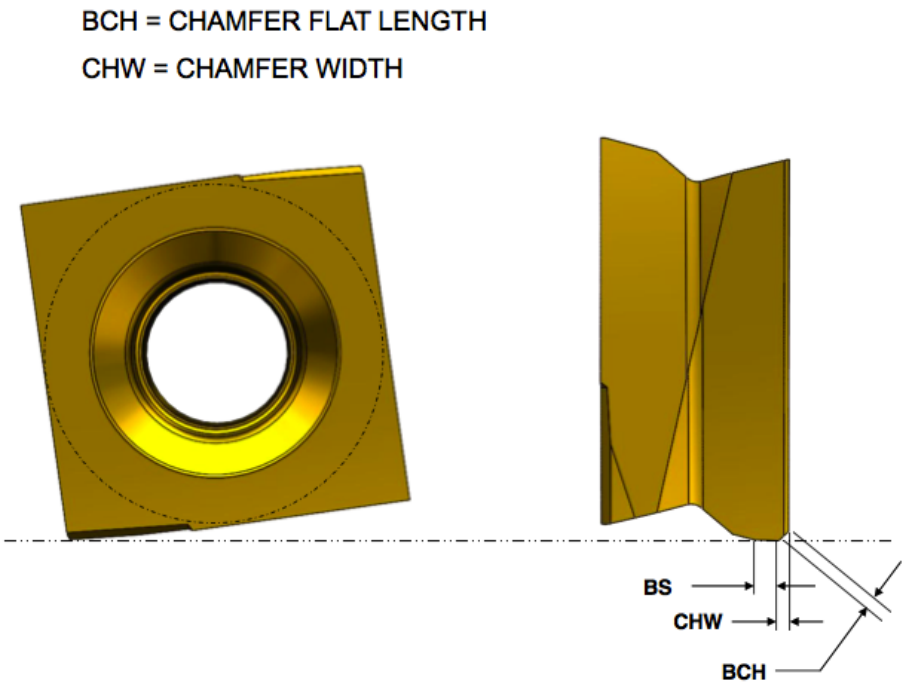


Figure 41: Cutting Tool Measurement 8

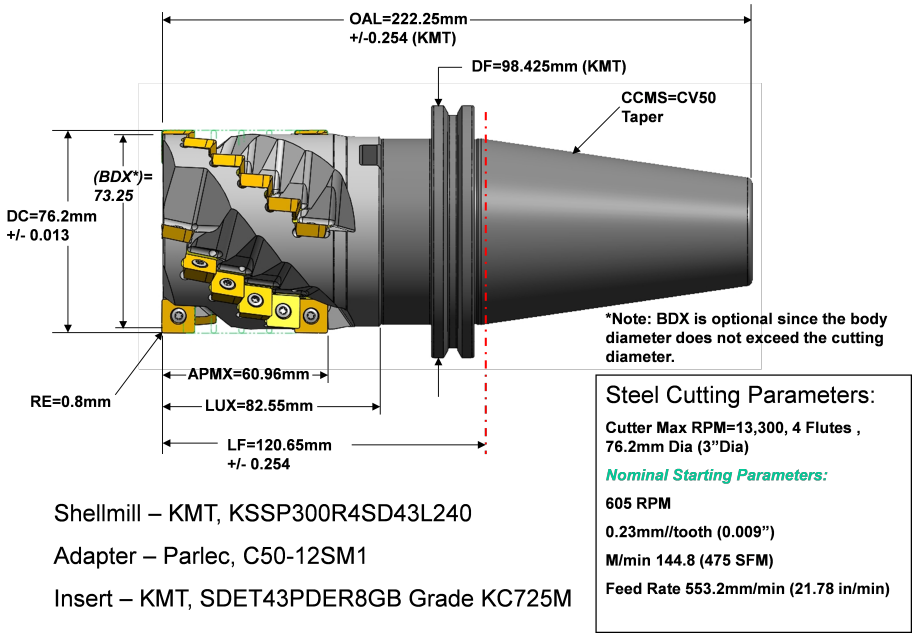


Figure 42: Shell Mill Side View

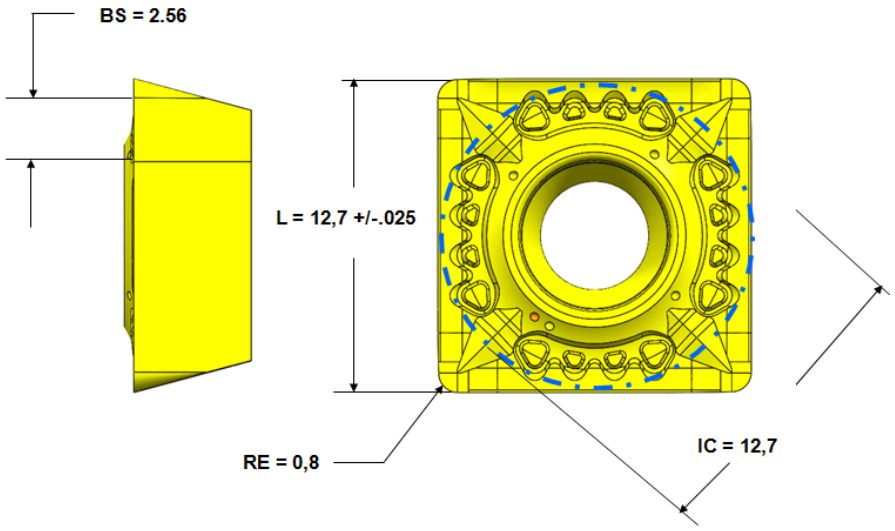


Figure 43: Indexable Insert Measurements

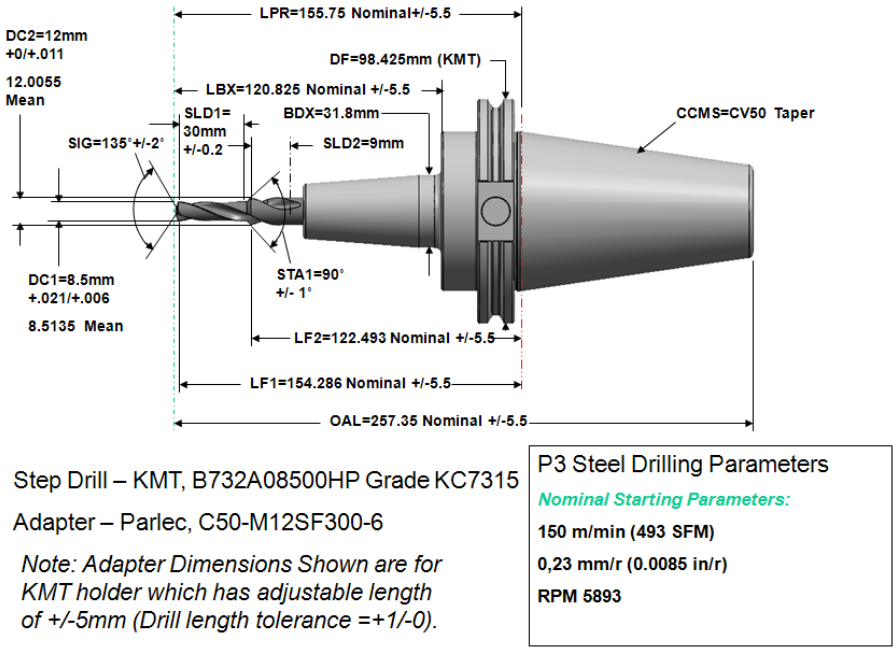
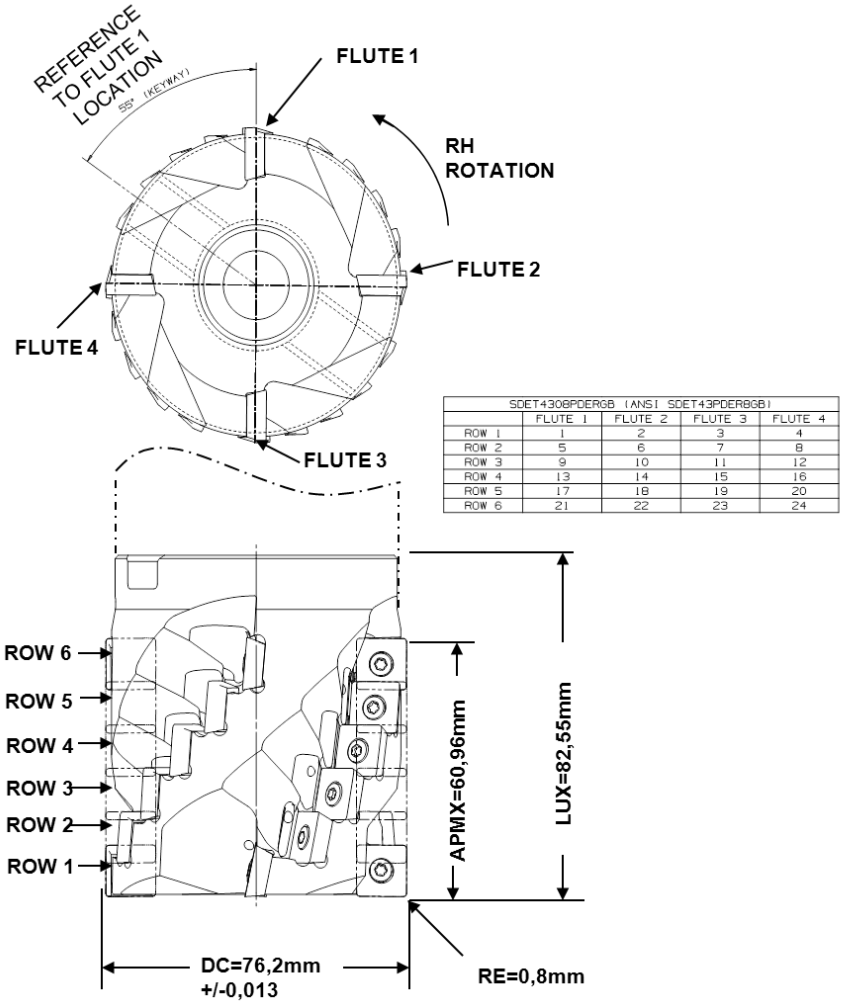


Figure 44: Step Mill Side View



SDET4308PDERGB (ANSI SDET43PDERBGB)

	FLUTE 1	FLUTE 2	FLUTE 3	FLUTE 4
ROW 1	1	2	3	4
ROW 2	5	6	7	8
ROW 3	9	10	11	12
ROW 4	13	14	15	16
ROW 5	17	18	19	20
ROW 6	21	22	23	24

Figure 45: Shell Mill with Explicate Loci

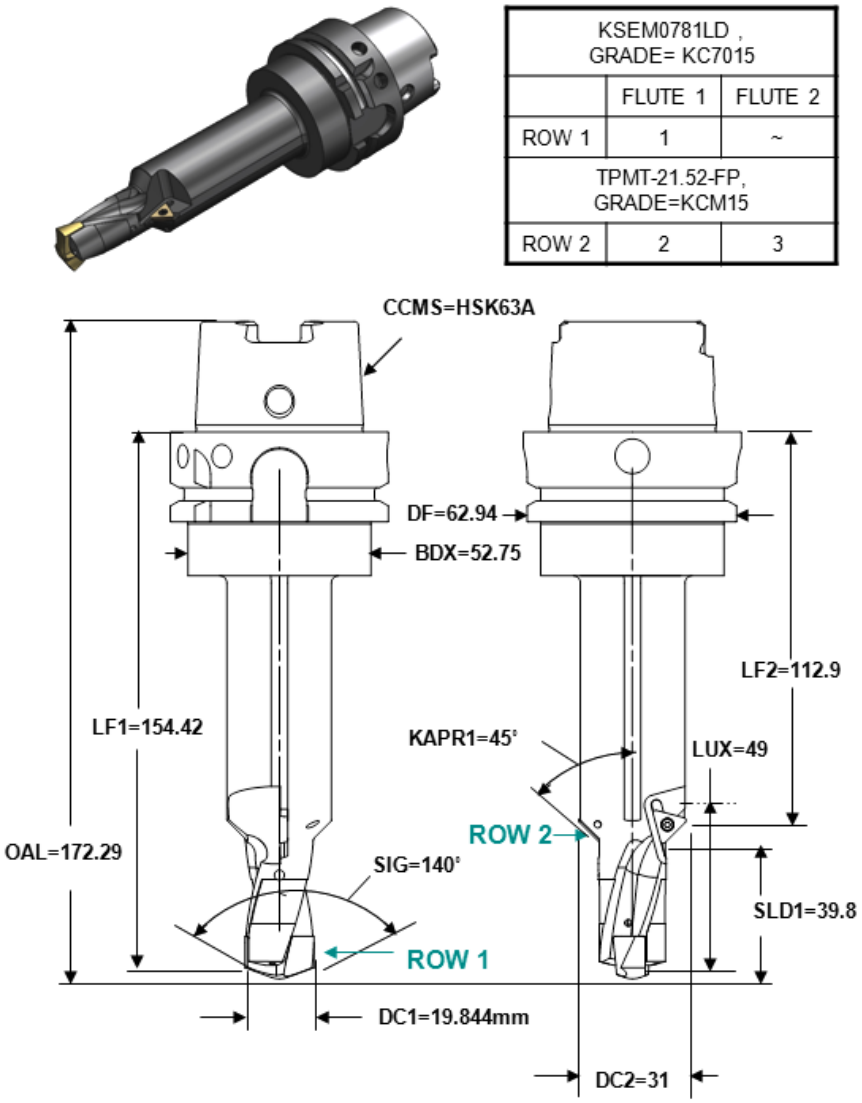
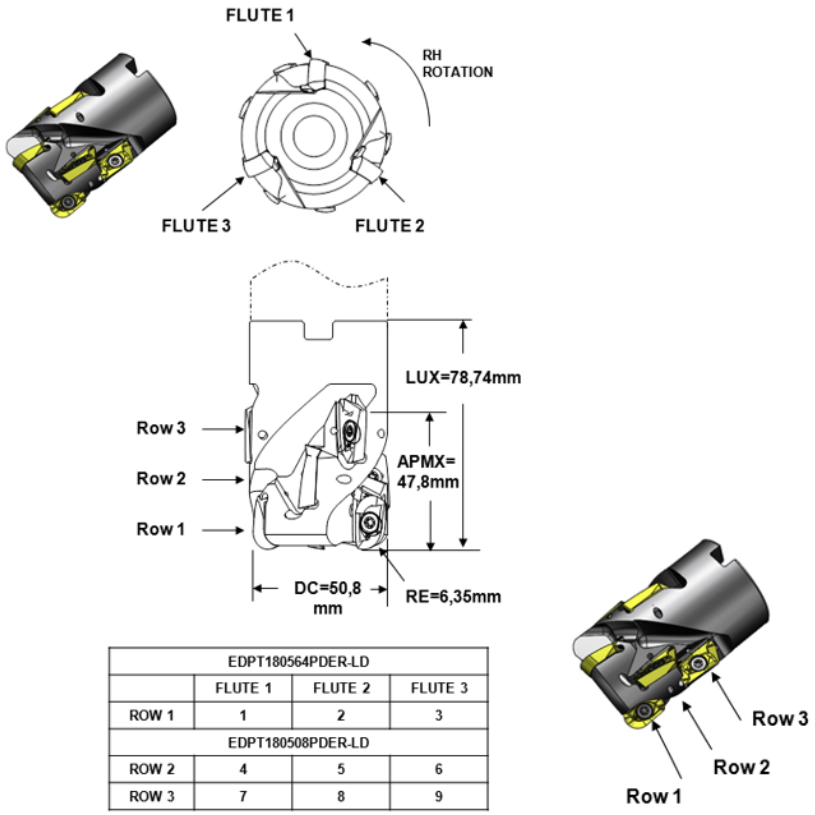


Figure 46: Step Drill with Explicate Loci



EDPT180564PDER-LD			
	FLUTE 1	FLUTE 2	FLUTE 3
ROW 1	1	2	3
EDPT180508PDER-LD			
ROW 2	4	5	6
ROW 3	7	8	9

Figure 47: Shell Mill with Different Inserts on First Row

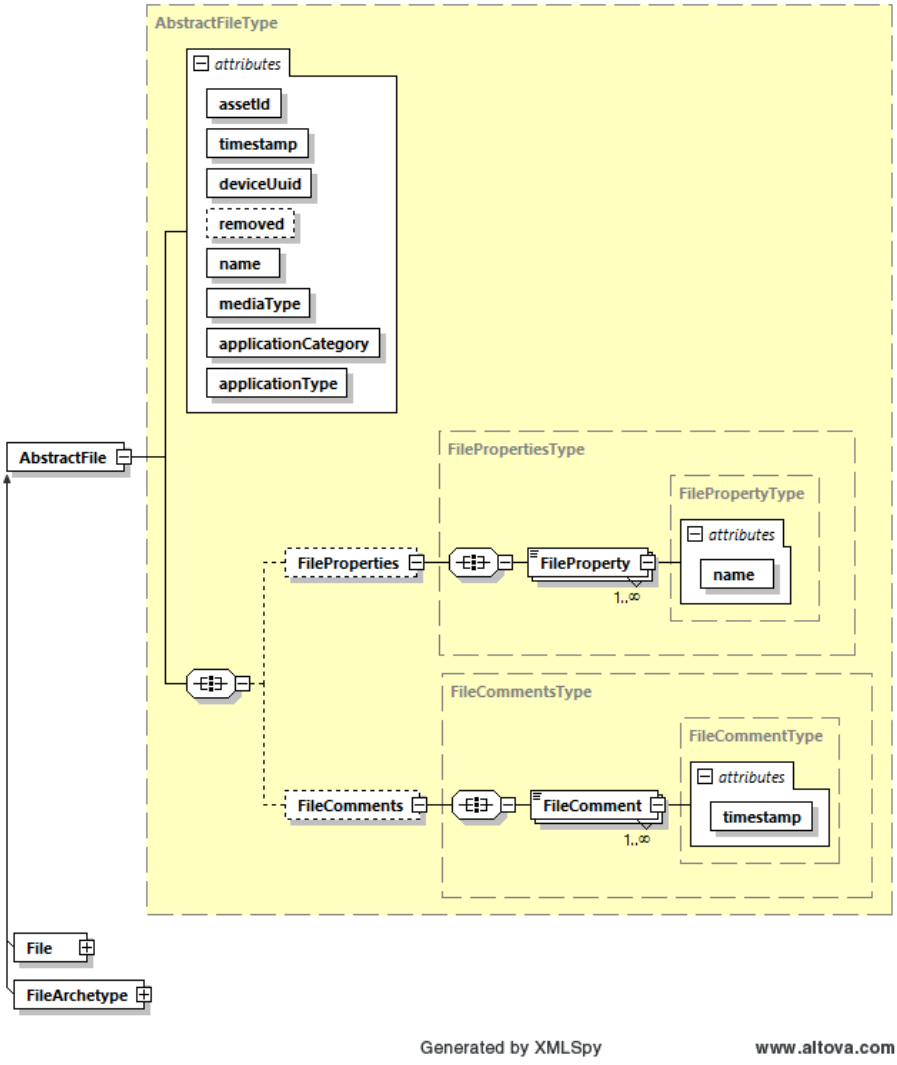


Figure 48: AbstractFile Schema

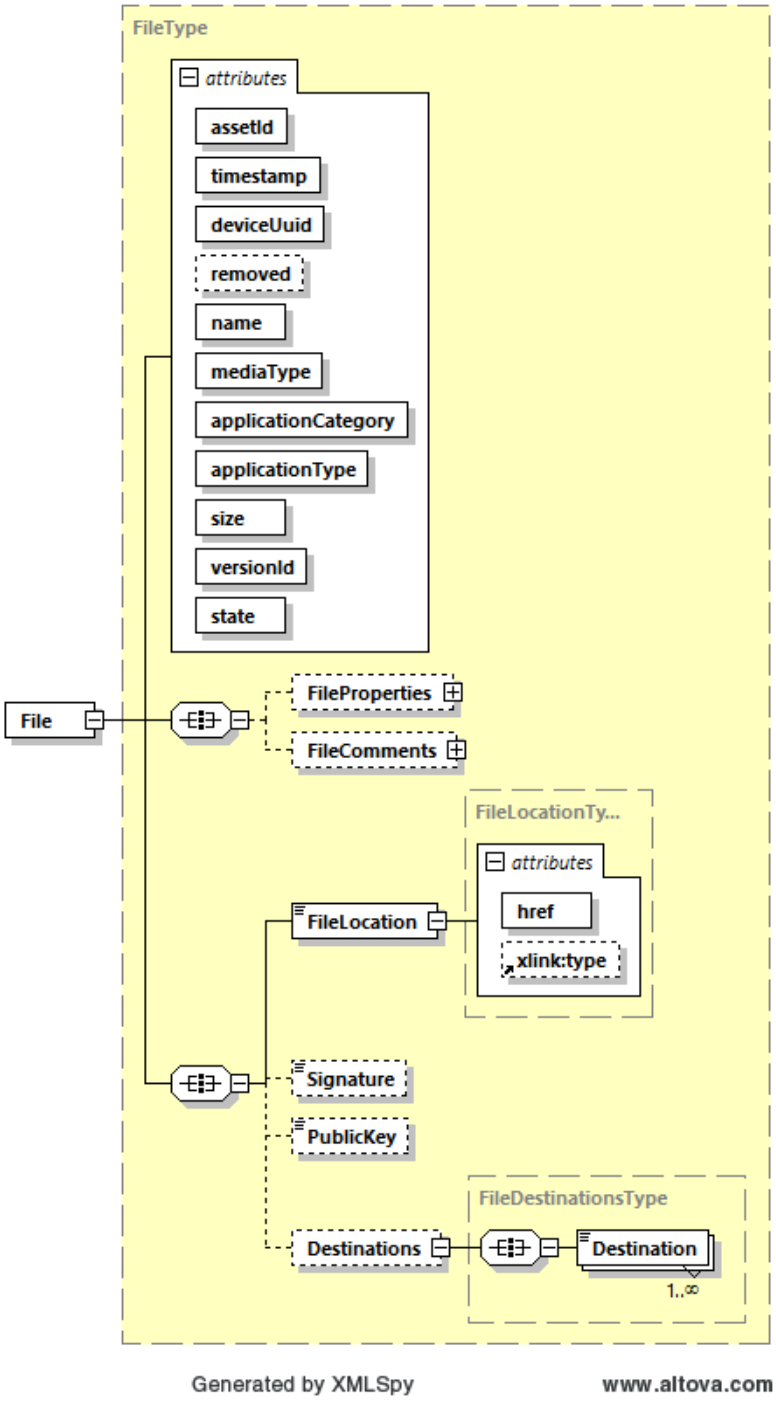


Figure 49: File Schema

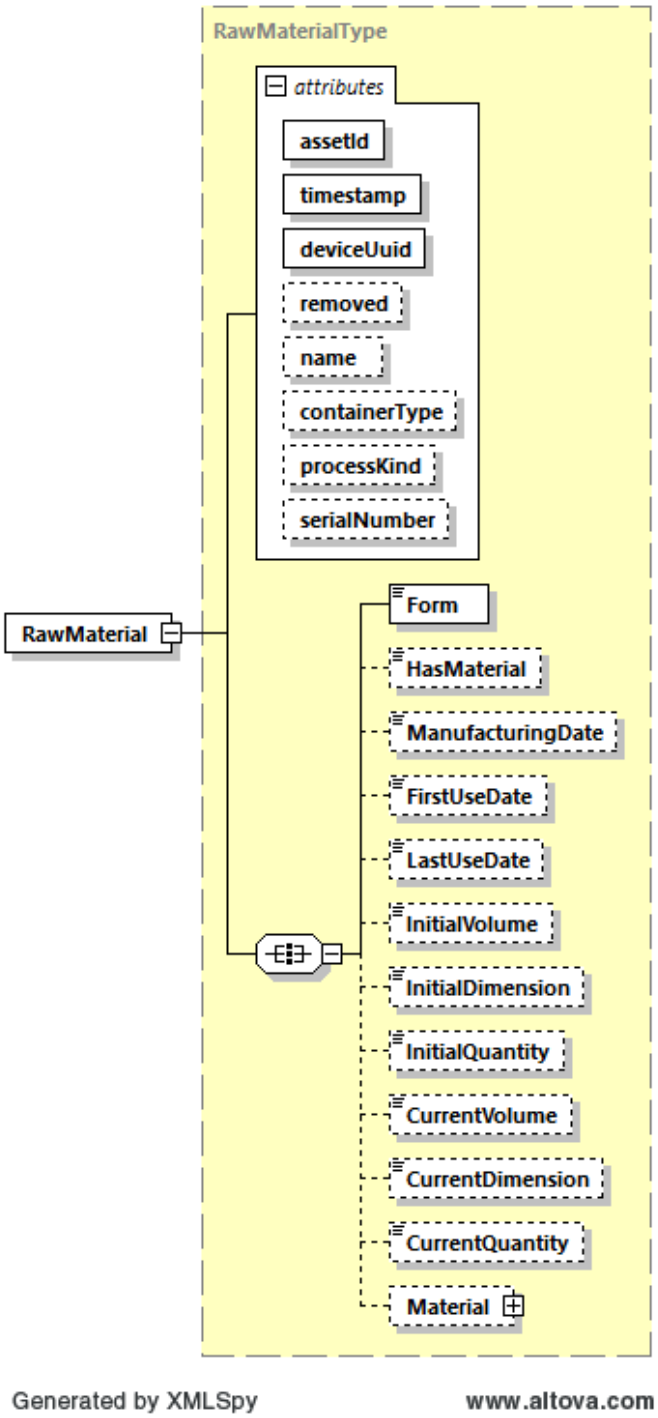


Figure 50: RawMaterial Schema

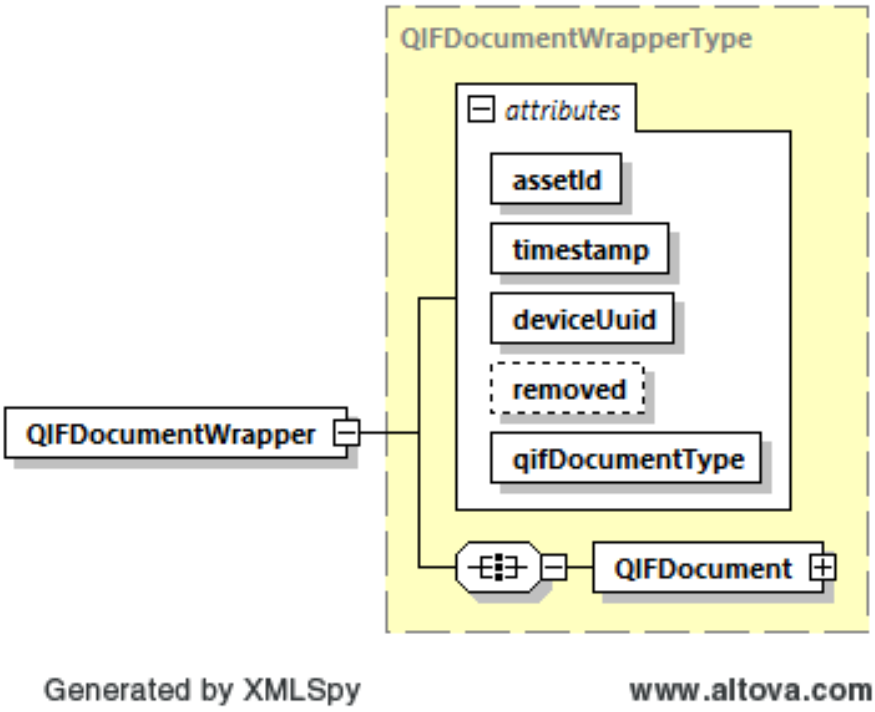


Figure 51: QIFDocumentWrapper Schema