MTConnect® Standard
Part 4 – Assets
Version 1.2.0 – Final

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MTConnect® Specification and Materials

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1 Overview

MTConnect® is a standard based on an open protocol for data integration. MTConnect® is not intended to replace the functionality of existing products, but it strives to enhance the data acquisition capabilities of devices and applications and move toward a plug-and-play environment to reduce the cost of integration.

MTConnect® is built upon the most prevalent standards in the manufacturing and software industry, maximizing the number of tools available for its implementation and providing the highest level of interoperability with other standards and tools in these industries.

To facilitate this level of interoperability, a number of objectives are being met. Foremost is the ability to transfer data via a standard protocol which includes:

- A device identity (i.e. model number, serial number, calibration data, etc.).
- The identity of all the independent components of the device.
- Possibly a device's design characteristics (i.e. axis length, maximum speeds, device thresholds, etc.).
- Most importantly, data captured in real or near-real-time (i.e. current speed, position data, temperature data, program block, etc.) by a device that can be utilized by other devices or applications (e.g. utilized by maintenance diagnostic systems, management production information systems, CAM products, etc.).

The types of data that may need to be addressed in MTConnect® could include:

- Physical and actual device design data
- Measurement or calibration data
- Near-real-time data from the device

To accommodate the vast amount of different types of devices and information that may come into play, MTConnect® will provide a common high-level vocabulary and structure.

The first version of MTConnect® will focus on a limited set of the characteristics mentioned above that were selected based on the fact that they can have an immediate affect on the efficiency of operations.

1.1 MTConnect® Document Structure

The MTConnect® specification is subdivided using the following scheme:

Part 1: Overview and Protocol
Part 2: Components and Data Items
Part 3: Streams, Events, Samples, and Condition
Part 4: Assets

These four documents are considered the bases of the MTConnect standard. Information applicable to basic machine and device types will be included in these documents. Additional parts to the standard will be added to provide information and extensions to the standard focused on specific devices, components, or technologies considered requiring separate emphasis. All

information specific to the topic of each additional part **MUST** be included within that document even when it is a subject matter of one of the base parts of the standard.

Documents will be named (file name convention) as follows:

MTC_Part_<Number>_<Description>.doc.

For example, the file name for Part 2 of the standard is MTC_Part_2_Components.doc.

All documents will be developed in Microsoft® Word format and released in Adobe® PDF format.

2 Purpose of This Document

The four base MTConnect® documents are intended to:

- define the MTConnect® standard;
- specify the requirements for compliance with the MTConnect® standard;
- provide engineers with sufficient information to implement *Agents* for their devices;
- provide developers with the necessary guidelines to use the standard to develop applications.

Part 1 of the MTConnect Standard provides an overview of the MTConnect Architecture and Protocol; including communication, fault tolerance, connectivity, and error handling requirements.

Part 2 of the MTConnect® standard focuses on the data model and description of the information that is available from the device. The descriptive data defines how a piece of equipment should be modeled, the structure of the component hierarchy, the names for each component (if restricted), and allowable data items for each of the components.

Part 3 of the MTConnect standard focuses on the data returned from a `current` or `sample` request (for more information on these requests, see Part 1). This section covers the data representing the state of the machine.

Part 4 of the MTConnect® standard provides a semantic model for entities that are used in the manufacturing process, but are not considered to be a device nor a component. These entities are defined as MTConnect® Assets. These assets may be removed from a device without detriment to the function of the device, and can be associated with other devices during their lifecycle. The data associated with these assets will be retrieved from multiple sources that are responsible for providing their knowledge of the asset. The first type of asset to be addressed is Tooling.

2.1 Terminology

Adapter An optional software component that connects the Agent to the Device.

Agent A process that implements the MTConnect® HTTP protocol, XML generation, and MTConnect protocol.

Alarm An alarm indicates an event that requires attention and indicates a deviation from normal operation. Alarms are reported in MTConnect as `Condition`.

Application A process or set of processes that access the MTConnect® *Agent* to perform some task.

Attribute A part of an XML element that provides additional information about that XML element. For example, the `name` XML element of the `Device` is given as `<Device name="mill-1">...</Device>`

CDATA The text in a simple content element. For example, *`This is some text`*, in `<Message ...>This is some text</Message>`.

Component A part of a device that can have sub-components and data items. A component is a basic building block of a device.

Controlled Vocabulary The value of an element or attribute is limited to a restricted set of possibilities. Examples of controlled vocabularies are country codes: US, JP, CA, FR, DE, etc…

Current A snapshot request to the *Agent* to retrieve the current values of all the data items specified in the path parameter. If no path parameter is given, then the values for all components are provided.

Data Item A data item provides the descriptive information regarding something that can be collected by the *Agent*.

Device A piece of equipment capable of performing an operation. A device may be composed of a set of components that provide data to the application. The device is a separate entity with at least one component or data item providing information about the device.

Discovery Discovery is a service that allows the application to locate *Agents* for devices in the manufacturing environment. The discovery service is also referred to as the *Name Service*.

Event An event represents a change in state that occurs at a point in time. Note: An event does not occur at predefined frequencies.

HTTP Hyper-Text Transport Protocol. The protocol used by all web browsers and web applications.

Instance When used in software engineering, the word *instance* is used to define a single physical example of that type. In object-oriented models, there is the class that describes the thing and the instance that is an example of that thing.

LDAP Lightweight Directory Access Protocol, better known as Active Directory in Microsoft Windows. This protocol provides resource location and contact information in a hierarchal structure.

MIME Multipurpose Internet Mail Extensions. A format used for encoding multipart mail and http content with separate sections separated by a fixed boundary.

Probe A request to determine the configuration and reporting capabilities of the device.

REST REpresentational State Transfer. A software architecture where the client and server move through a series of state transitions based solely on the request from the client and the response from the server.

Results A general term for the `Samples`, `Events`, and `Condition` contained in a `ComponentStream` as a response from a `sample` or `current` request.

Sample	A sample is a data point from within a continuous series of data points. An example of a Sample is the position of an axis.
Socket	When used concerning inter-process communication, it refers to a connection between two end-points (usually processes). Socket communication most often uses TCP/IP as the underlying protocol.
Stream	A collection of `Events, Samples,` and `Condition` organized by devices and components.
Service	An application that provides necessary functionality.
Tag	Used to reference an instance of an XML element.
TCP/IP	TCP/IP is the most prevalent stream-based protocol for inter-process communication. It is based on the IP stack (Internet Protocol) and provides the flow-control and reliable transmission layer on top of the IP routing infrastructure.
URI	Universal Resource Identifier. This is the official name for a web address as seen in the address bar of a browser.
UUID	Universally unique identifier.
XPath	XPath is a language for addressing parts of an XML Document. See the XPath specification for more information. http://www.w3.org/TR/xpath
XML	Extensible Markup Language. http://www.w3.org/XML/
XML Schema	The definition of the XML structure and vocabularies used in the XML Document.
XML Document	An instance of an XML Schema which has a single root XML element and conforms to the XML specification and schema.
XML Element	An element is the central building block of any XML Document. For example, in MTConnect® the Device XML element is specified as **`<Device>...</Device>`**
XML `NMTOKEN`	The data type for XML identifiers. It **MUST** start with a letter, an underscore "_" or a colon ":" and then it **MUST** be followed by a letter, a number, or one of the following ".", "-", "_", ":". An `NMTOKEN` cannot have any spaces or special characters.

2.2 Terminology and Conventions

Please refer to Part 1 "Overview and Protocol" Section 2 for XML Terminology and Documentation conventions.

3 Extension to Part 1, Overview and Protocol

As documented in Part 1, additional queries will be added to the *Agent* to support the storage and retrieval of assets. There is more detail in Part 1; what follows is a summary of the protocol additions:

Asset protocol:

- Request an asset by id:
  - `url: http://example.com/asset/hh1`
  - Returns the `MTConnectAssets` document for asset hh1
- Request multiple assets by id:
  - `url: http://example.com/asset/hh1;cc;123;g5`
  - Returns the `MTConnectAssets` document for asset hh1, cc, 123, and g5.
- Request for all the assets in the *Agent*:
  - `url: http://example.com/assets`
  - Returns all available MTConnect assets in the *Agent*. MTConnect **MAY** return a limited set if there are too many asset records. The assets **MUST** be added to the beginning with the most recently modified assets.
- Request for all assets of a given type in the *Agent*:
  - `url: http://example.com/assets?type="CuttingTool"`
  - Returns all available `CuttingTool` assets from the MTConnect *Agent*. MTConnect **MAY** return a limited set if there are too many asset records. The assets **MUST** be added to the beginning with the most recently modified assets.

4 Extensions to Part 2, Components and Data Items

This document will add the following data item types to support change notification when an asset is added or updated. The data item **MUST** be placed in the `DataItems` collection of the top level device. The device **MUST** be the device that is supplying the asset data.

4.1 Data Item Types for EVENT Category

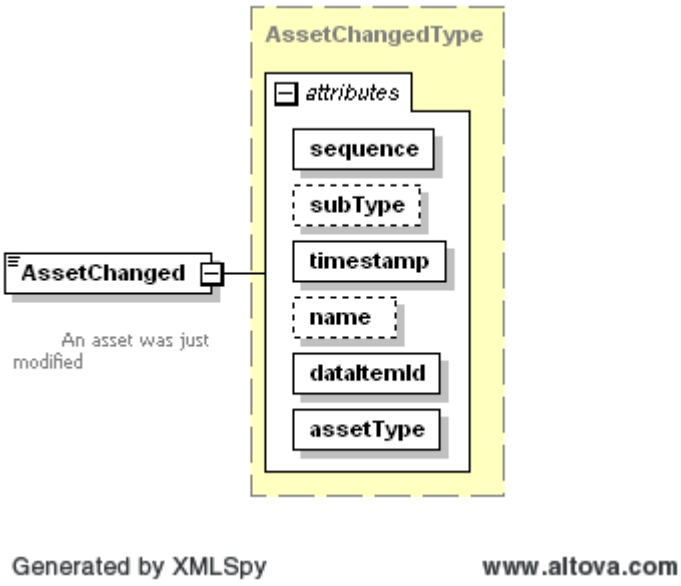
Data Item type/subtype	Description
`ASSET_CHANGED`	The value of the **CDATA** for the event **MUST** be the `assetId` of the asset that has been added or changed. There will not be a separate message for new assets.

5 Extensions to Part 3, Streams, Events, Samples, and Condition

The associated modifications **MUST** be added to Part 3 to add the following event to the events in the streams.

5.1 Extension to `Events` section 3.9

The `AssetChanged` element extends the base `Event` type defined in *Part 3, Streams, Events, Samples, and Condition* and adds the `assetType` attribute to the base `Event`. This new event will signal whenever a new asset is added or the existing definition of an asset is updated. The asset Id is provide as the CDATA value and can be used to request the asset data from the *Agent* as described in *Part 1, Overview and Protocol.*



`AssetChanged` An asset has been added or modified. The **CDATA** for the `AssetChanged` element **MUST** be the `assetId` of the asset that has been modified.

5.1.1 Additional `AssetChanged` attributes:

Attribute	Description	Occurrence
`assetType`	The type of asset that changed	1

6 Assets

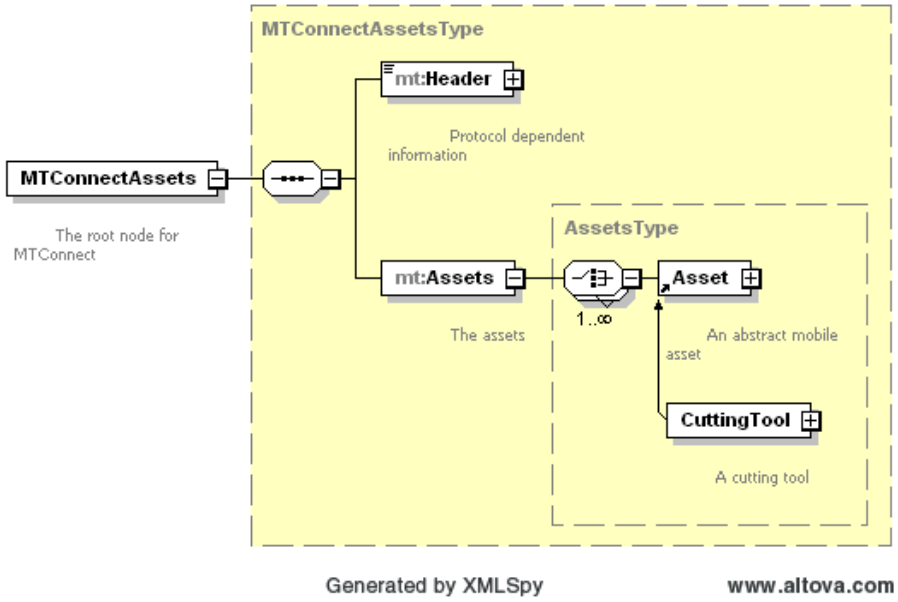


Figure 1: Assets Schema

An Asset is something that is associated with the manufacturing process that is not a component of a device, can be removed without detriment to the function of the device, and can be associated with other devices during their lifecycle. An asset does not have computational capabilities, but may carry information in some media physically attached to the asset.

Concrete examples of Assets are things like Cutting Tools, Workholding Systems, and Fixtures. Part 4 of the MTConnect standard will concern itself with the modeling of these assets and the management and communication of asset data using MTConnect.

At the top level of the MTConnectAssets document we have a standard header as documented in Part 1: Overview and Protocol and one or more assets. Each asset is required to have an assetId that serves as a unique identifier of that asset. The id allows the application to request the asset data from the agent, as prescribed in Part 1.

In the remaining document, we will be discussing Cutting Tools as the first asset type covered by the standard. The cutting tool must have an assetId that differs from all the other assets tracked by this agent. There **MUST** never be more than one asset provided by MTConnect with the same asset Id in the same agent.

6.1 Cutting Tool

A Cutting Tool, also referred to as *an assembly* in this document, is an assembly of items for removing material from a work-piece through a shearing action at the defined cutting edge or edges of the Cutting Item. A Cutting Tool can be a single item or an assembly of one or more Adaptive Items, a Tool Item and several Cutting Items on a Tool Item.

MTConnect will adopt the ISO 13399 structure when formulating the vocabulary for cutting tool geometries and structure. MTConnect will focus on the application of the cutting tool and cutting

items. At this time we 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 previous diagram 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 MTConnect.

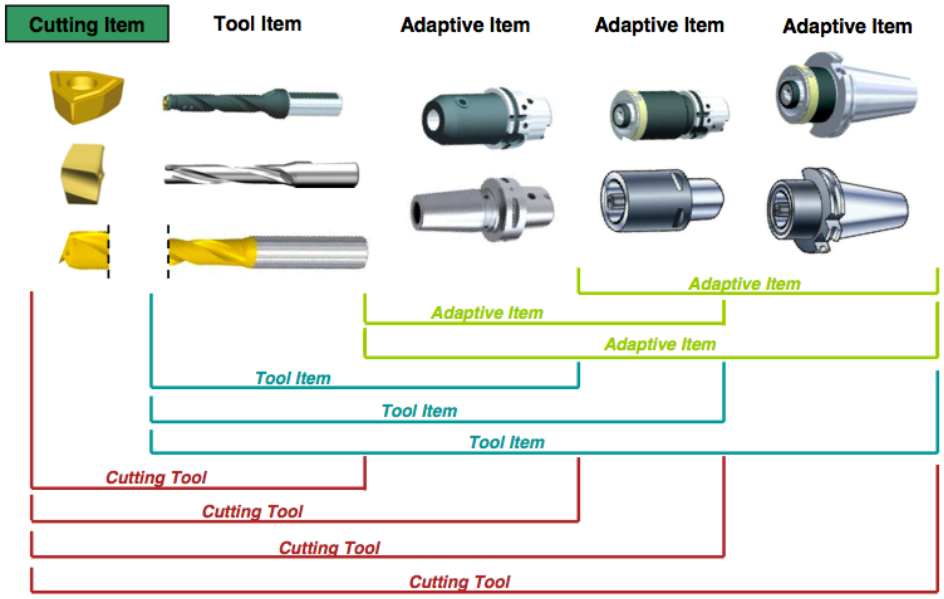


Figure 3: Cutting Tool Composition

Figure 3 provides another view of the cutting tool composition model. 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.

Figures 4 and 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.

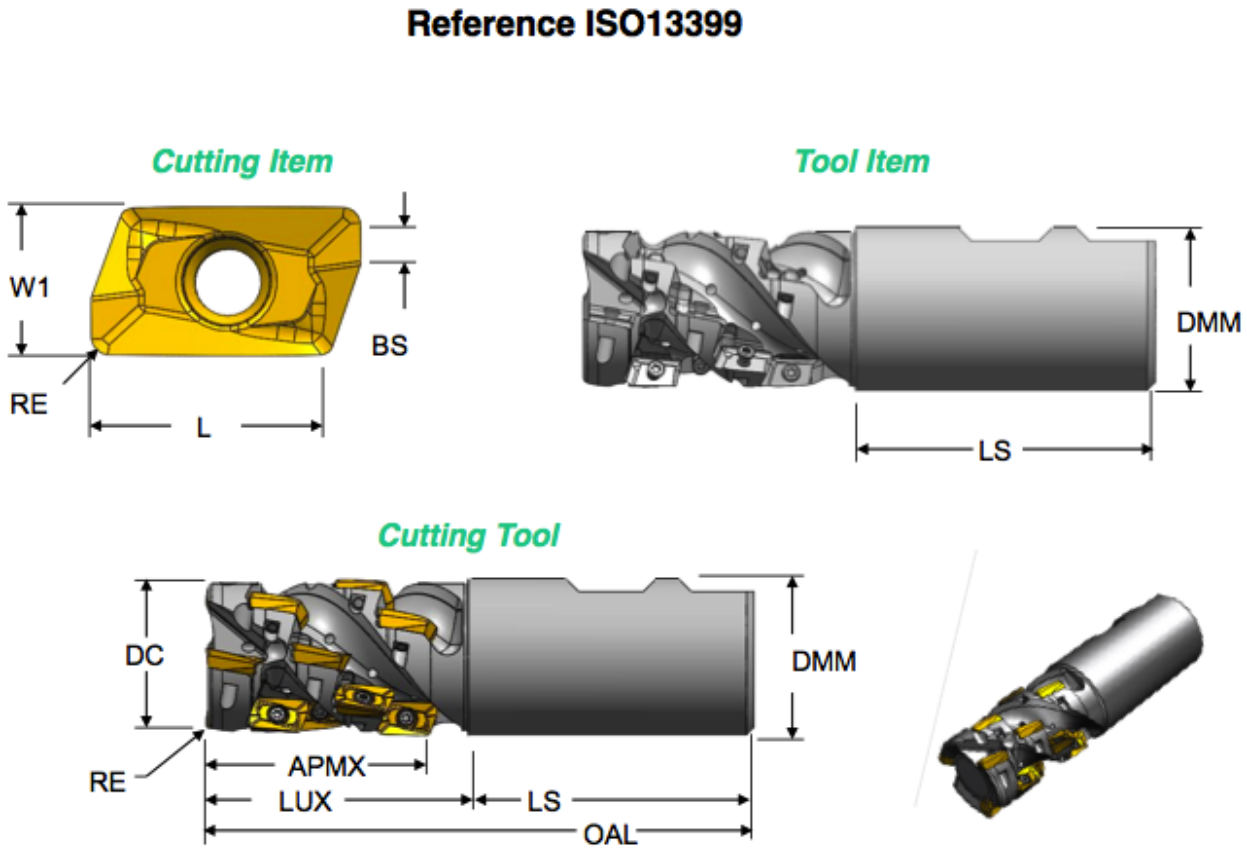


Figure 4: Cutting Tool, Tool Item and Cutting Item

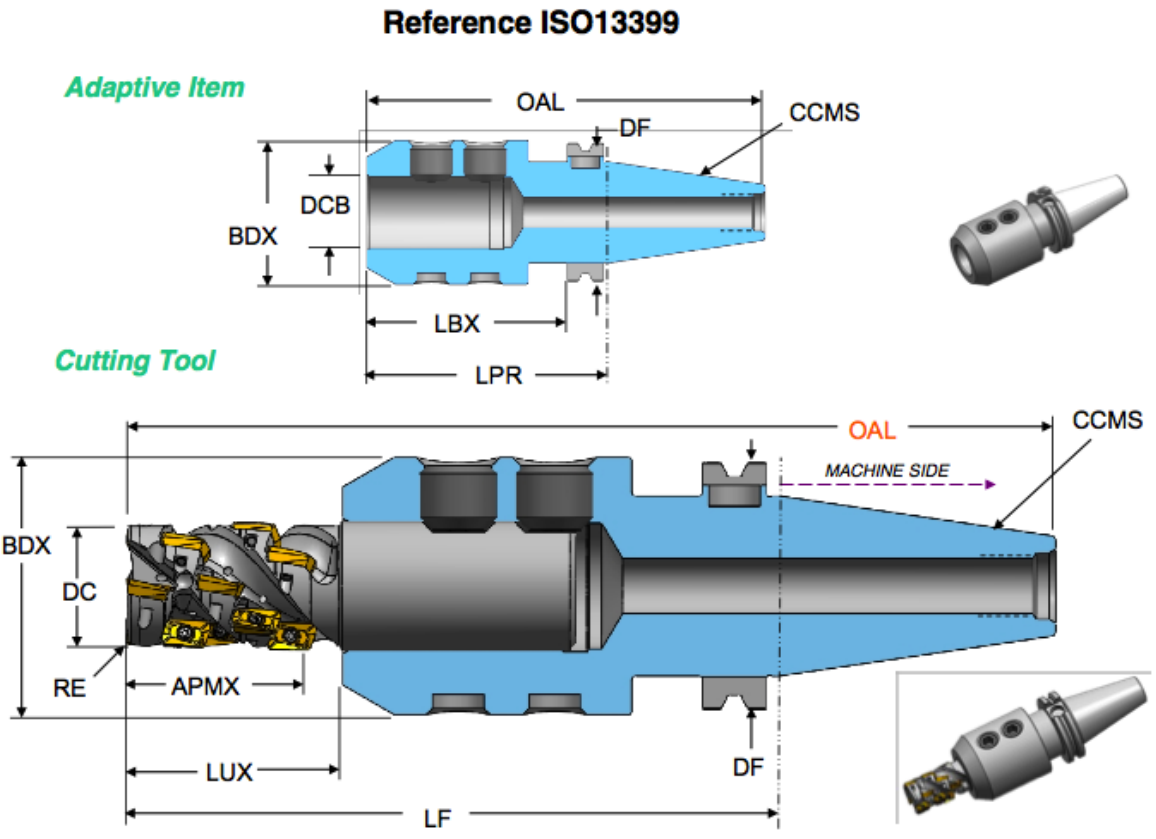


Figure 5: Cutting Tool, Tool Item and Cutting Item

The above diagrams use the ISO 13399 codes for each of the measurements. These codes will be translated into the MTConnect vocabulary as illustrated below. The measurements will have a maximum, minimum, and nominal value representing the tolerance of allowable values for this dimension. See below for a full discussion.

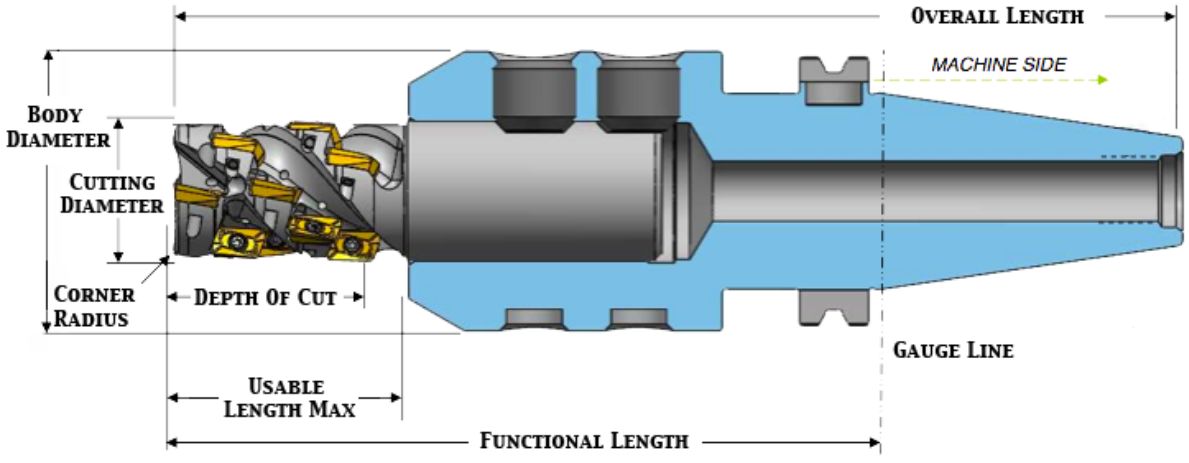


Figure 6: Cutting Tool Measurements

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 will use the full text name for clarity in the XML document.

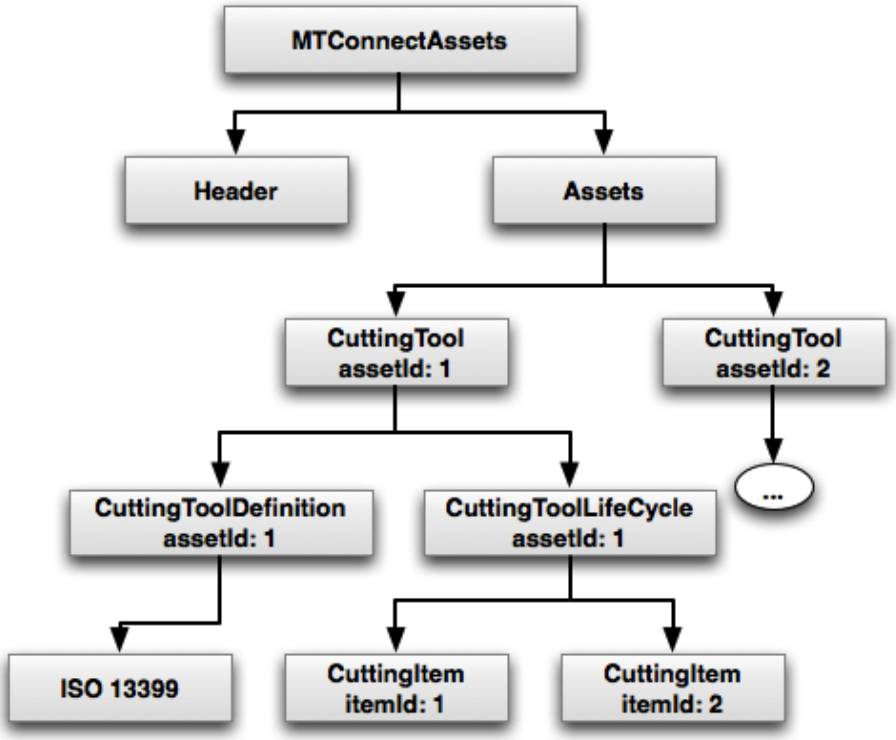


Figure 7: Cutting Tool Asset Structure

The structure of the MTConnectAssets header is defined in *Part 1: Overview and Protocol* of the standard. A finite number of assets will be stored in the MTConnect agent. This finite number will be implementation specific and will depend on memory and storage constraints. The standard will not prescribe the number or capacity requirements for an implementation.

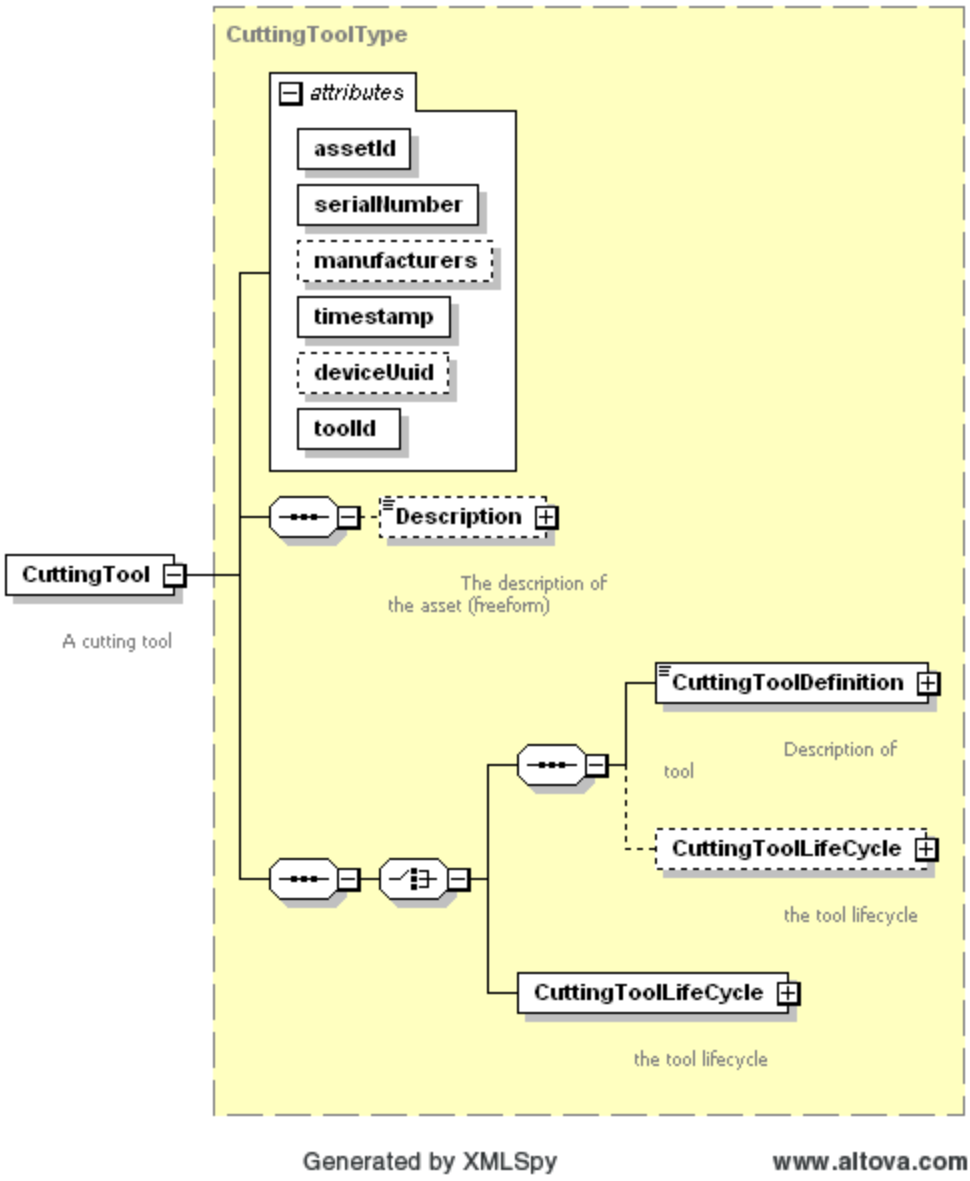


Figure 8: Cutting Tool Schema

6.1.1 CuttingTool attributes:

Attribute	Description	Occurrence
`timestamp`	The time this asset was last modified. Always given in UTC. The timestamp **MUST** be provided in UTC (Universal Time Coordinate, also known as GMT). This is the time the asset data was last modified.	1
`assetId`	The unique identifier of the instance of this tool. The unique identifier of the instance of this tool. This will be the same as the `toolId` and `serialNumber` in most cases. The `assetId` **SHOULD** be the combination of the `toolId` and `serialNumber` as in `toolId.serialNumber` or an equivalent implementation dependent identification scheme.	1

Attribute	Description	Occurrence
serialNumber	The unique identifier for this assembly. The unique identifier for this assembly. This is defined as an XML string type and is implementation dependent.	1
toolId	The identifier for the class of cutting tool. The identifier for a class of cutting tools. This is defined as an XML string type and is implementation dependent.	1
deviceUuid	The device's UUID that supplied this data. This optional element References to the UUID attribute given in the device element. This can be any series of numbers and letters as defined by the XML type NMTOKEN.	1
manufacturers	The manufacturers of the cutting tool. An optional attribute referring to the manufacturers of this tool, for this element, this will reference the Tool Item and Adaptive Items specifically. The Cutting Items manufacturers' will be an attribute of the CuttingItem elements. The representation will be a comma (,) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type string.	0..1

6.1.2 CuttingTool Elements

The elements associated with this cutting tool are given below. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements **MUST** be provided in the following order as prescribed by XML. At least one of CuttingToolDefinition or CuttingToolLifeCycle **MUST** be supplied.

Element	Description	Occurrence
Description	An element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect.	0..1
CuttingToolDefinition	Reference to a ISO 13399	0..1
CuttingToolLifeCycle	MTConnect data regarding the use phase of this tool.	0..1

6.1.3 Description

The description **MAY** contain mixed content, meaning that an additional XML element or plain text may be provided as part of the content of the description tag. Currently the description contains no additional attributes.

6.1.4 CuttingToolDefinition

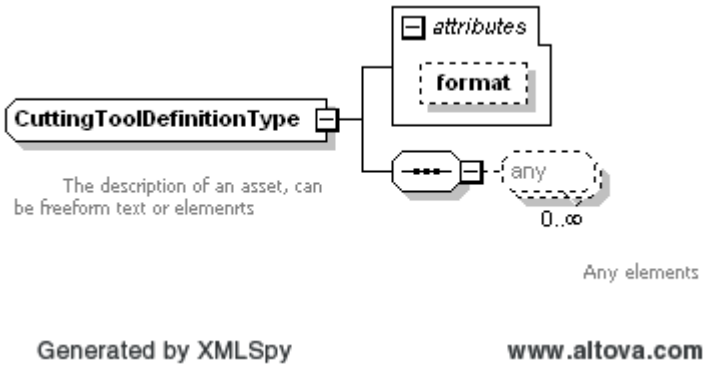


Figure 9: Cutting Tool Definition

The `CuttingToolDefinition` contains the detailed structure of the cutting tool. The information contained in this element will be static during its lifecycle. Currently we are referring to the external ISO 13399 standard to provide the complete definition and composition of the cutting tool as defined in *Section 6.1* of this document.

6.1.5 `CuttingToolDefinition` attributes:

Attribute	Description	Occurrence
`format`	Format – EXPRESS, XML, TEXT, or UNDEFINED. Default: XML	0..1

6.1.5.1 `format`

The format attribute describes the expected representation of the enclosed data. If no value is given, the assumed format will be `XML`.

Value	Description
`XML`	The default value for the definition. The content will be an XML document.
`EXPRESS`	The document will confirm to the ISO 10303 standard. STEP-NC part 21 file formats.
`TEXT`	The document will be a text representation of the tool data.
`UNDEFINED`	The document will be provided in an undefined format.

6.1.6 `CuttingToolDefinition` Elements

The only acceptable cutting tool definition at present is ISO 13399. Additional formats **MAY** be considered in the future.

6.1.7 ISO 13399

The ISO 13399 data **MUST** be presented in either XML (ISO 10303-28) or EXPRESS format (ISO 10303-21). An XML schema will be preferred as this will allow for easier integration with

the MTConnect XML tools. EXPRESS will also be supported, but software tools will need to be provided or made available for handling this data representation.

There will be the root element of the ISO13399 document when XML is used. When EXPRESS is used the XML element will be replaced by the text representation.

6.1.8 CuttingToolLifeCycle

The life cycle refers to the data pertaining the the application or the use of the tool. This data is provided by various devices, machine tool, presetters, and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured. The life cycle has three conceptual parts; tool and cutting item identity, properties, and measurements. A measurement is defined as a constrained value that is reported in defined units and as a W3C floating point format.

The `CuttingToolLifeCycle` contains data for the entire tool assembly. The specific cutting items that are part of the `CuttingToolLifeCycle` are contained in the `CuttingItems` element. Each cutting item has similar properties as the assembly; identity, properties, and measurements.

The units for all measurements have been predefined in MTConnect and will be consistent with Part 2 and Part 3 of the standard. This means that all lengths and distances will be given in millimeters and all angular measures will be given in degrees. Quantities like `ProcessSpindleSpeed` will be given in RPM, the same as the RotaryVelocity in Part 3.

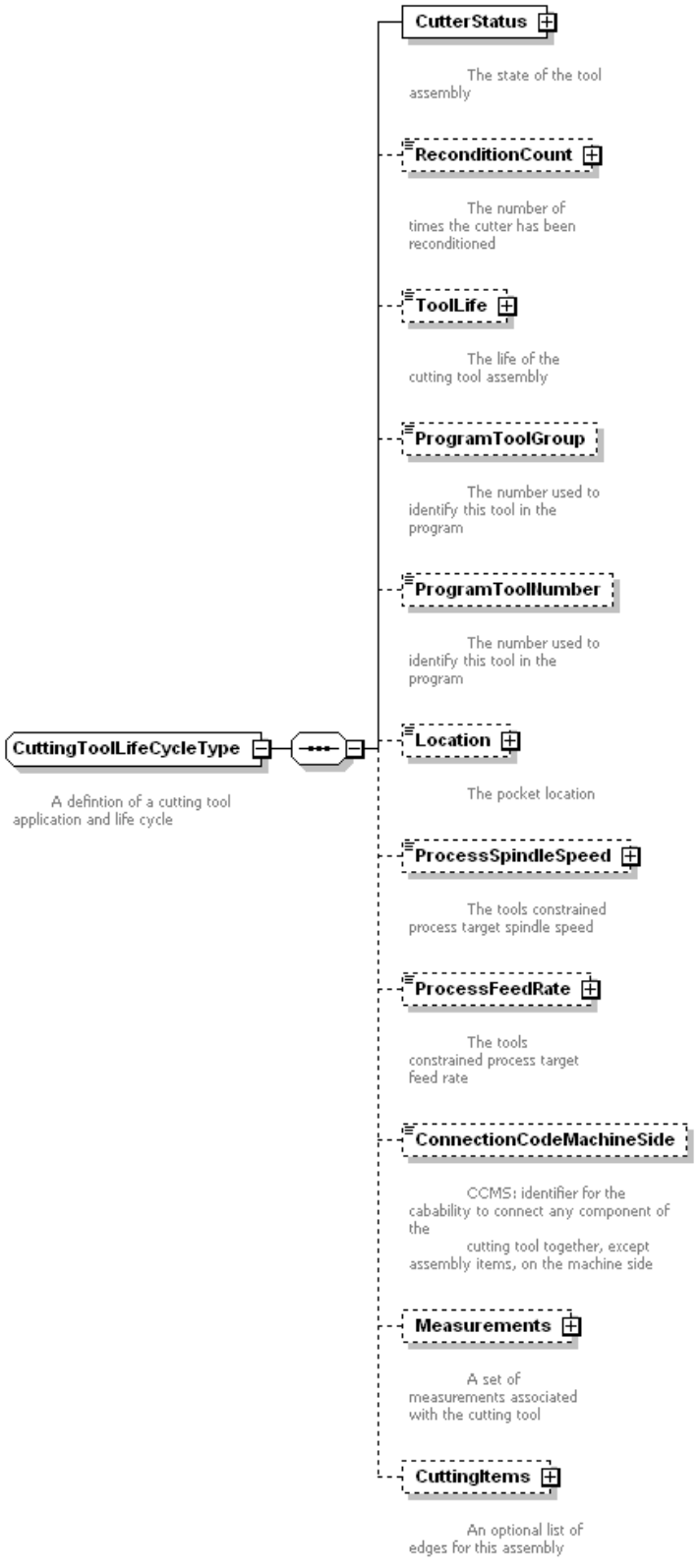


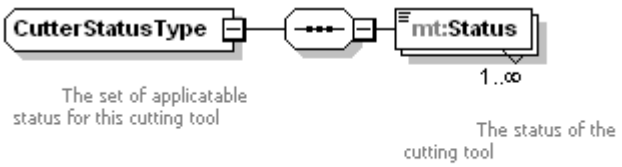
Figure 10: Cutting Tool Life Cycle

6.1.9 CuttingToolLifeCycle Elements

The elements associated with this cutting tool are given below. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements **MUST** be provided in the following order as prescribed by XML.

Element	Description	Occurrence
CutterStatus	The status of the this assembly. Can be one more of the following values: NEW, AVAILABLE, UNAVAILABLE, ALLOCATED, UNALLOCATED, MEASURED, RECONDITIONED, NOT_REGISTERED, USED, EXPIRED, BROKEN, or UNKNOWN.	1
ReconditionCount	The number of times this cutter has been reconditioned.	0..1
ToolLife	The cutting tool life as related to this assembly	0..1
Location	The location this tool now resides in.	0..1
ProgramToolGroup	The tool group this tool is assigned in the part program.	0..1
ProgramToolNumber	The number of the tool as referenced in the part program.	0..1
ProcessSpindleSpeed	The constrained process spindle speed for this tool	0..1
ProcessFeedRate	The constrained process feed rate for this tool in mm/s.	0..1
ConnectionCodeMachineSide	Identifier for the capability to connect any component of the cutting tool together, except assembly items, on the machine side. Code: CCMS	0..1
Measurements	A collection of measurements for the tool assembly.	0..1
CuttingItems	An optional set of individual cutting items.	0..1

6.1.10 CutterStatus



The elements of the CutterStatus element can be a combined set of Status elements. The standard allows any set of statuses to be combined, but only certain combinations make sense. A cutting tool SHOULD not be both NEW and USED at the same time. There are no rules in the schema to enforce this, but this is left to the implementer. The following combinations **MUST NOT** occur:

- 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.
- All other combinations are allowed.

Element	Description	Occurrence
Status	The status of the cutting tool. There can be multiple Status elements.	1..INF

6.1.10.1 Status

One of the values for the status of the cutting tool.

Value	Description
NEW	A new tool that has not been used or first use. Marks the start of the tool history.
AVAILABLE	Indicates the tool is available for use. If this is not present, the tool is currently not ready to be used
UNAVAILABLE	Indicates the tool is unavailable for use in metal removal. If this is not present, the tool is currently not ready to be used
ALLOCATED	Indicates if this tool is has been committed to a device for use and is not available for use in any other device. If this is not present, this tool has not been allocated for this device and can be used by another device
UNALLOCATED	Indicates this Cutting Tool has not been committed to a process and can be allocated.
MEASURED	The tool has been measured.
RECONDITIONED	The cutting tool has been reconditioned. See ReconditionCount for the number of times this cutter has been reconditioned.
USED	The tool is in process and has remaining tool life.
EXPIRED	The cutting tool has reached the end of its useful life.
BROKEN	Premature tool failure.
NOT_REGISTERED	This cutting tool cannot be used until it is entered into the system.
UNKNOWN	The cutting tool is an indeterminate state. This is the default value.

6.1.11 Location

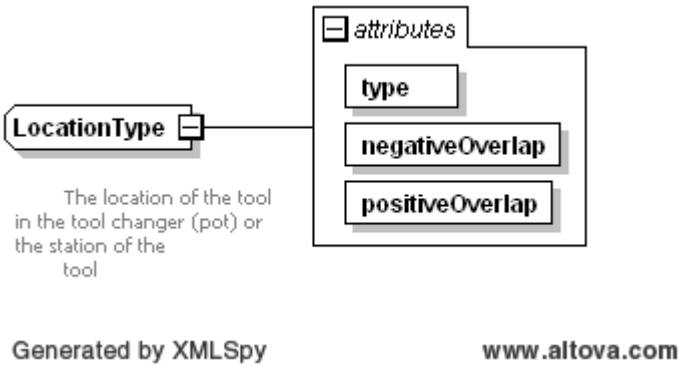


Figure 11: Location

This is the optional device specific pocket id providing the current pocket number this tool resides in. This can be any series of numbers and letters as defined by the XML type NMTOKEN. When a `POT` or `STATION` type is used, the value **MUST** be a numeric value. If a `negativeOverlap` or the `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 index-able 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.

6.1.11.1 `Location` attributes:

Attribute	Description	Occurrence
`type`	The type of location being identified. Current **MUST** be one of `POT`, `STATION`, or `CRIB`.	1
`positiveOverlap`	The number of locations at higher index value from this location.	0..1
`negativeOverlap`	The number of location at lower index values from this location.	0..1

6.1.11.2 type

.The type of location being identifier.

Value	Description
`POT`	The number of the pot in the tool handling system.
`STATION`	The tool location in a horizontal turning machine.
`CRIB`	The location with regard to a tool crib.

6.1.11.3 positiveOverlap

The number of locations at higher index values that the cutting tool occupies due to interference. The value **MUST** be an integer. If not provided it is assumed to be 0.

6.1.11.4 negativeOverlap

The number of locations at lower index values that the cutting tool occupies due to interference. The value **MUST** be an integer. If not provided it is not assumed to be 0.

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value **MUST** be an integer.

6.1.12 ProgramToolGroup

The optional identifier for the group of cutting tools when multiple tools can be used interchangeably. This is defined as an XML string type and is implementation dependent.

6.1.13 ProgramToolNumber

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value **MUST** be an integer.

6.1.14 ReconditionCount

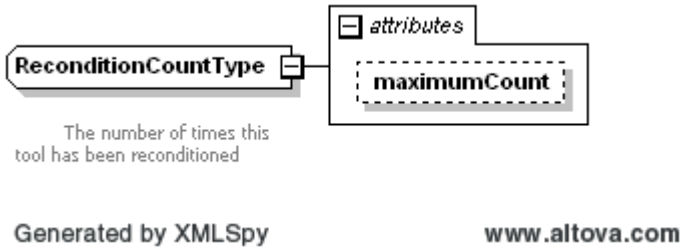


Figure 12: Cutting Tool Life Cycle

This element **MUST** contain an integer value as the CDATA that represents the number of times the cutter has been reconditioned.

6.1.14.1 `ReconditionCount` attributes

Attribute	Description	Occurrence
`maximumCount`	The maximum number of times this tool may be reconditioned	0..1

6.1.15 ToolLife:

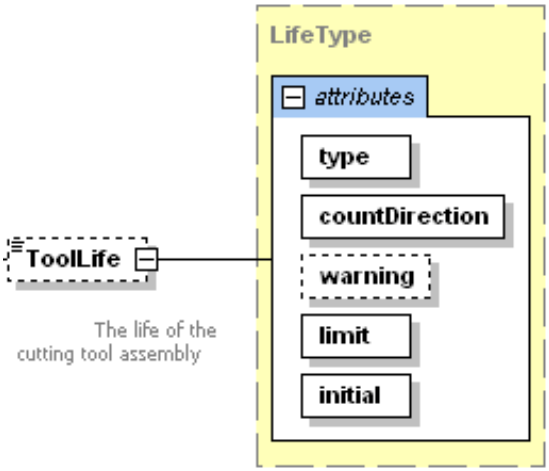


Figure 13: Tool Life

The value is the current value for the tool life. The value **MUST** be a number. Tool life is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One tool life element can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

6.1.15.1 ToolLife attributes:

These is an optional attribute that can be used to further classify the operation type.

Attribute	Description	Occurrence
`type`	The type of tool life being accumulated. `MINUTES`, `PART_COUNT`, or `WEAR`	1
`countDirection`	Indicates if the tool life counts from zero to maximum or maximum to zero, The values **MUST** be one of `UP` or `DOWN`.	1
`warning`	The point at which a tool life warning will be raised.	0..1
`limit`	The end of life limit for this tool. If the `countDirection` is `DOWN`, the point at which this tool should be expired, usually zero. If the `countDirection` is `UP`, this is the upper limit for which this tool should be expired.	0..1
`initial`	The initial life of the tool when it is new.	0..1

6.1.15.1.1 ToolLife `type` attribute:

The value of type must be one of the following:

Value	Description
`MINUTES`	The tool life measured in minutes. All units for minimum, maximum, and warningLevel **MUST** be provided in minutes.

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

6.1.15.1.2 ToolLife `countDirection` attribute:

The value of type must be one of the following:

Value	Description
DOWN	The tool life counts down from the maximum to zero.
UP	The tool life counts up from zero to the maximum.

6.1.16 ProcessSpindleSpeed

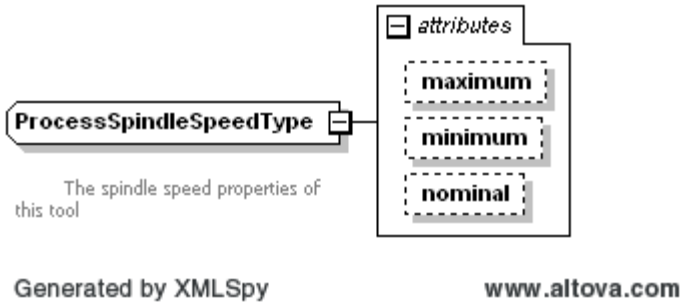


Figure 14: Process Spindle Speed

The Process Spindle Speed **MUST** be specified in revolutions/minute (RPM). The CDATA **MAY** contain the process target spindle speed if available. The maximum and minimum speeds **MAY** be provided as attributes. At least one value **MUST** be provided.

6.1.16.1 `ProcessSpindleSpeed` attributes

Attribute	Description	Occurrence
maximum	The upper bound for the tool's target spindle speed	0..1
minimum	The lower bound for the tools spindle speed.	0..1
nominal	The nominal speed the tool is designed to operate at.	0..1

6.1.17 ProcessFeedRate

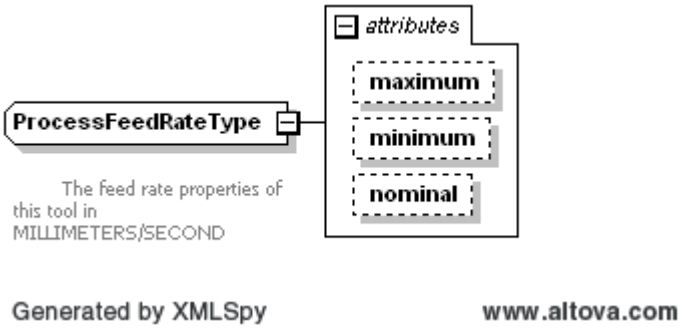


Figure 15: Process Feed Rate

The Process Feed Rate **MUST** be specified in millimeters/second (mm/s). The CDATA **MAY** contain the process target feed rate if available. The maximum and minimum rates **MAY** be provided as attributes. At least one value **MUST** be provided.

6.1.17.1 `ConnectionCodeMachineSide`

This is an optional identifier for implementation specific connection component of the cutting tool on the machine side. Code: `CCMS`. The CDATA **MAY** be any valid string according to the referenced connection code standards.

6.1.17.2 `ProcessSpindleSpeed` attributes

Attribute	Description	Occurrence
`maximum`	The upper bound for the tool's process target feed rate	0..1
`minimum`	The lower bound for the tools feed rate.	0..1
`nominal`	The nominal feed rate the tool is designed to operate at.	0..1

6.1.18 Measurements

The `Measurements` element is a collection of one or more constrained scalar values associated with this cutting tool. The contents **MUST** be a subtype of `CommonMeasurement` or `AssemblyMeasurement`. The following section will define the abstract `Measurement` type used in both `CuttingToolLifeCycle` and `CuttingItem`. This section will then describe the `AssemblyMeasurement` types. The `CuttingItemMeasurement` types will be described at the end of the `CuttingItem` section.

A measurement is specific to a process and a machine tool 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 does not standardize the manufacturing process or the definition of the zero point.

6.1.19 Measurement

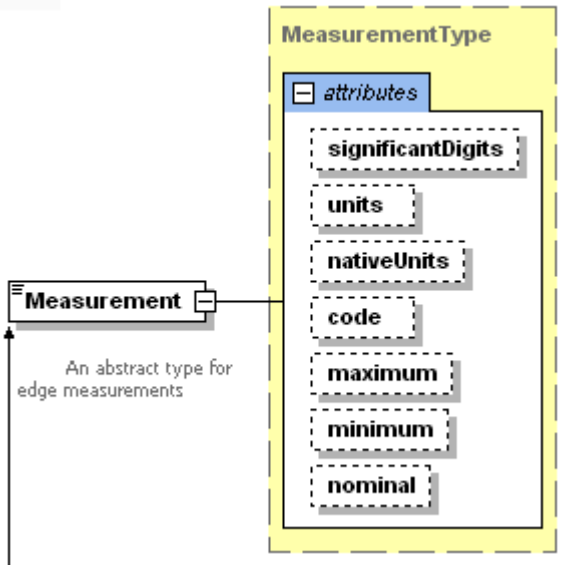


Figure 16: Measurement

A measurement **MUST** be a scalar floating point value that **MAY** be constrained to a maximum and minimum value. Since the `CuttingToolLifeCycle`'s main responsibility is to track aspects of the tool that change over it's use in the shop, MTConnect represents the current value of the measurement **MUST** be in the `CDATA` (text between the start and end element) as the most current valid value.

The minimum and maximum **MAY** be supplied if they are known or relevant to the measurement. A nominal value **MAY** be provided to show the reference value for this measurement.

There are three subtypes of `Measurement`: `CommonMeasurement`, `AssemblyMeasurement`, and `CuttingItemMeasurement`. These abstract types **MUST NOT** appear in an `MTConnectAssets` document, but are used in the schema as a way to separate which measurements **MAY** appear in the different sections of the document. Only subtypes that have extended these types **MAY** appear in the `MTConnectAssets` XML.

Measurements in the CuttingToolLifeCycle section **MUST** refer to the entire assembly and not to an individual cutting item. Cutting item measurements **MUST** be located in the measurements associated with the individual Cutting Item.

Measurements **MAY** provide an optional `units` attribute to reinforce the given units. The units **MUST** always be given in the predefined MTConnect units. If `units` are provided, they are only for documentation purposes. `nativeUnits` **MAY** optionally be provided to indicate the original units provided for the measurements.

6.1.19.1 `Measurement` attributes

Attribute	Description	Occurrence

Attribute	Description	Occurrence
code	A shop specific code for this measurement. ISO 13399 codes **MAY** be used to for these codes as well.	0..1
maximum	The maximum value for this measurement. Exceeding this value would indicate the tool is not usable.	0..1
minimum	The minimum value for this measurement. Exceeding this value would indicate the tool is not usable.	0..1
nominal	The as advertised value for this measurement.	0..1
significantDigits	The number of significant digits in the reported value. This is used by applications to determine accuracy of values. This **MAY** be specified for all numeric values.	0..1
units	The units for the measurements. MTConnect defines all the units for each measurement, so this is mainly for documentation sake. See *MTConnect Part 2 – Components and Data Items* section 4.1.5: units for the full list.	0..1
nativeUnits	The units the measurement was originally recorded in. This is only necessary if they differ from units. See *MTConnect Part 2 – Components and Data Items* section 4.1.8: nativeUnits for the full list.	0..1

6.1.20 CuttingToolMeasurement subtypes

These measurements are specific to the entire assembly and **MUST NOT** be used for the measurement pertaining to a CuttingItem. The following diagram will be used to for reference for the assembly specific measurements.

The Code in the following table will refer to the acronyms in the diagrams. We will be referring to many diagrams to disambiguate all measurements of the CuttingTool and CuttingItem.

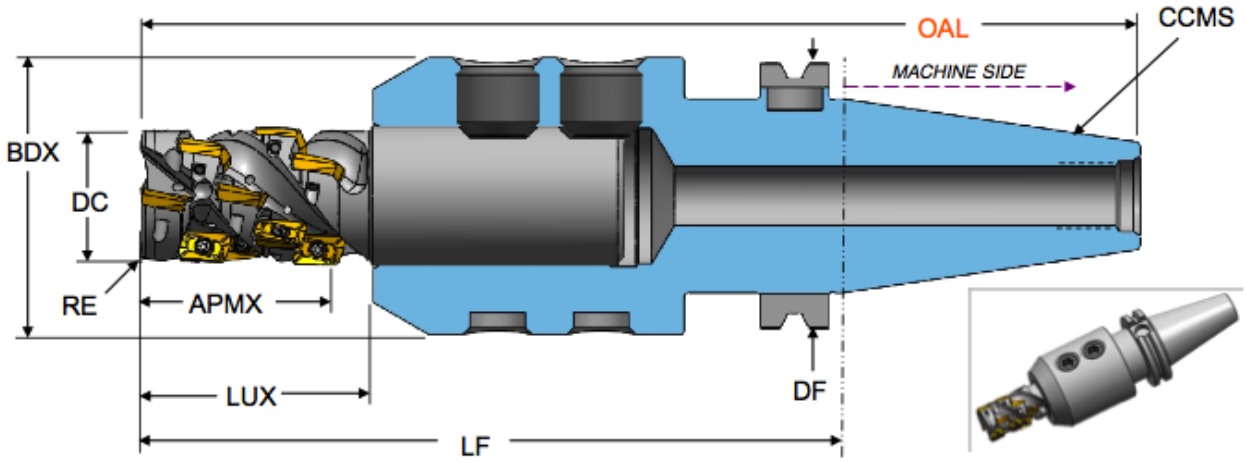


Figure 17: Cutting Tool Measurement Diagram 1
(Cutting Item, Tool Item, and Adaptive Item – ISO 13399)

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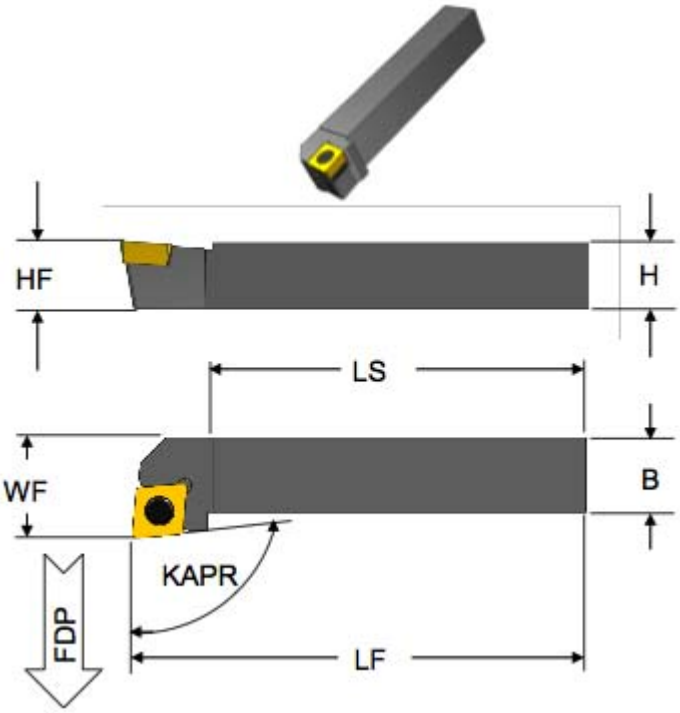

457

458 **Figure 18: Cutting Tool Measurement Diagram 2**
459 **(Cutting Item, Tool Item, and Adaptive Item – ISO 13399)**

Measurement	Code	Description	Units
BodyDiameterMax	BDX	The largest diameter of the body of a tool item.	mm
BodyLengthMax	LBX	The 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.	mm
DepthOfCutMax	APMX	The maximum engagement of the cutting edge or edges with the workpiece measured perpendicular to the feed motion.	mm
CuttingDiameterMax	DC	The maximum diameter of a circle on which the defined point Pk of each of the master inserts is located on a tool item. The normal of the machined peripheral surface points towards the axis of the cutting tool.	mm
FlangeDiameterMax	DF	The dimension between two parallel tangents on the outside edge of a flange.	mm
OverallToolLength	OAL	The largest length dimension of the cutting tool including the master insert where applicable.	mm
ShankDiameter	DMM	The dimension of the diameter of a cylindrical portion of a tool item or an adaptive item that can participate in a connection.	mm

Measurement	Code	Description	Units
ShankHeight	H	The dimension of the height of the shank.	mm
ShankLength	LS	The dimension of the length of the shank.	mm
UsableLengthMax	LUX	maximum length of a cutting tool that can be used in a particular cutting operation including the non-cutting portions of the tool.	mm
ProtrudingLength	LPR	The dimension from the yz-plane to the furthest point of the tool item or adaptive item measured in the -X direction.	mm
Weight	WT	The total weight of the cutting tool in grams. The force exerted by the mass of the cutting tool.	grams
FunctionalLength	LF	The 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.	mm

6.1.21 CuttingItems

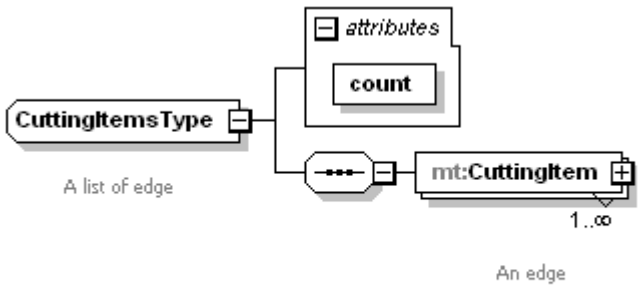

Figure 19: Cutting Items

An optional collection of cutting items that **SHOULD** be provided for each independent edge or insert. If the CuttingItems are not present; it indicates there is no specific information with respect to each of the cutting items. This does not imply there are no cutting items – there **MUST** be at least one cutting item – but there is no specific information.

6.1.21.1 CuttingItems attributes

Attribute	Description	Occurrence
count	The number of cutting items.	1

6.1.22 CuttingItem

A cutting item 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

tool item or it can be one or more separate pieces of material attached to the tool item using a permanent or removable attachment. A cutting item can be comprised of one or more cutting edges. Cutting items include: replaceable inserts, brazed tips and the cutting portions of solid cutting tools.

MTConnect considers Cutting Items as part of the Cutting Tool. A Cutting Item **MUST NOT** exist in MTConnect unless it is attached to a cutting tool. Some of the measurements, such as `FunctionalLength`, **MUST** be made with reference to the entire cutting tool to be meaningful.

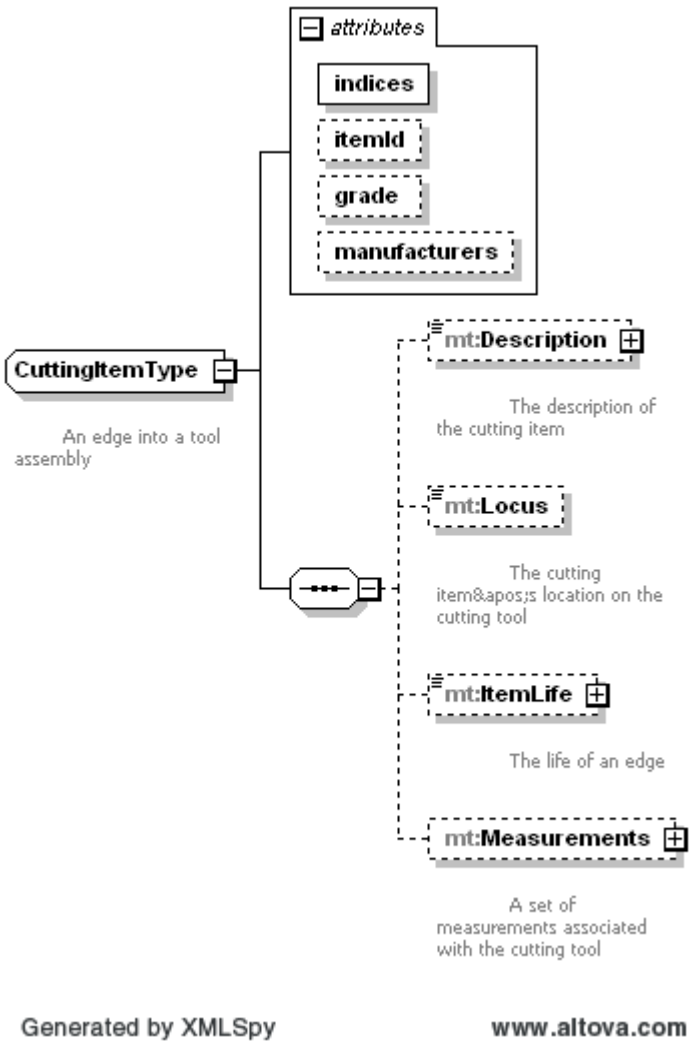

Figure 20: Cutting Item

6.1.22.1 `CuttingItem` attributes

Attribute	Description	Occurrence
`indices`	The number or numbers representing the individual cutting item or items on the tool.	1
`itemId`	The manufacturer identifier of this cutting item	0..1

Attribute	Description	Occurrence
manufacturers	The manufacturers of the cutting item	0..1
grade	The material composition for this cutting item	0..1

6.1.22.2 indices

An identifier that indicates the cutting item or items these data are associated with. The value **MUST** a single numbers (“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.

Indices **SHOULD** start numbering with the inserts or cutting items 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.

6.1.22.3 itemId

The manufactures’ identifier for this cutting item that **MAY** be the its catalog or reference number. The value **MUST** be an XML NMTOKEN value of numbers and letters.

6.1.22.4 manufacturers

This optional element references the manufacturers of this tool. At this level the manufacturers will reference the Cutting Item specifically. The representation will be a comma (`,`) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type `string`.

6.1.22.5 grade

This provides an implementation specific designation for the material composition of this cutting item.

6.1.23 A `CuttingItem` contains the following elements.

Element	Description	Occurrence
Description	A free-form description of the cutting item.	0..1
Locus	A free form description of the location on the cutting tool.	0..1
ItemLife	The life of this cutting item.	0..3
Measurements	A collection of measurements relating to this cutting item.	0..1

6.1.24 Description

An optional free form text description of this cutting item.

6.1.25 Locus

Locus represents the location of the cutting item with respect to the cutting tool. For clarity, the words FLUTE, INSERT, and CARTRIDGE **SHOULD** be used to assist in noting the location of

a cutting item. The Locus **MAY** be any free form text, but **SHOULD** adhere to the following rules:

1. The location numbering **SHOULD** start at the furthest cutting item (#1) and work it's way back to the cutting item closest to the gauge line.

2. 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.

3. Other designations such as `CARTRIDGE` **MAY** be included, but should be identified using upper case and followed by a colon (`:`).

6.1.26 ItemLife

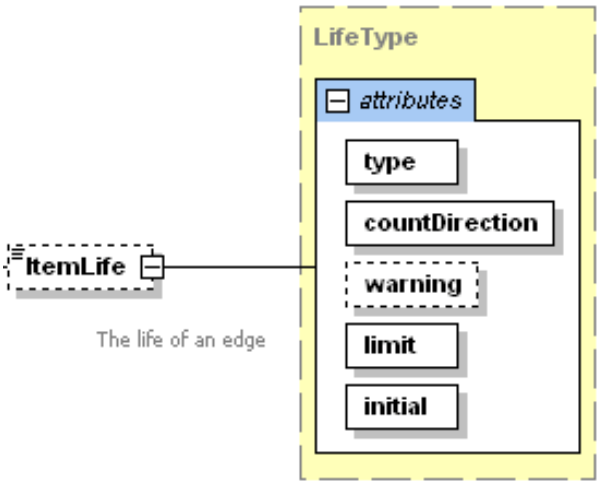

Figure 21: Item Life

The value is the current value for the tool life. The value **MUST** be a number. Tool life is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One tool life can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

6.1.26.1 ItemLife attributes:

These is an optional attribute that can be used to further classify the operation type.

Attribute	Description	Occurrence
`type`	The type of tool life being accumulated. `MINUTES`, `PART_COUNT`, or `WEAR`	1
`countDirection`	Indicates if the tool life counts from zero to maximum or maximum to zero, The values **MUST** be one of `UP` or `DOWN.`	1
`warning`	The point at which a tool life warning will be raised.	0..1

Attribute	Description	Occurrence
limit	The end of life limit for this tool. If the countDirection is DOWN, the point at which this tool should be expired, usually zero. If the countDirection is UP, this is the upper limit for which this tool should be expired.	0..1
initial	The initial life of the tool when it is new.	0..1

6.1.26.1.1 ItemLife type attribute:

The value of type must be one of the following:

Value	Description
MINUTES	The tool life measured in minutes. All units for minimum, maximum, and warningLevel **MUST** be provided in minutes.
PART_COUNT	The tool life measured in parts. All units for minimum, maximum, and warningLevel **MUST** be provided supplied as the number of parts.
WEAR	The tool life measured in tool wear. Wear **MUST** be provided in millimeters as an offset to nominal. All units for minimum, maximum, and warningLevel **MUST** be given as millimeter offsets as well.

6.1.26.1.2 ItemLife direction attribute:

The value of type must be one of the following:

Value	Description
DOWN	The tool life counts down from the maximum to zero.
UP	The tool life counts up from zero to the maximum.

6.1.27 CuttingItemMeasurement subtypes

These measurements are specific to an individual cutting item and **MUST NOT** be used for the measurement pertaining to an assembly. The following diagram will be used to for reference for the cutting item specific measurements.

The Code in the following table will refer to the acronym in the diagram. We will be referring to many diagrams to disambiguate all measurements of the cutting tools and items. We will present a few here; please refer to Appendix B for additional reference material.

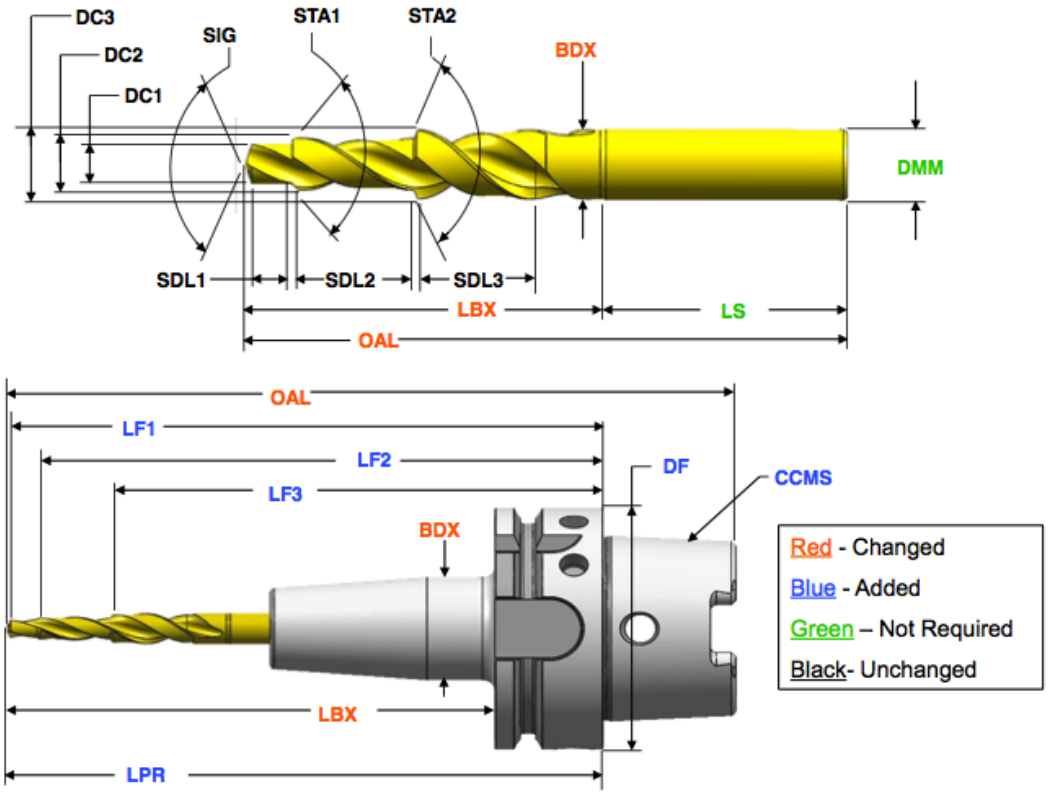

Figure 22: Cutting Tool

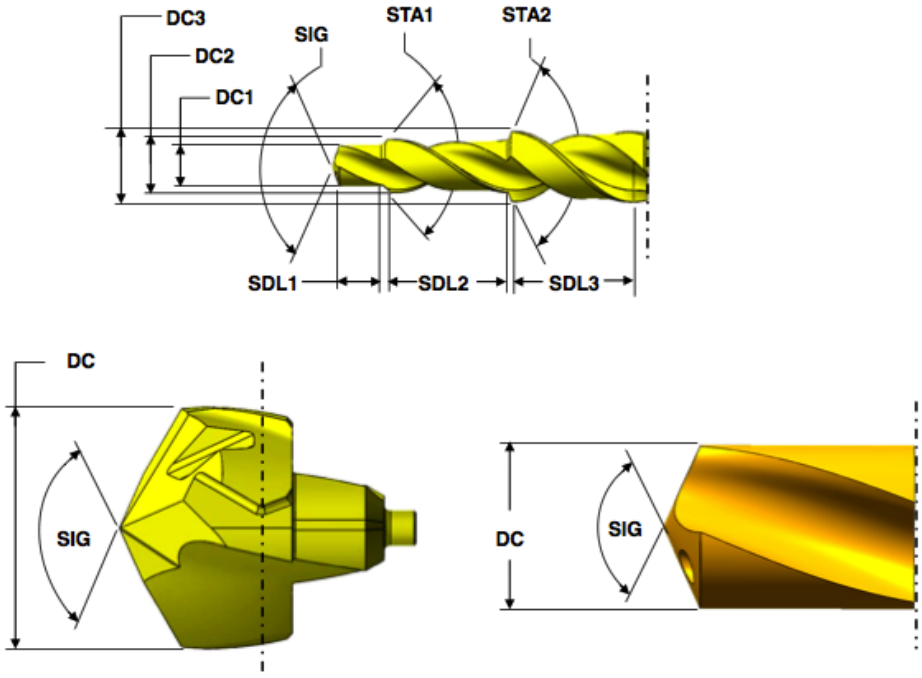

Figure 23: Cutting Item

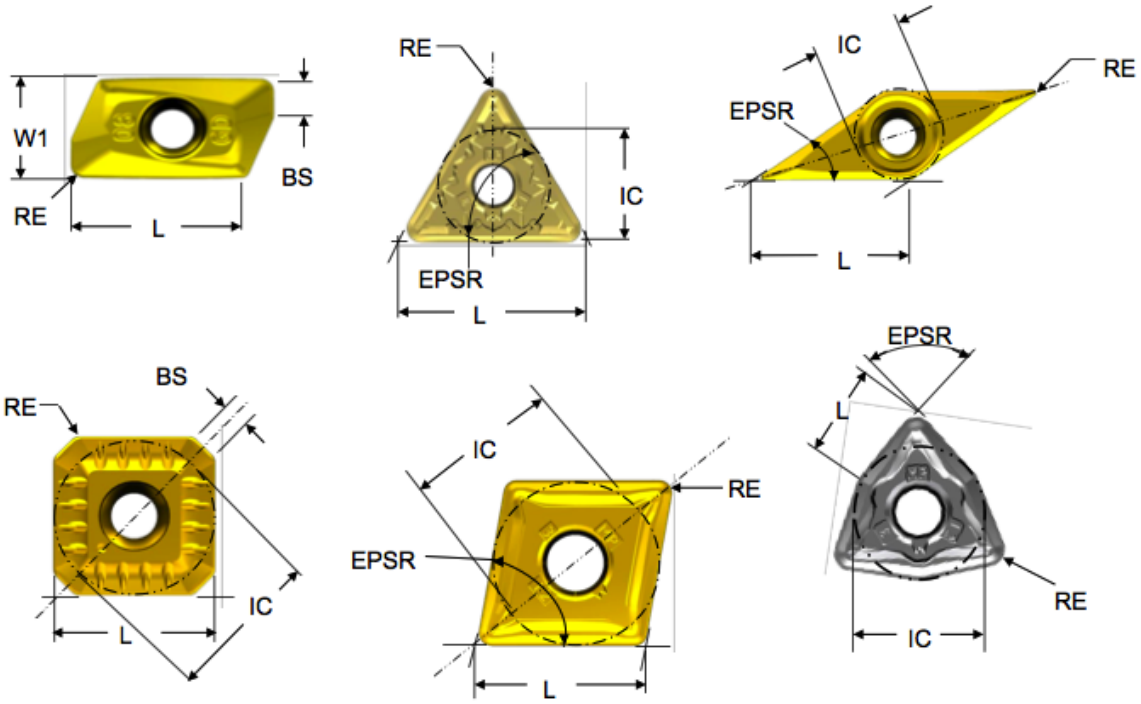

Figure 24: Cutting Item Measurement Diagram 3
(Cutting Item – ISO 13399)

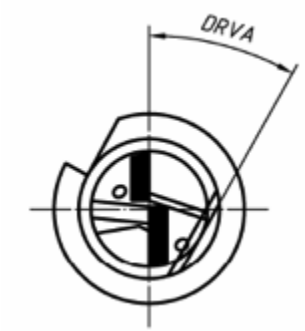

Figure 25: Cutting Item Drive Angle
(Cutting Item – ISO 13399)

The following `CuttingItem Measurements` will refer the diagram above.

Measurement	Code	Description	Units
`CuttingReferncePoint`	`CRP`	The theoretical sharp point of the cutting tool from which the major functional dimensions are taken.	mm
`CuttingEdgeLength`	`L`	The theoretical length of the cutting edge of a cutting item over sharp corners.	mm
`DriveAngle`	`DRVA`	Angle between the driving mechanism locator on a tool item and the main cutting edge	degree

Measurement	Code	Description	Units
FlangeDiameter	DF	The dimension between two parallel tangents on the outside edge of a flange.	mm
FunctionalWidth	WF	The distance between the cutting reference point and the rear backing surface of a turning tool or the axis of a boring bar.	mm
IncribedCircleDiameter	IC	The diameter of a circle to which all edges of a equilateral and round regular insert are tangential.	mm
PointAngle	SIG	The angle between the major cutting edge and the same cutting edge rotated by 180 degrees about the tool axis.	degree
ToolCuttingEdgeAngle	KAPR	The angle between the tool cutting edge plane and the tool feed plane measured in a plane parallel the xy-plane.	degree
ToolLeadAngle	PSIR	The angle between the tool cutting edge plane and a plane perpendicular to the tool feed plane measured in a plane parallel the xy-plane.	degree
ToolOrientation	N/A	The angle of the tool with respect to the workpiece for a given process. The value is application specific.	degree
WiperEdgeLength	BS	The measure of the length of a wiper edge of a cutting item.	mm
StepDiameterLength	SDLx	The 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.	mm
StepIncludedAngle	STAx	The angle between a major edge on a step of a stepped tool and the same cutting edge rotated 180 degrees about its tool axis.	degree
CuttingDiameter	DCx	The nominal radius of a rounded corner measured in the XY-plane.	mm
CuttingHeight	HF	The distance from the basal plane of the tool item to the cutting point.	mm
CornerRadius	RE	The nominal radius of a rounded corner measured in the X Y-plane.	mm
Weight	WT	The total weight of the cutting tool in grams. The force exerted by the mass of the cutting tool.	grams
FunctionalLength	LFx	The distance from the gauge plane or from the end of the shank of the cutting tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool. This measurement will be with reference to the Cutting Tool and **MUST NOT** exist without a cutting tool.	mm
ChamferFlatLength	BCH	The flat length of a chamfer.	mm
ChamferWidth	CHW	The width of the chamfer	mm
InsertWidth	W1	W1 is used for the insert width when an inscribed circle diameter is not practical.	mm

Appendices

A. Bibliography

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15. International Organization for Standardization. *ISO 13399*: *Cutting tool data representation and exchange*. Geneva, Switzerland, 2000.

B. Additional Illustrations

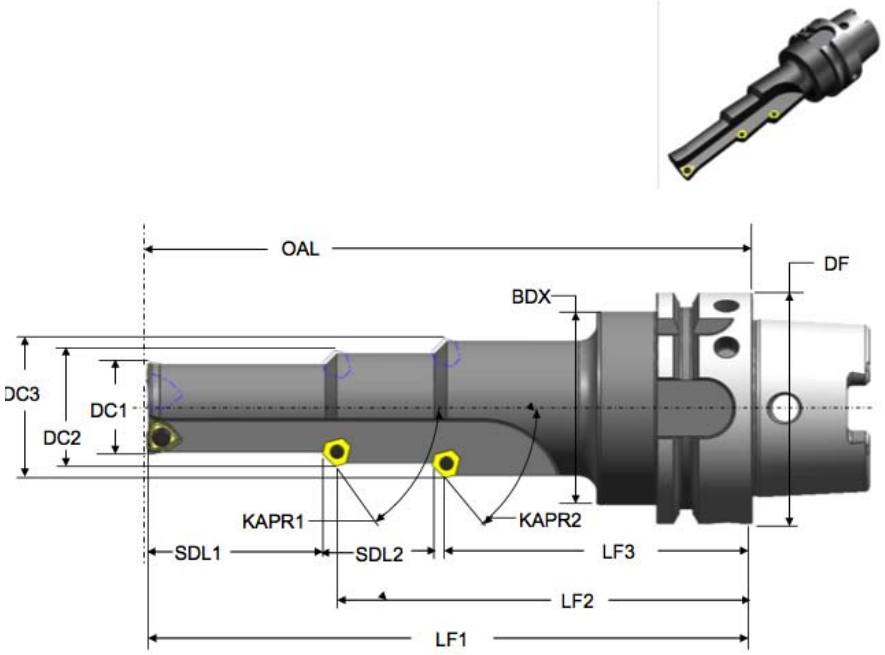


Figure 26: Cutting Tool Measurement Diagram 1
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)

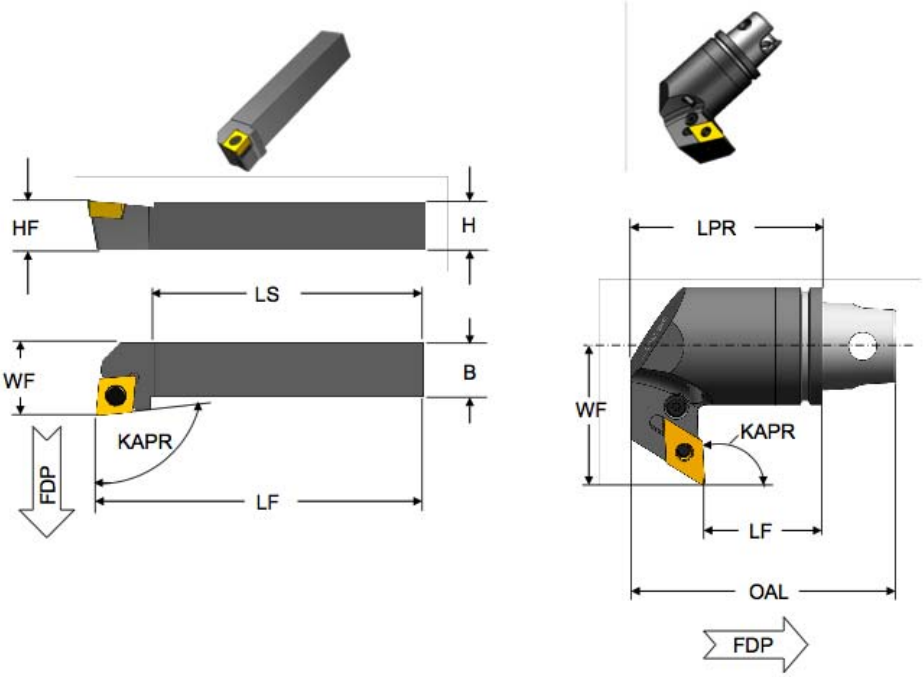
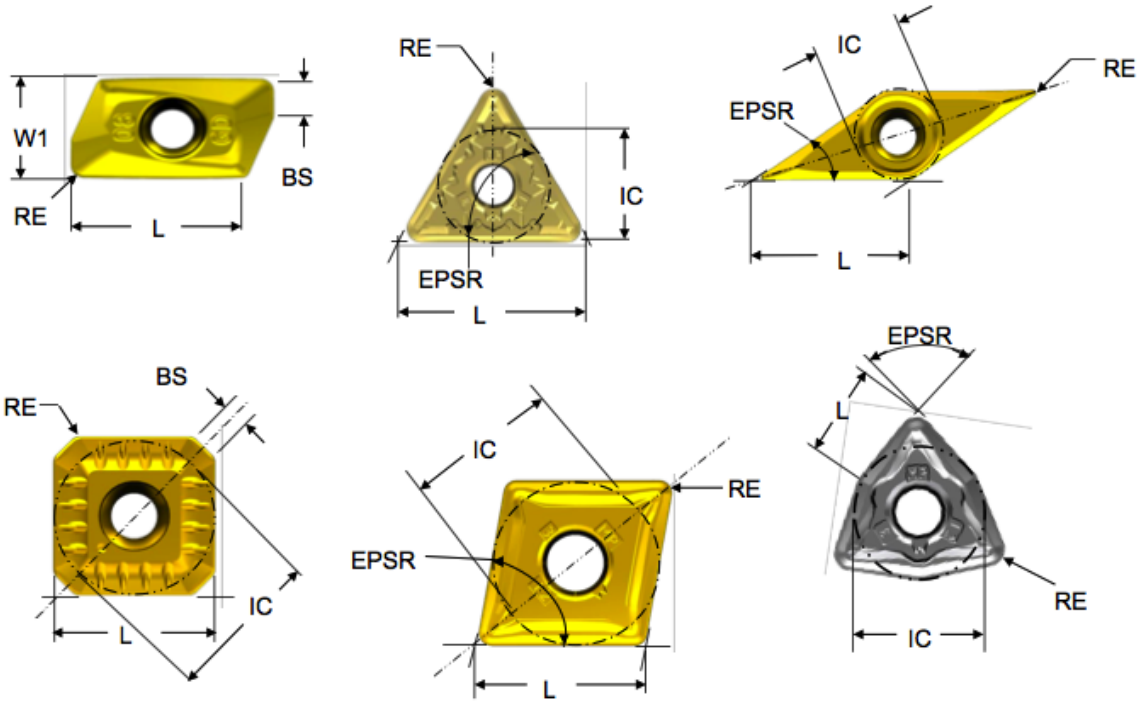
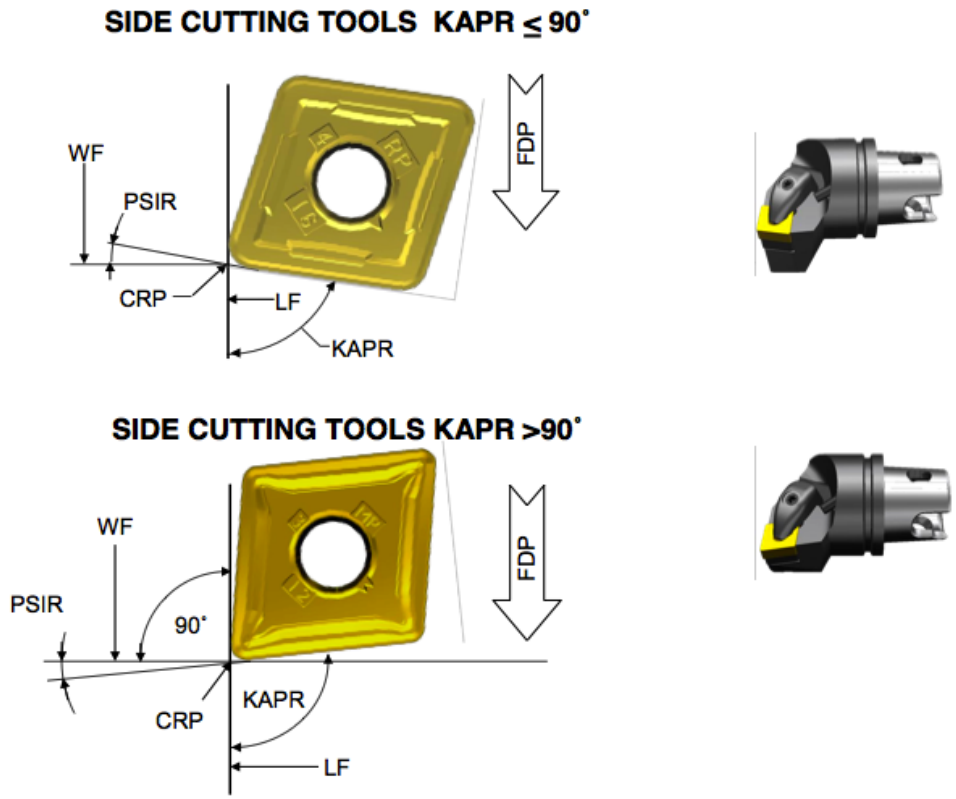


Figure 27: Cutting Tool Measurement Diagram 2
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)



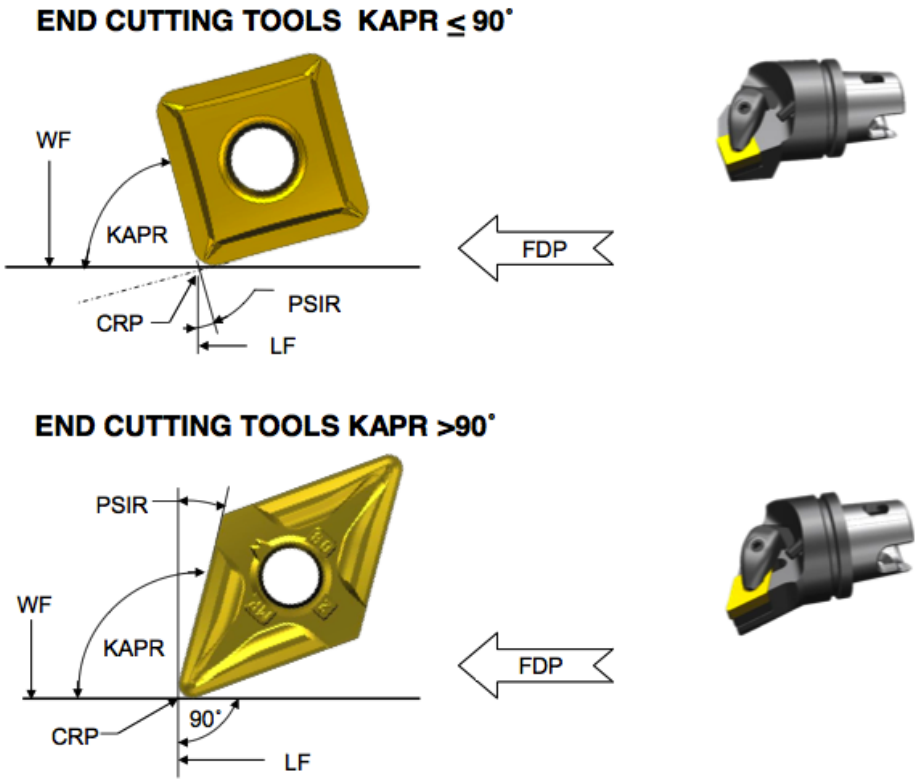
606

607 **Figure 28: Cutting Item Measurement Diagram 3**
608 **(Cutting Item – ISO 13399)**



609

610 **Figure 29: Cutting Item Measurement Diagram 4**
611 **(Cutting Item – ISO 13399)**

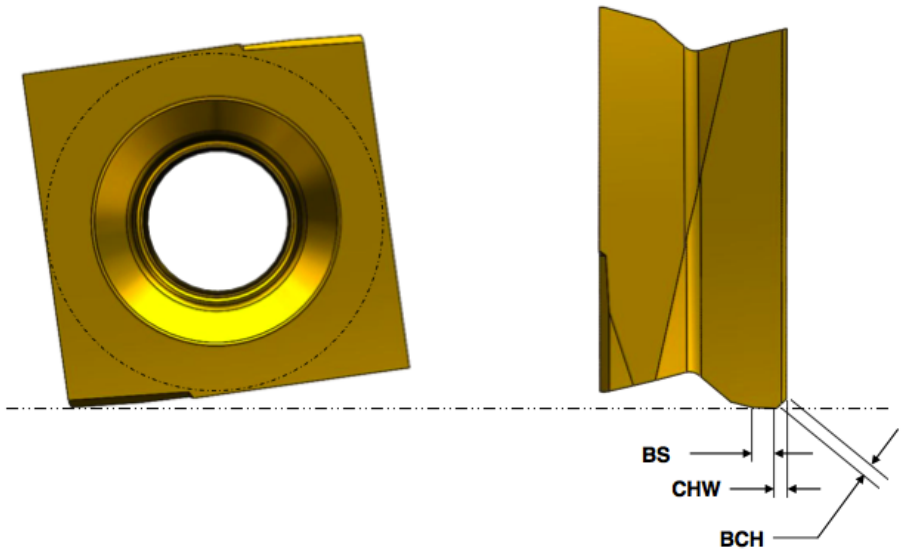


612

613 **Figure 30: Cutting Item Measurement Diagram 5**
614 **(Cutting Item – ISO 13399)**

BCH = CHAMFER FLAT LENGTH

CHW = CHAMFER WIDTH

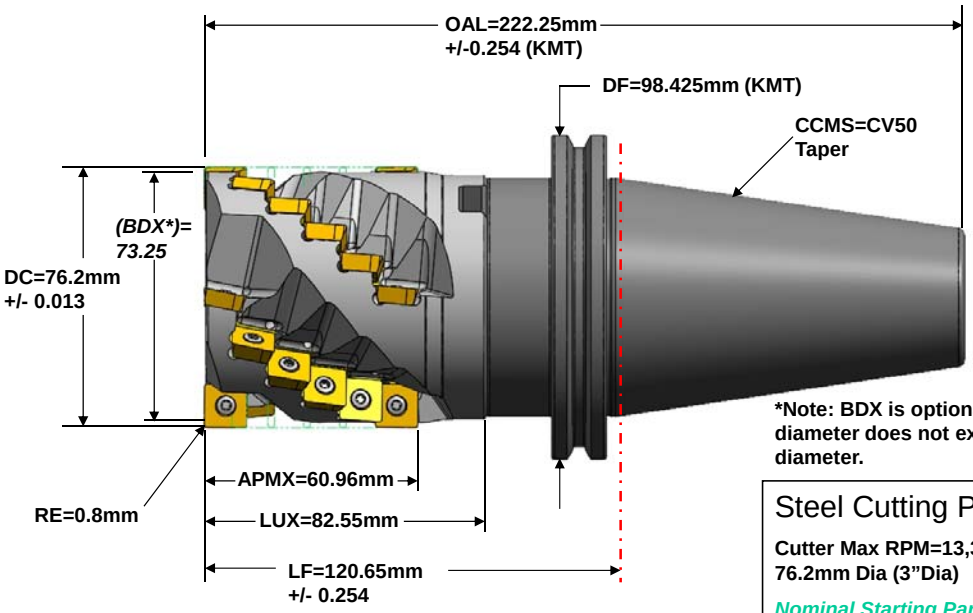


615

616 **Figure 31: Cutting Item Measurement Diagram 6**
617 **(Cutting Item – ISO 13399)**

C. Cutting Tool Example

C.1 Shell Mill



*Note: BDX is optional since the body diameter does not exceed the cutting diameter.

Steel Cutting Parameters:

Cutter Max RPM=13,300, 4 Flutes , 76.2mm Dia (3”Dia)

Nominal Starting Parameters:

605 RPM

0.23mm//tooth (0.009”)

M/min 144.8 (475 SFM)

Feed Rate 553.2mm/min (21.78 in/min)

Shellmill – KMT, KSSP300R4SD43L240

Adapter – Parlec, C50-12SM1

Insert – KMT, SDET43PDER8GB Grade KC725M

Figure 32: Shell Mill Side View

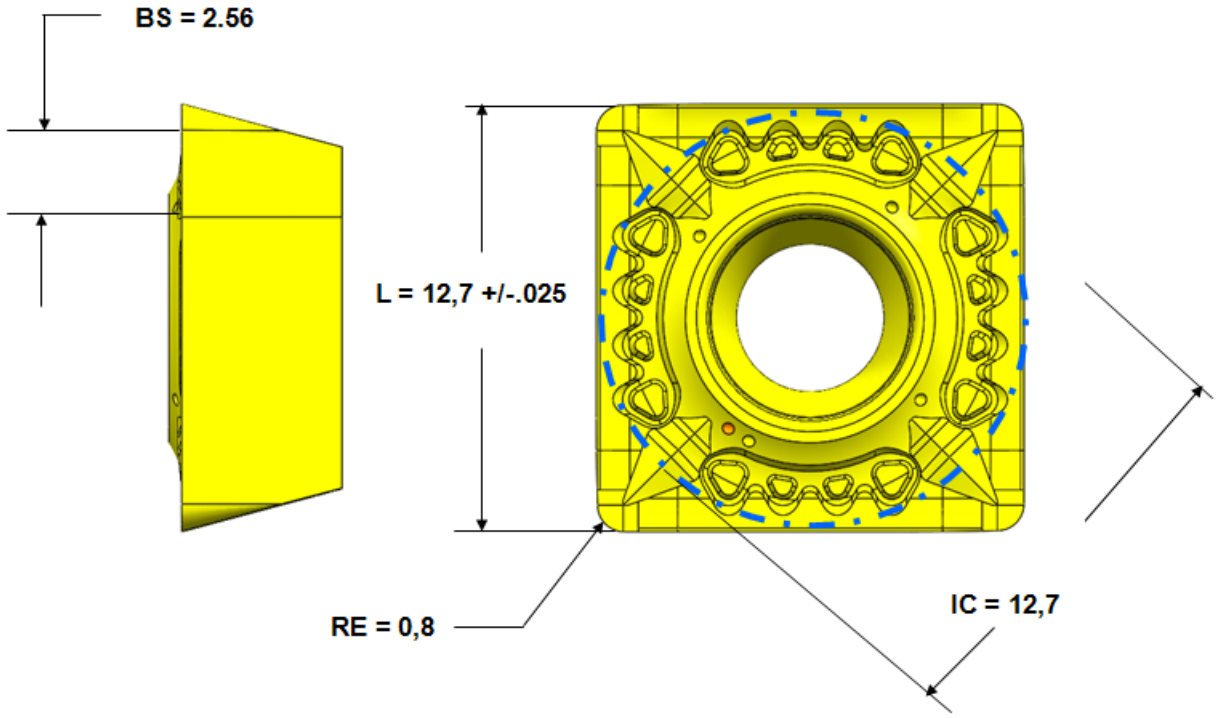
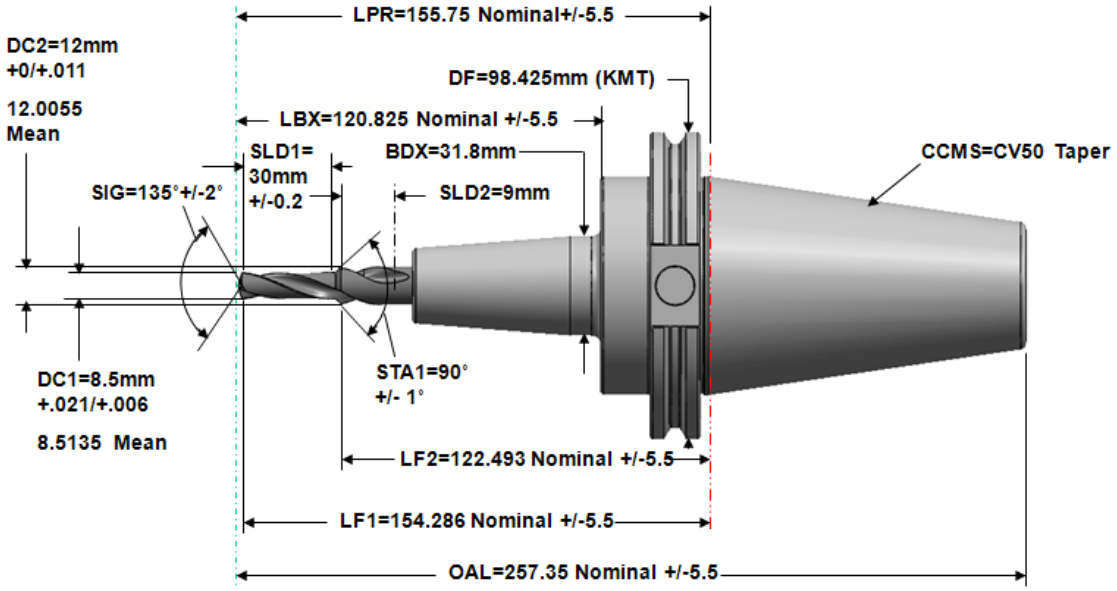


Figure 33: Indexable Insert Measurements

```
<?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_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">
     <CuttingToolLifeCycle>
      <CutterStatus><Status>NEW</Status></CutterStatus>
      <ProcessSpindleSpeed maximum="13300"
   nominal="605">10000</ProcessSpindleSpeed>
      <ProcessFeedRate nominal="9.22">9.22</ProcessSpindleSpeed>
      <ConnectionCodeMachineSide>CV50</ConnectionCodeMachineSide>
      <Measurements>
       <BodyDiameterMax code="BDX">73.25</BodyDiameterMax>
       <OverallToolLength nominal="222.25" 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>
```

C.2 Step Drill



Step Drill – KMT, B732A08500HP Grade KC7315

Adapter – Parlec, C50-M12SF300-6

Note: Adapter Dimensions Shown are for KMT holder which has adjustable length of +/-5mm (Drill length tolerance =+1/-0).

P3 Steel Drilling Parameters

Nominal Starting Parameters:

150 m/min (493 SFM)

0,23 mm/r (0.0085 in/r)

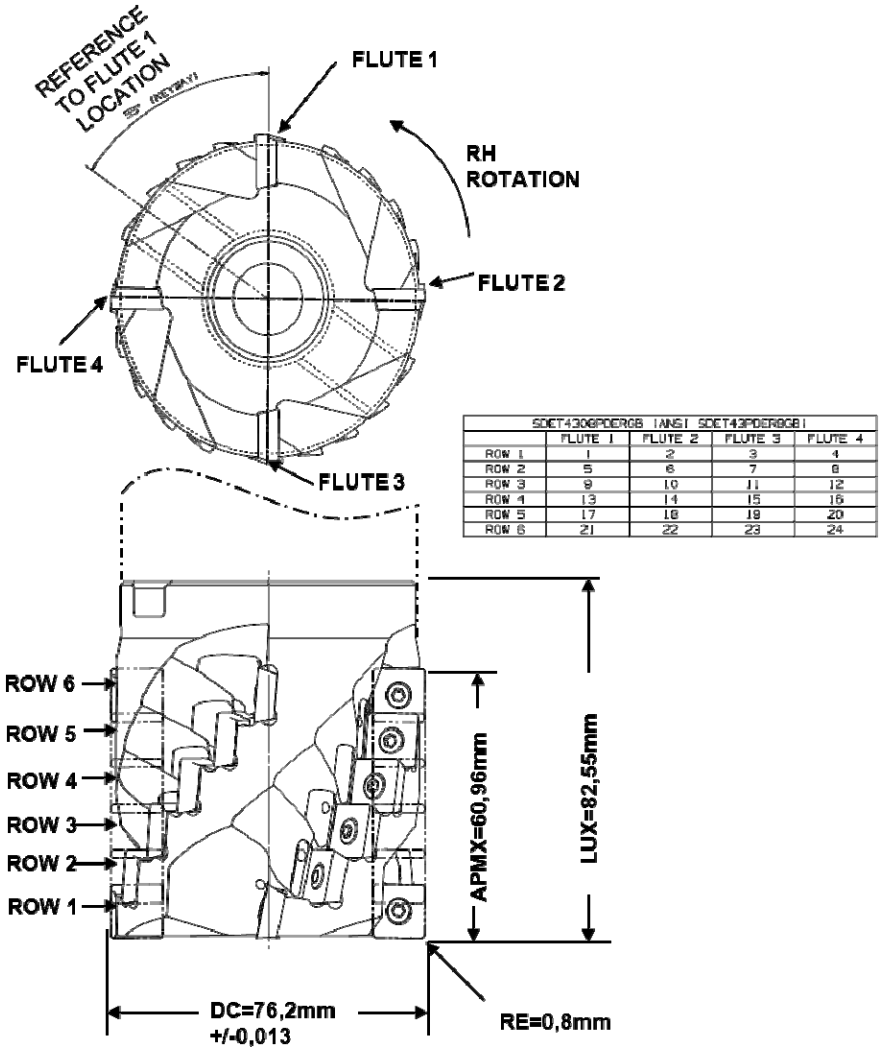
RPM 5893

Figure 34: Step Drill 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_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>
```

```
695         <CutterStatus><Status>NEW</Status></CutterStatus>
696         <ProcessSpindleSpeed nominal="5893">5893</ProcessSpindleSpeed>
697         <ProcessFeedRate nominal="2.5">2.5</ProcessFeedRate>
698         <ConnectionCodeMachineSide>CV50 Taper</ConnectionCodeMachineSide>
699         <Measurements>
700           <BodyDiameterMax code="BDX">31.8</BodyDiameterMax>
701           <BodyLengthMax code="LBX" nominal="120.825" maximum="126.325"
702       minimum="115.325">120.825</BodyLengthMax>
703           <ProtrudingLength code="LPR" nominal="155.75" maximum="161.25"
704       minimum="150.26">155.75</ProtrudingLength>
705           <FlangeDiameterMax code="DF"
706       nominal="98.425">98.425</FlangeDiameterMax>
707           <OverallToolLength nominal="257.35" minimum="251.85" maximum="262.85"
708       code="OAL">257.35</OverallToolLength>
709         </Measurements>
710         <CuttingItems count="2">
711           <CuttingItem indices="1" manufacturers="KMT" grade="KC7315">>
712             <Measurements>
713               <CuttingDiameter code="DC1" nominal="8.5" maximum="8.521"
714       minimum="8.506">8.5135</CuttingDiameter>
715               <StepIncludedAngle code="STA1" nominal="90" maximum="91"
716       minimum="89">90</StepIncludedAngle>
717               <FunctionalLength code="LF1" nominal="154.286" minimum="148.786"
718       maximum="159.786">154.286</FunctionalLength>
719               <StepDiameterLength code="SDL1" nominal="9">9</StepDiameterLength>
720               <PointAngle code="SIG" nominal="135" minimum="133"
721       maximum="137">135</PointAngle>
722             </Measurements>
723           </CuttingItem>
724           <CuttingItem indices="2" manufacturers="KMT" grade="KC7315">>
725             <Measurements>
726               <CuttingDiameter code="DC2" nominal="12" maximum="12.011"
727       minimum="12">12</CuttingDiameter>
728               <FunctionalLength code="LF2" nominal="122.493" maximum="127.993"
729       minimum="116.993">122.493</FunctionalLength>
730               <StepDiameterLength code="SDL2" nominal="9">9</StepDiameterLength>
731             </Measurements>
732           </CuttingItem>
733         </CuttingItems>
734       </CuttingToolLifeCycle>
735     </CuttingTool>
736     </Assets>
737   </MTConnectAssets>
```

C.3 Shell Mill with Individual Loci



SDET4306PDER08 (ANSI SDET43PDER08)

	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 35: 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_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" send-
er="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>
```

```
757         <CuttingDiameterMax code="DC" nominal="76.2" maximum="76.213" mini-
758   mum="76.187">76.2</CuttingDiameterMax>
759         <DepthOfCutMax code="APMX" nominal="60.96">60.95</DepthOfCutMax>
760        </Measurements>
761        <CuttingItems count="24">
762         <CuttingItem indices="1" itemId="SDET43PDER8GB" manufacturers="KMT">
763          <Locus>FLUTE: 1, ROW: 1</Locus>
764          <Measurements>
765            <DriveAngle code="DRVA" nominal="55">55</DriveAngle>
766          </Measurements>
767         </CuttingItem>
768         <CuttingItem indices="2-24" itemId="SDET43PDER8GB" manufacturers="KMT">
769          <Locus>FLUTE: 2-4, ROW: 1; FLUTE: 1-4, ROW 2-6</Locus>
770         </CuttingItem>
771        </CuttingItems>
772       </CuttingToolLifeCycle>
773     </CuttingTool>
774   </Assets>
775  </MTConnectAssets>
776
```

C.4 Drill with Individual Loci

KSEM0781LD , GRADE= KC7015		
	FLUTE 1	FLUTE 2
ROW 1	1	~
TPMT-21.52-FP, GRADE=KCM15		
ROW 2	2	3

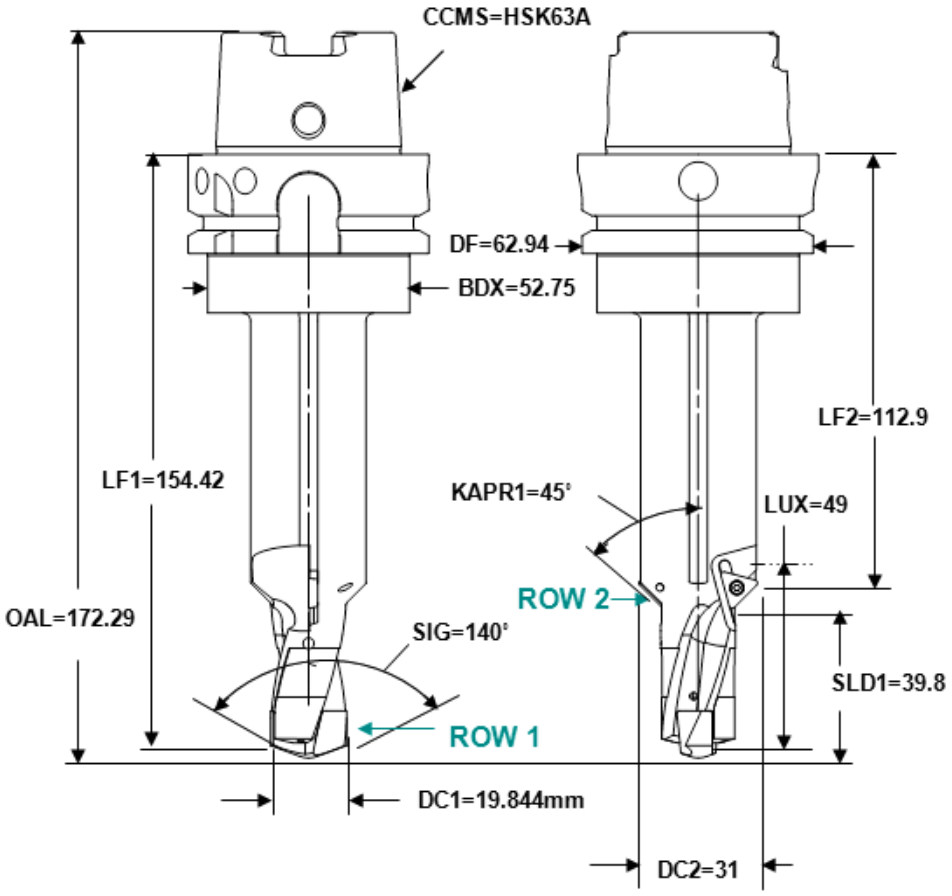
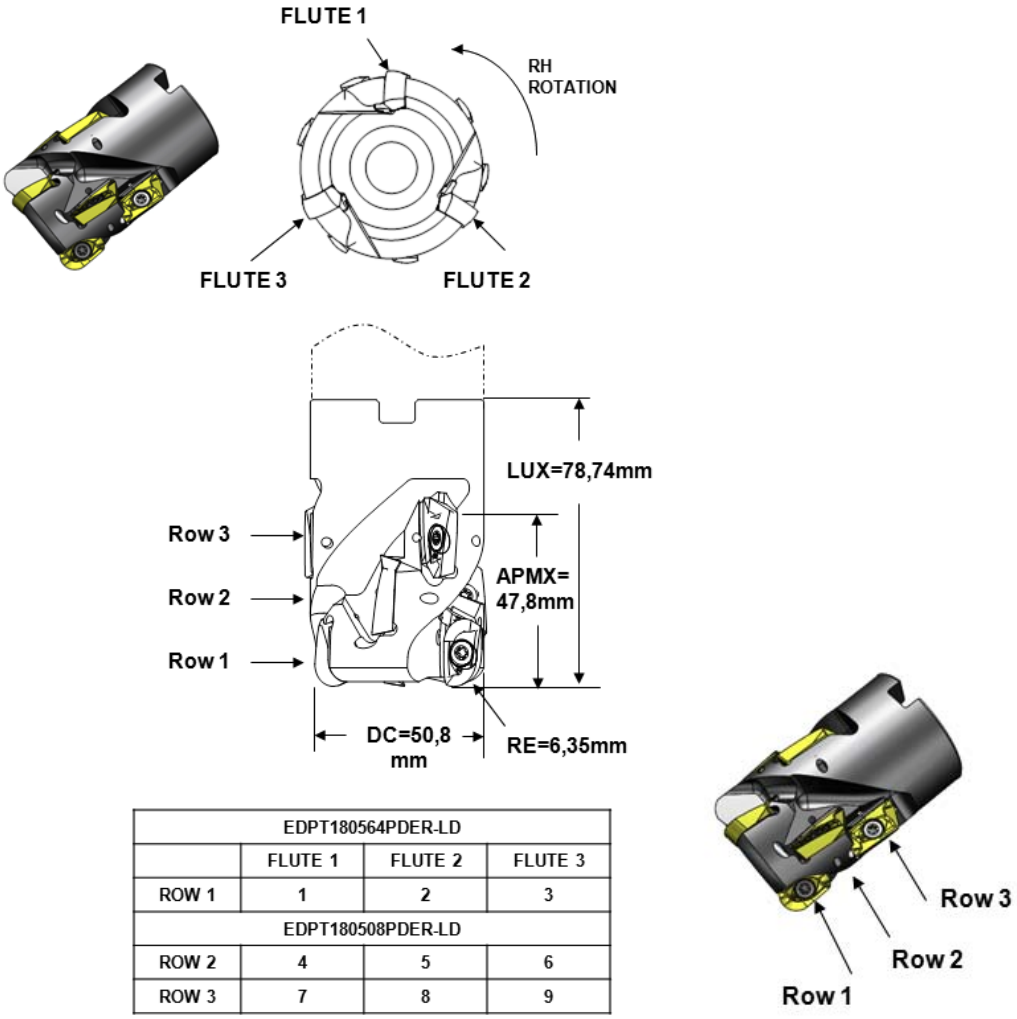


Figure 36: Step Drill with Explicate Loci

```
<?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_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" send-
er="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">
```

```
791       <CuttingToolLifeCycle>
792         <CutterStatus><Status>NEW</Status></CutterStatus>
793         <ConnectionCodeMachineSide>HSK63A</ConnectionCodeMachineSide>
794         <Measurements>
795           <BodyDiameterMax code="BDX">52.75</BodyDiameterMax>
796           <OverallToolLength nominal="172.29"
797   code="OAL">172.29</OverallToolLength>
798           <UsableLengthMax code="LUX" nominal="49">49</UsableLengthMax>
799           <FlangeDiameterMax code="DF" nominal="62.94">62.94</FlangeDiameterMax>
800         </Measurements>
801         <CuttingItems count="3">
802           <CuttingItem indices="1" itemId="KSEM0781LD" manufacturers="KMT"
803   grade="KC7015">
804             <Locus>FLUTE: 1, ROW: 1</Locus>
805             <Measurements>
806               <FunctionalLength code="LF1" nomin-
807   al="154.42">154.42</FunctionalLength>
808               <CuttingDiameter code="DC1" nomin-
809   al="19.844">19.844</CuttingDiameter>
810               <PointAngle code="SIG" nominal="140">140</PointAngle>
811               <ToolCuttingEdgeAngle code="KAPR1" nomin-
812   al="45">45</ToolCuttingEdgeAngle>
813               <StepDiameterLength code="SLD1" nomin-
814   al="39.8">39.8</StepDiameterLength>
815             </Measurements>
816           </CuttingItem>
817           <CuttingItem indices="2-3" itemId="TPMT-21.52-FP" manufacturers="KMT"
818   grade="KCM15">
819             <Locus>FLUTE: 1-2, ROW: 2</Locus>
820             <Measurements>
821               <FunctionalLength code="LF2" nomin-
822   al="112.9">119.2</FunctionalLength>
823               <CuttingDiameter code="DC2" nominal="31">31</CuttingDiameter>
824             </Measurements>
825           </CuttingItem>
826         </CuttingItems>
827       </CuttingToolLifeCycle>
828     </CuttingTool>
829   </Assets>
830 </MTConnectAssets>
```

C.5 Shell Mill with Different Inserts on First Row



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 37: 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_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" send-
er="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="XXX" timestamp="2011-05-11T13:55:22"
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>
```

```
852         <CuttingItems count="9">
853           <CuttingItem indices="1-3" itemId="EDPT180564PDER-LD" manufactur-
854   ers="KMT">
855             <Locus>FLUTE: 1-3, ROW: 1</Locus>
856             <Measurements>
857               <CornerRadius code="RE" nominal="6.25">6.35</CornerRadius>
858             </Measurements>
859           </CuttingItem>
860           <CuttingItem indices="4-9" itemId="EDPT180508PDER-LD" manufactur-
861   ers="KMT">
862             <Locus>FLANGE: 1-4, ROW: 2-3</Locus>
863           </CuttingItem>
864         </CuttingItems>
865       </CuttingToolLifeCycle>
866     </CuttingTool>
867   </Assets>
868 </MTConnectAssets>
869
```