

Physikalisch- Technische Bundesanstalt



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Instructions on how to use the DCC
schema to create a digital
calibration certificate for force

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Deutscher Kalibrierdienst (DKD) – German Calibration Service

Since its foundation in 1977, the German Calibration Service has brought together calibration laboratories of industrial enterprises, research institutes, technical authorities, inspection and testing institutes. On 3rd May 2011, the German Calibration Service was reestablished as a technical body of PTB and accredited laboratories.

This body is known as Deutscher Kalibrierdienst (DKD for short) and is under the direction of PTB. The guidelines and guides developed by DKD represent the state of the art in the respective areas of technical expertise and can be used by the Deutsche Akkreditierungsstelle GmbH (the German accreditation body – DAkkS) for the accreditation of calibration laboratories.

The accredited calibration laboratories are now accredited and supervised by DAkkS as legal successor to the DKD. They carry out calibrations of measuring instruments and measuring standards for the measurands and measuring ranges defined during accreditation. The calibration certificates issued by these laboratories prove the traceability to national standards as required by the family of standards DIN EN ISO 9000 and DIN EN ISO/IEC 17025.

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Foreword

DKD expert reports aim to provide background information and references in connection with other DKD documents as, for example, the DKD guidelines. In some cases, they may even go far beyond these documents. They do not replace the original DKD documents but do provide a lot of supplementary information worth knowing. The expert reports do not necessarily reflect the views of the DKD's Management Board or Technical Committees in all details.

DKD expert reports are intended to present significant aspects from the field of calibration. Through publication by the DKD they are made available to the large community of calibration laboratories, both nationally and internationally.




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0 Editorial note

Chapters 1 and 2 of this expert report are based on an equivalent expert report on DCCs for weights and mass [1] and have been adapted where necessary to ISO 376 [2] DCCs. These chapters cover general aspects of Digital Calibration Certificates.

1 Background

Advancing digitalisation does also affect the field of calibration. In view of this development and responding to the needs of industry, the digital calibration certificate (DCC) has been developed [3] [4]. The DCC is an XSD file (XML Schema Definition) that serves as a kind of template for digital calibration certificates for all measurands in XML format (Extensible Markup Language). Its implementation therefore requires further, subject-related specifications. To examine potential applications for the force calibration and to determine the related specifications, the DKD Technical Committees *Force and Acceleration* and *Torque* have set up a group of experts who have created the present document.

This document describes the contents of the digital calibration certificate for force calibration. All considerations made here are intended for calibration according to ISO 376 [2]. The focus here is on the flexible information in the DCC. The mandatory information, such as details of the calibration laboratory, customer or calibration date, is described in [1]. The application of the specifications described here to similar calibration items, such as force standards, is possible in many cases without any problems.

The present document refers to version 3.3.0 of the DCC schema. For implementation, it is recommended to refer to the latest version of the schema. This version is completely downward compatible and allows, among other things, improved indication of references.


Given the continuous changes in the field of digital certificates, this report can only reflect the current state of discussions – something to be considered in any kind of evaluation or referencing. These changes may refer to changes in the schema file or to higher-level specifications such as coordinated *refType* attributes. The validity of the remaining regulations remains unaffected.

2 DCC – General remarks

The term DCC is used hereinafter to refer to the XSD schema file and its specifications. Detailed examples of the implementation in an XML file can be found in the tables and in the appendix.

2.1 Structure

The general structure of the DCC is described on the [DCCWiki](#). The DCC consists of the root element `dcc:digitalCalibrationCertificate`, which contains two mandatory child elements `dcc:administrativeData` and `dcc:measurementResults`. Additionally, there are three optional child elements, i.e. `dcc:comments`, `dcc:document`, and `ds:Signature`. Most elements within the root element `dcc:digitalCalibrationCertificate` contain several child elements in which the actual information, such as calibration certificate number, customer information, and calibration results,

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is arranged at different levels. This document focuses on the elements `dcc:administrativeData` and `dcc:measurementResults`, while the remaining elements are explained in the [DCCWiki](#). A potentially relevant use of the element `ds:Signature` is the "eAttestation" of the German accreditation body DAkkS [\[2\]](#).

2.2 Attributes

It is also possible to attach so-called attributes to various elements. In the DCC these are *id*, *refType* and *refId*. Links are possible with the help of *id* and *refId* (more on this at https://dccwiki.ptb.de/en/id_refid). *refType* attributes are used to improve machine comprehensibility, particularly for elements that occur more than once. The definition and grouping of *refType* attributes as well as their explanation and use are published in the Thesaurus database. The specific *refType* used for the force calibration certificate can be found in Section 6.

2.3 Namespaces

The "namespaces" used in XML indicate the affiliation of an element to a schema. Due to the fact that the digital SI (D-SI) has its own schema in the digital calibration certificate, there are the namespaces (<https://ptb.de/dcc> and <https://ptb.de/si>) with the prefixes "dcc" and "si". The labelling is carried out using a prefix and a separating colon (example: `dcc:administrativeData` and `si:real`). Additionally, the MathML XML schema can be integrated into the DCC schema using the namespace (<http://www.w3.org/1998/Math/MathML>) with the prefix "ml" for formulas and equations (example `ml:math`).

2.4 Notation


In the DCC, lower camel case is used for all contents (elements, attributes, and specifications in *refType*). This means that a) words are combined, b) the initial letter is written in lower case and c) new word beginnings within the composition are written in upper case. Examples of this are `dcc:coreData`, `dcc:measurementResults` and `dcc:measuringEquipmentQuantity`.

2.5 Multi-language support

Depending on the element type in the DCC, it is possible to specify several languages. Many values are expressed as numbers, dates, or the link. In these cases, multi-language support is not possible. For the elements `dcc:name`, `dcc:description`, and `dcc:text`, however, more than one language can be used continuously (multi-language support). The language is specified in child elements by the corresponding country abbreviation:

```
<dcc:content lang="de">Kraftaufnehmer</dcc:content> for a German language variant,
<dcc:content lang="en">Force transducer</dcc:content> for an English language variant.
```

Information on the languages used can be found in the element `dcc:coreData` in the child elements `dcc:usedLangCodeISO639_1` and `dcc:mandatoryLangCodeISO639_1`.

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2.6 Basic rules in the DCC

2.6.1 *The plural in element descriptions*

Within the DCC, a combination of the plural form in the parent element and the singular form in the child element can be found.

Example: dcc:measurementResults → dcc:measurementResult

In all cases, it is possible to create a list of child elements here, with the parent element serving as a kind of collective folder. In some cases, it is also possible to globally define a name, a description and other information for a list at parent element level.

2.6.2 *Local before global*

A lot of information, such as measurement methods or general comments, can be stored at various points in the DCC. Hence, the following statement applies: Local information takes precedence over global information. In the absence of local information, the global information passes on to the next level (below).

Example: If a general reference to accreditation is made in the DCC, then it is to be assumed that the accreditation applies to all the information listed. Individual results outside the scope of accreditation should then be explicitly marked. Alternatively, information on accreditation can also be given exclusively for each individual result.

2.7 D-SI indications in the DCC


The Digital SI (D-SI) is described in a separate XML schema; elements are therefore marked by the prefix "si". It concentrates on the indication of numerical values including their associated uncertainties. For more information on this schema, see [5] and [6].

The D-SI does also contain various child elements. For calibration certificates for force, however, si:real, si:hybrid, and si:realListXMLList elements are used.

The child elements of the si:real element that are used in DCCs for force are listed in the following table. There are further child elements possible for the si:real element (namely si:quantityType, si:significantDigit, si:dateTime) that are not used for force.

Element	Mandatory (M) or Optional (O)	Explanation	Sample value
si:label	Optional	Designation (optional)	R
si:value	Mandatory	Numerical value	0.037
si:unit	Mandatory	Unit to numerical value	\one

Table 1: Examples of content elements in the element si:real.

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Furthermore, where appropriate, the measurement uncertainty should be reported within an element `si:measurementUncertaintyUnivariate` that comprises the optional selectable subelements `si:standardMU` (if a standard uncertainty shall be reported, not recommended here), `si:expandedMU` (if an expanded uncertainty shall be reported, recommended here) or `si:coverageIntervalMU` (if a coverage interval shall be reported, not used in force DCCs).

Element	Mandatory (M) or Optional (O)	Explanation	Sample value
<code>si:valueExpandedMU</code>	Mandatory	Value of the measurement uncertainty (in the same unit as the associated value)	0.2
<code>si:coverageFactor</code>	Mandatory	Coverage factor	2
<code>si:coverageProbability</code>	Mandatory	Coverage probability	0.95
<code>si:distribution</code>	Optional	Uncertainty distribution	normal

Table 2: Examples of content elements in the element `si:expandedMU`.

For reporting quantity values in the force DCC, the element `si:realListXMLList` is primarily used. In contrast to the `si:real` element, which represents a single value, the `si:realListXMLList` enables the representation of a list of space-separated values. An example for `si:realListXMLList` element is shown in Figure 1.

```


1 <si:realListXMLList>
2   <si:valueXMLList>0 100 200 300 400 500 600 800 1000 0</si:valueXMLList>
3   <si:unitXMLList>\kilo\newton</si:unitXMLList>
4 </si:realListXMLList>

```

Figure 1: Example for `si:realListXMLList` with a space-separated list of values and a unit.

Note: If all entries of an "XMLList" element are the same, it is sufficient to state the entry only once, i.e. `<si:coverageFactorXMLList>2 2 2</si:coverageFactorXMLList>` is the same as `<si:coverageFactorXMLList>2</si:coverageFactorXMLList>`.

Additionally, the `si:hybrid` element (see Figure 2) is used specifically for the maximum and minimum relative humidity during force calibration.

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```

1 <si:hybrid>
2   <si:real>
3     <si:value>0.4</si:value>
4     <si:unit>\one</si:unit>
5     <si:measurementUncertaintyUnivariate>
6       <si:expandedMU>
7         <si:valueExpandedMU>0.01</si:valueExpandedMU>
8         <si:coverageFactor>2</si:coverageFactor>
9         <si:coverageProbability>0.95</si:coverageProbability>
10      </si:expandedMU>
11    </si:measurementUncertaintyUnivariate>
12  </si:real>
13  <si:real>
14    <si:value>40</si:value>
15    <si:unit>\percent</si:unit>
16  </si:real>
17 </si:hybrid>

```

Figure 2: Example for si:hybrid with quantity value stated with SI unit and non-SI unit

3 Using the DCC elements for force calibration in administrative data

The dcc:administrativeData element consists of 8 child elements:


- dcc:dccSoftware (mandatory)
- dcc:refTypeDefinitions (optional)
- dcc:coreData (mandatory)
- dcc:items (mandatory)
- dcc:calibrationLaboratory (mandatory)
- dcc:respPersons (mandatory)
- dcc:customer (mandatory)
- dcc:statements (optional)

General rules and considerations for force calibration certificates apply to most child elements of dcc:administrativeData, namely dcc:dccSoftware, dcc:coreData, dcc:calibrationLaboratory, dcc:respPersons, and dcc:customer. For the remaining elements, specific rules are provided below for dcc:items and dcc:statements.

Regarding dcc:refTypeDefinitions, force calibration certificates use three namespaces with the prefixes, i.e. “basic”, “math”, and “force”. Valid refTypes, including respective definitions and scope notes, are stored in a dedicated TemaTres database. The *refTypes* that may be used in force calibration certificates are listed in Chapter 6.

3.1 Description of calibration item(s)

The calibration item is described within the child element dcc:items. Its content here depends on the type of object to be calibrated. Generally, the element dcc:items includes additional child

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elements, such as `dcc:name` and `dcc:item`, which are used in force calibration certificates to describe devices under test.

The child element `dcc:item` can be used more than once to store the descriptions of individual devices, such as force transducers, indicators, and extension cables, as shown in Figure 3. For frequently used identifiers, the `refType` attribute must be used. Definitions for the `refType` attribute can be found in Chapter 6.

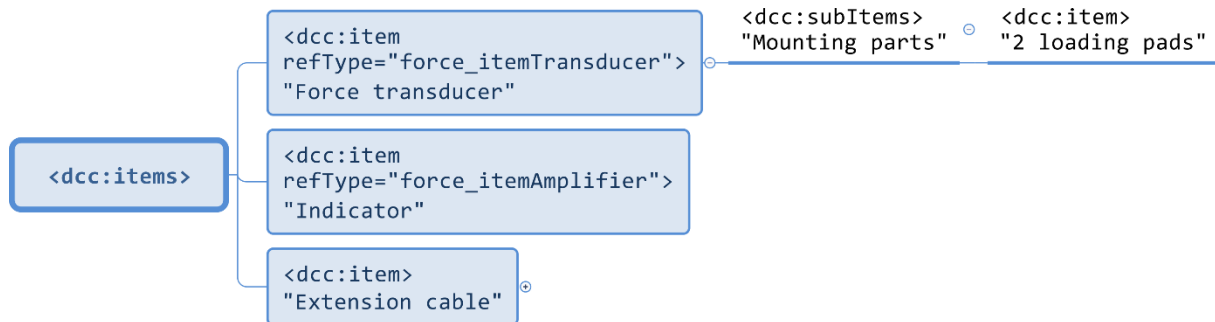


Figure 3: Schematic structure of `dcc:items`


In the child elements of `dcc:item`, all the information of the instrument shall be individually and uniquely identified, e.g. by the name of the manufacturer, the model and the serial number. The element `dcc:item` comprises several mandatory (M) or optional (O) further child elements:

- `dcc:description` (O)
- `dcc:equipmentClass` (O, not used)
- `dcc:identifications` (M)
- `dcc:installedSoftwares` (O)
- `dcc:itemQuantities` (O)
- `dcc:manufacturer` (O)
- `dcc:model` (O)
- `dcc:name` (M)
- `dcc:owner` (O, not used)
- `dcc:subItems` (O)

For most of them (namely `dcc:name`, `dcc:description`, `dcc:installedSoftwares`, `dcc:manufacturer`, `dcc:model` and `dcc:owner`), no considerations specific for the calibration of force are necessary so that general rules and considerations apply instead. From the remaining child elements, `dcc:identifications`, `dcc:itemQuantities` and `dcc:subItems` should be used as demonstrated.

The element `dcc:identifications` includes a list of `dcc:identification` elements to provide individual information necessary for the recognition and description of the instruments, specifying the name, the description, and the issuing body. In force calibration certificates, the information may include serial numbers, markings, or identification numbers. Each of them is identified in an independent `dcc:identification` element, using the `refType` “*basic_serialNumber*”, “*basic_marking*”, or “*basic_identificationNumber*”, respectively.

To specify properties of the calibration item, the element `dcc:item` contains the child element `dcc:itemQuantities`, in which the metrological characteristics can be specified in a

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dcc:itemQuantity element, such as numerical value(s), type, and formula. When using numerical value(s), the element si:real or si:realListXMLList from the D-SI schema is used here. When using text and/or formulas, the element dcc:noQuantity is used. The formula is provided in the child element dcc:formular in latex or mathml.

Parts of devices that shall each be identified, e.g. mounting parts of a force transducer, should be identified as one dcc:subItems in the same dcc:item element, which can be seen in **Figure 4**.


```

1 <dcc:item refType="force_itemTransducer">
2   <dcc:name>
3     <dcc:content lang="en">Force transducer</dcc:content>
4   </dcc:name>
5   <dcc:manufacturer>
6     <!--Manufacturer of the test device-->
7   </dcc:manufacturer>
8   <dcc:model>Typ KA</dcc:model>
9   <dcc:identifications>
10    <!--Identifications (e.g. serial number...) of the test device-->
11  </dcc:identifications>
12  <dcc:itemQuantities>
13    <dcc:itemQuantity refType="basic_nominalValue">
14      <!--Nominal force in D-SI-->
15    </dcc:itemQuantity>
16    <dcc:itemQuantity refType="force_itemCableLength">
17      <!--Cable length in D-SI-->
18    </dcc:itemQuantity>
19    <dcc:itemQuantity refType="force_itemConnectorNumber">
20      <!--Number of connectors in D-SI-->
21    </dcc:itemQuantity>
22  </dcc:itemQuantities>
23  <dcc:subItems>
24    <dcc:item>
25      <dcc:name>
26        <dcc:content lang="en">Mounting parts</dcc:content>
27      </dcc:name>
28      <dcc:description>
29        <!--Description of mounting parts-->
30      </dcc:description>
31      <dcc:identifications>
32        <!--Identifications (e.g. serial number...) of the test device-->
33      </dcc:identifications>
34    </dcc:item>
35  </dcc:subItems>
36 </dcc:item>

```

Figure 4: Example for the item element that describes the device (e.g. force transducer) to be calibrated (code has been shortened for clarity; the full version is available in Appendix A:

Example of an extended digital calibration certificate for force calibration, lines 104-181)

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3.2 Description of statement(s)

The `dcc:statements` element contains a list of `dcc:statement` elements used to report various statements. Figure 5 shows the schematic structure of `dcc:statements` used in force DCCs.

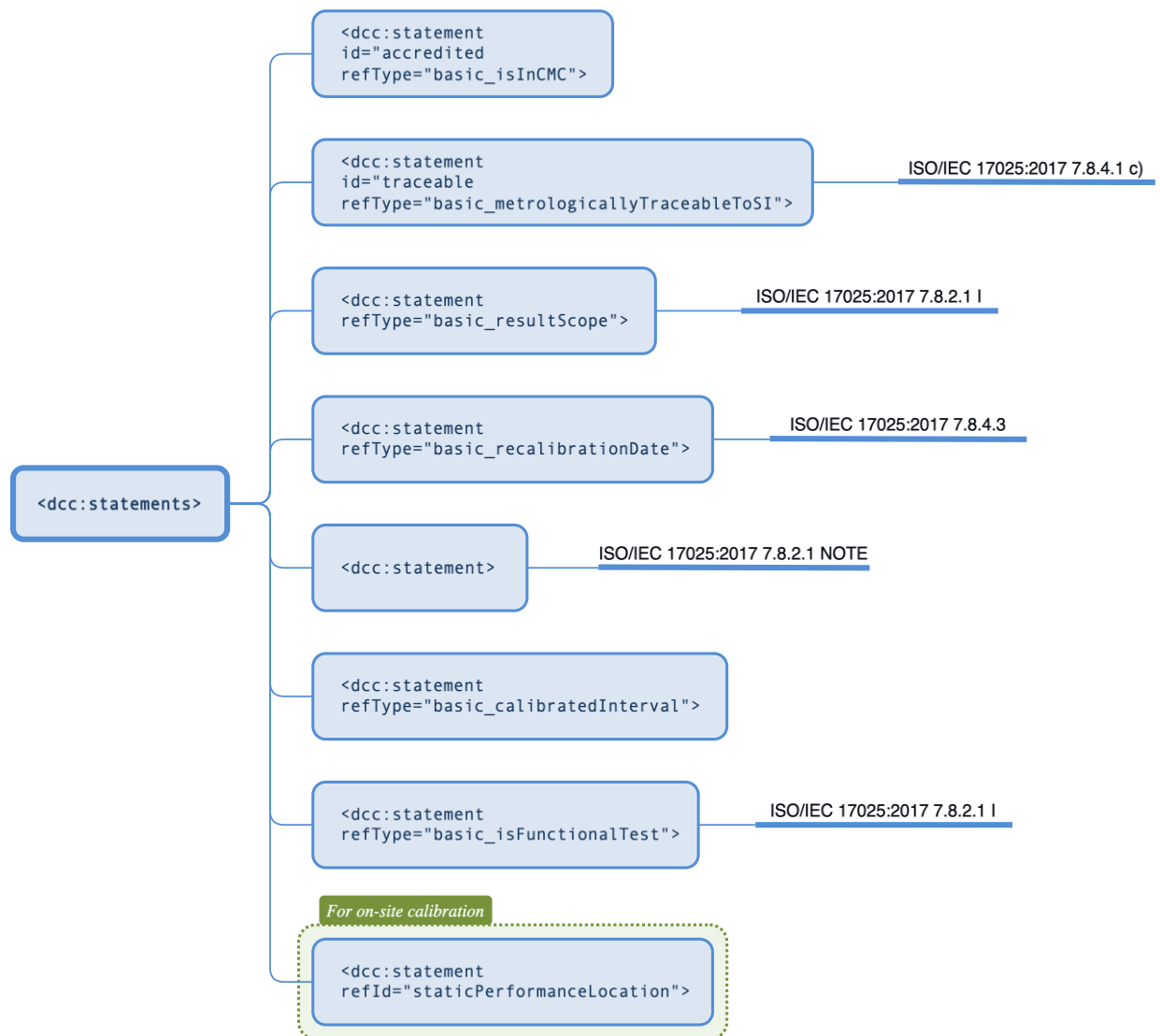



Figure 5: Schematic structure of `dcc:statements`.

In most harmonized implementations, `dcc:statement` is not specific for force application, particularly those consistent with ISO/IEC 17025:2017 [7]. Each statement of this standard is implemented through the element `dcc:statement`, where necessary with a `refType` and/or `id`. For example, according to ISO 17025:2017 7.8.4.1 c), a statement identifying how the measurements are metrologically traceable is implemented through an element `dcc:statement` with `refType="basic_metrologicallyTraceableToSI"` and `id="traceable"`, which contains the child elements `dcc:norm`, `dcc:reference`, `dcc:link`, and `dcc:declaration`.

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In force calibration certificates, a calibrated interval statement should be provided to specify the force range with lower limit and upper limit within which the calibration was performed. This statement is implemented using an element `dcc:statement` with `refType="basic_calibratedInterval"`, where the range boundaries are explicitly defined through two `dcc:quantity` child elements (see Figure 6).

```


1 <dcc:statement refType="basic_calibratedInterval">
2   <dcc:declaration>
3     <dcc:content lang="en">The calibration was performed within the
4       following force range:</dcc:content>
5   </dcc:declaration>
6   <dcc:data>
7     <dcc:list>
8       <dcc:quantity refType="math_minimum">
9         <dcc:name>
10          <dcc:content lang="de">Unteres Limit</dcc:content>
11          <dcc:content lang="en">Lower limit</dcc:content>
12        </dcc:name>
13        <si:real>
14          <si:value>100</si:value>
15          <si:unit>\kilo\newton</si:unit>
16        </si:real>
17      </dcc:quantity>
18      <dcc:quantity refType="math_maximum">
19        <dcc:name>
20          <dcc:content lang="de">Oberes Limit</dcc:content>
21          <dcc:content lang="en">Upper limit</dcc:content>
22        </dcc:name>
23        <si:real>
24          <si:value>1000</si:value>
25          <si:unit>\kilo\newton</si:unit>
26        </si:real>
27      </dcc:quantity>
28    </dcc:list>
29  </dcc:data>
30 </dcc:statement>

```

Figure 6: Statement declaring the calibrated interval with lower and upper calibration limit (see Appendix A: Example of an extended digital calibration certificate for force calibration, lines 567-596).

Moreover, a statement should be provided to clearly and transparently indicate whether the associated result(s) are covered by the calibration and measurement capabilities (CMCs). A `dcc:statement` element is used with `refType="basic_isInCMC"` and `id="accredited"`, which includes the child elements `dcc:declaration` and `dcc:valid` (or `dcc:validXMLList`). This statement element is linked via `id` attributes to `dcc:valid` elements.

Note: For on-site calibration, a statement should be specified with `refId="staticPerformanceLocation"`, and the linked `id` is given in the `dcc:performanceLocation` element.

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4 Using the DCC elements for force calibration in measurement results

The dcc:measurementResults element comprises 6 child elements:

- dcc:usedMethods (optional)
- dcc:usedSoftware (optional)
- dcc:measuringEquipments (optional)
- dcc:influenceConditions (optional)
- dcc:measurementMetaData (optional)
- dcc:measurementResult (mandatory)

In force calibration certificates, 4 child elements of dcc:measurementResults are used, namely dcc:usedMethods, dcc:measuringEquipments, dcc:influenceConditions, and dcc:measurementResult, and specific rules of each child element are provided below.

4.1 Description of measurement methods

The element dcc:measurementResults contains the child element dcc:usedMethods to describe the calibration methods used. The element dcc:usedMethods consists of an arbitrary number of child elements of type dcc:usedMethodType. Each dcc:usedMethod element contains a name, a description, an optional reference to a standard, and optional quantity values used in the calibration method that are not specified in the standard.

In force calibration, the methods used are based on the standard ISO 376:2011-09 [2], which is referenced using the child element dcc:norm of element dcc:usedMethod. The description of the calibration procedure is identified using the *refType*="basic_calibrationMethod" (see Figure 7). The minimum dwell time, which is the waiting time on a force level before acquisition of a measurement value, is identified using the *refType*="force_minimumDwellTime". The value of the minimum dwell time is given in a child element dcc:usedMethodQuantity of the parent element dcc:usedMethodQuantities.

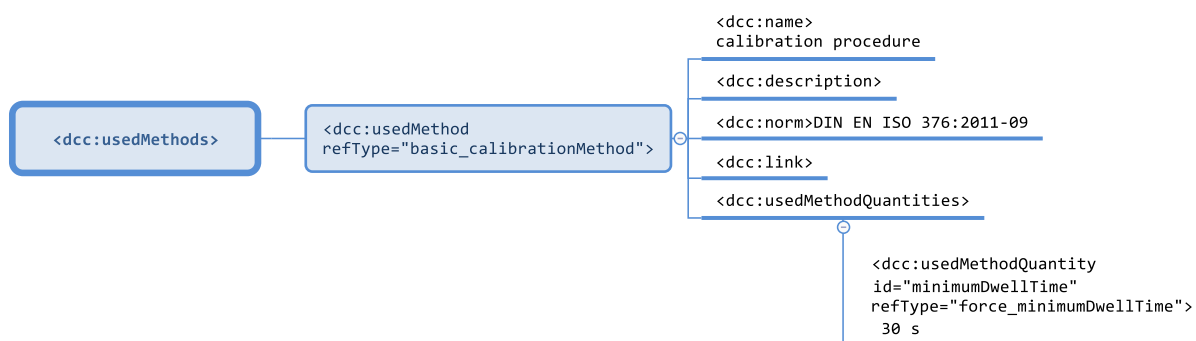



Figure 7: Example of the schematic structure of dcc:usedMethods in force DCCs.

4.2 Description of measuring equipment

In the element dcc:measurementResults, it is possible to insert a list of dcc:measuringEquipment elements documenting the measuring equipment used, such as the force standard machine, digital multimeter, indicator, and mounting parts. For individual measuring equipment, it is

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recommended to include necessary information for recognition and description, such as dcc:name, dcc:manufacturer, and dcc:identifications. If necessary, a list of quantity values can be included as well.

To specify properties of the measuring equipment, the element dcc:measuringEquipment contains the child element dcc:measuringEquipmentQuantities, in which the metrological characteristics can be specified. Each property of the measuring equipment is provided in one element dcc:measuringEquipmentQuantity with numerical value(s), text or formulas. When using numerical values, the D-SI schema is used here. When using text, dcc:noQuantity or dcc:charsXMLList is used.

4.3 Description of influence quantities

Both the dcc:measurementResults and dcc:measurementResult elements contain a dcc:influenceConditions child element which describes the ambient and boundary conditions acting on the calibration. As shown in Figure 8, if all measurements are performed under the same ambient conditions, this information is stored in the dcc:influenceConditions child element of dcc:measurementResults. Conversely, if measurements have different ambient conditions, each dcc:measurementResult element contains its own dcc:influenceConditions child element with the specific conditions of that measurement.

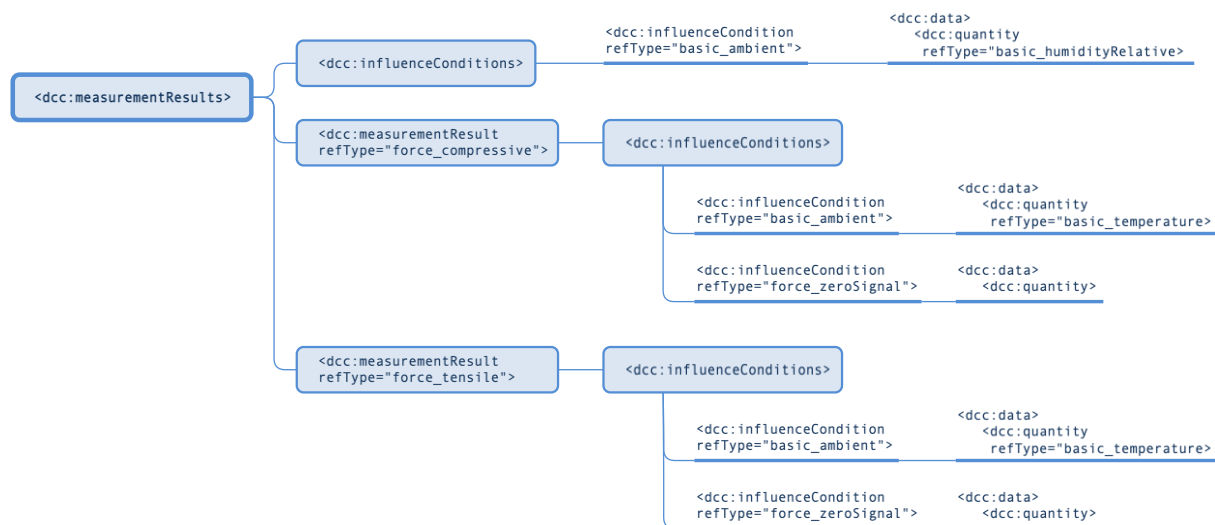



Figure 8: Example of the schematic structure of dcc:influenceConditions used in the force DCC.

The dcc:influenceConditions element consists of any number of child elements dcc:influenceCondition, which, in addition to name and description, can also have an optional status specification and a dcc:data element for specifying numerical values with or without measurement uncertainty or formulas. When using numerical values, the D-SI schema is used here.

Ambient conditions specified as ranges with minimum and maximum values, such as temperature and relative humidity, should be represented by a single value with a uniformly distributed uncertainty covering the entire interval (see Figure 9).

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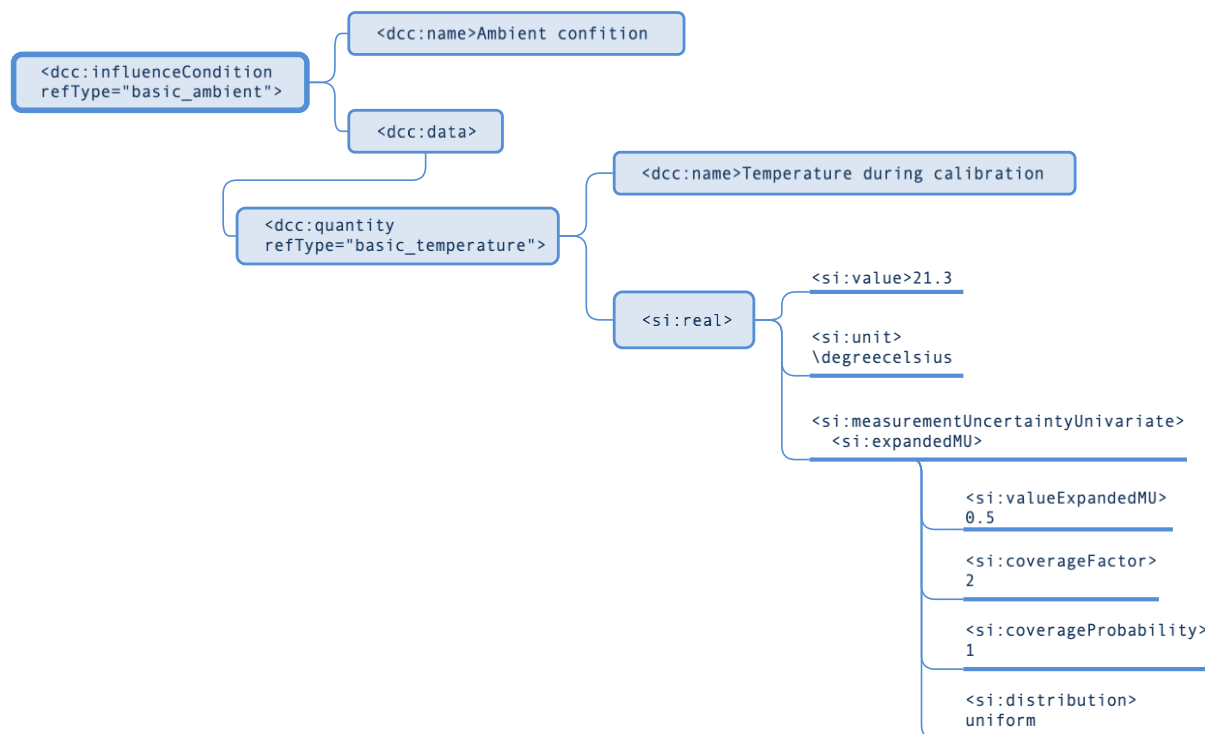


Figure 9: Example of the schematic structure dcc:influenceCondition for temperature.

4.4 Description of measurement results

The dcc:measurementResults element contains the dcc:measurementResult child element to describe the calibration results. One dcc:measurementResult element is used for each force application, i.e. for both compressive and tensile forces. For differentiation, the dcc:measurementResult elements each receive a refType: “force_compressive” or “force_tensile” as shown in Figure 10.

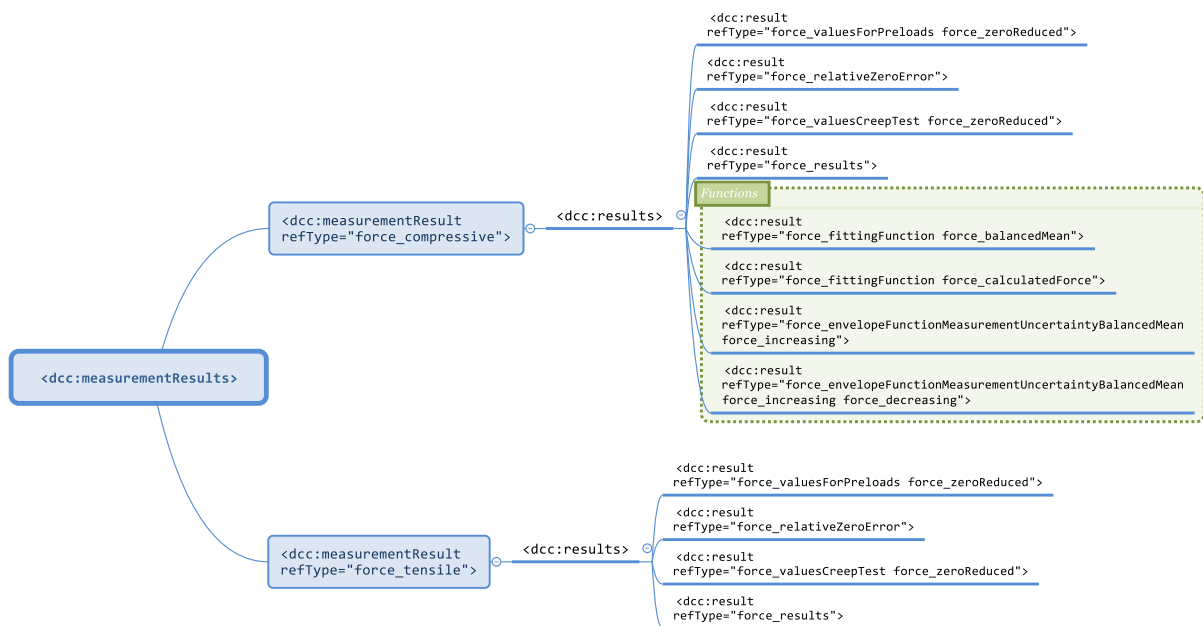


Figure 10: Example of the schematic structure dcc:results for compressive and tensile force transducers.

The dcc:measurementResult element contains a dcc:results child element which offers the possibility to insert several dcc:result elements, each identified by a refType, e.g. “force_results”, “force_fittingFunction”.

The dcc:result element has three child elements: dcc:name (mandatory), dcc:description (optional) and dcc:data (mandatory). The dcc:data child element is used to represent the measurement results. This element in turn provides the possibility to enter texts, lists, formulas, and individual measurement values. In the case of force calibration certificates, the dcc:list and dcc:formula child elements are used to represent numerical values and functions, respectively. Moreover, specific application rules should be applied to represent measurement results in dcc:list and dcc:formula elements, such as table, fitting functions, and relative measurement uncertainties. Details of these application rules are given in Section 5.

5 Application rules for force in DCCs

5.1 Good practice: table

5.1.1 Example for a single table

Figure 11 is an example of a table extracted from a human-readable PTB certificate.


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Tabelle 1: Nullkorrigierte Anzeigewerte der Vorbelastungen in mV/V			
Table 1: Zero-reduced values indicated for preloads in mV/V			
Einbaustellung Mounting position	0 °	120 °	240 °
Nullanzeige i_0 Indication at zero load	0,000000	0,000000	0,000000
Anzeige bei Höchstkraft F_N Indication at max force	2,000100	2,000000	2,000000
Restanzeige i_f Indication after preloading	0,000011	0,000033	0,000055

Figure 11: Extract from a human-readable PTB certificate for the table of zero-reduced values indicated for preloads.

The schematic structure of the table is shown in Figure 12, with all data stored within a `dcc:result` element of `dcc:results` element. The `dcc:result` element contains three child elements: `dcc:name` element for the table title, i.e. “Zero-reduced values indicated for preloads”; `dcc:description` element for additional information; `dcc:data` element for measurement results.

In the table, a single `dcc:list` element within `dcc:data` is used, where the first row (mounting positions) is defined in the `dcc:metadata` of `dcc:measurementMetaData`. Within `dcc:metadata`, the name (i.e. mounting position) and corresponding values are represented using a `dcc:quantity` element with the `refType` “*force_mountingPosition*”. Starting from DCC XSD v3.4.0, the additional attribute `index="0"` is included to designate this element as the (single) index column of the table. Rows 2-4 contain measurement results for indication at zero load, at max force, and after preloading, respectively. Each result is stored in separate `dcc:quantity` elements with unique `refTypes`. The first column is the name of the quantity, and stored in `dcc:name`, while the remaining three columns use `si:realListXMLList` with `si:valueXMLList` for numerical values and `si:unitXMLList` for units. Additionally, a further `dcc:metadata` element indicates whether the values in the table correspond to a functional test. This element is linked via a `refId` to the respective statement with the `refType` “*basic_isFunctionalTest*” (see Figure 5).

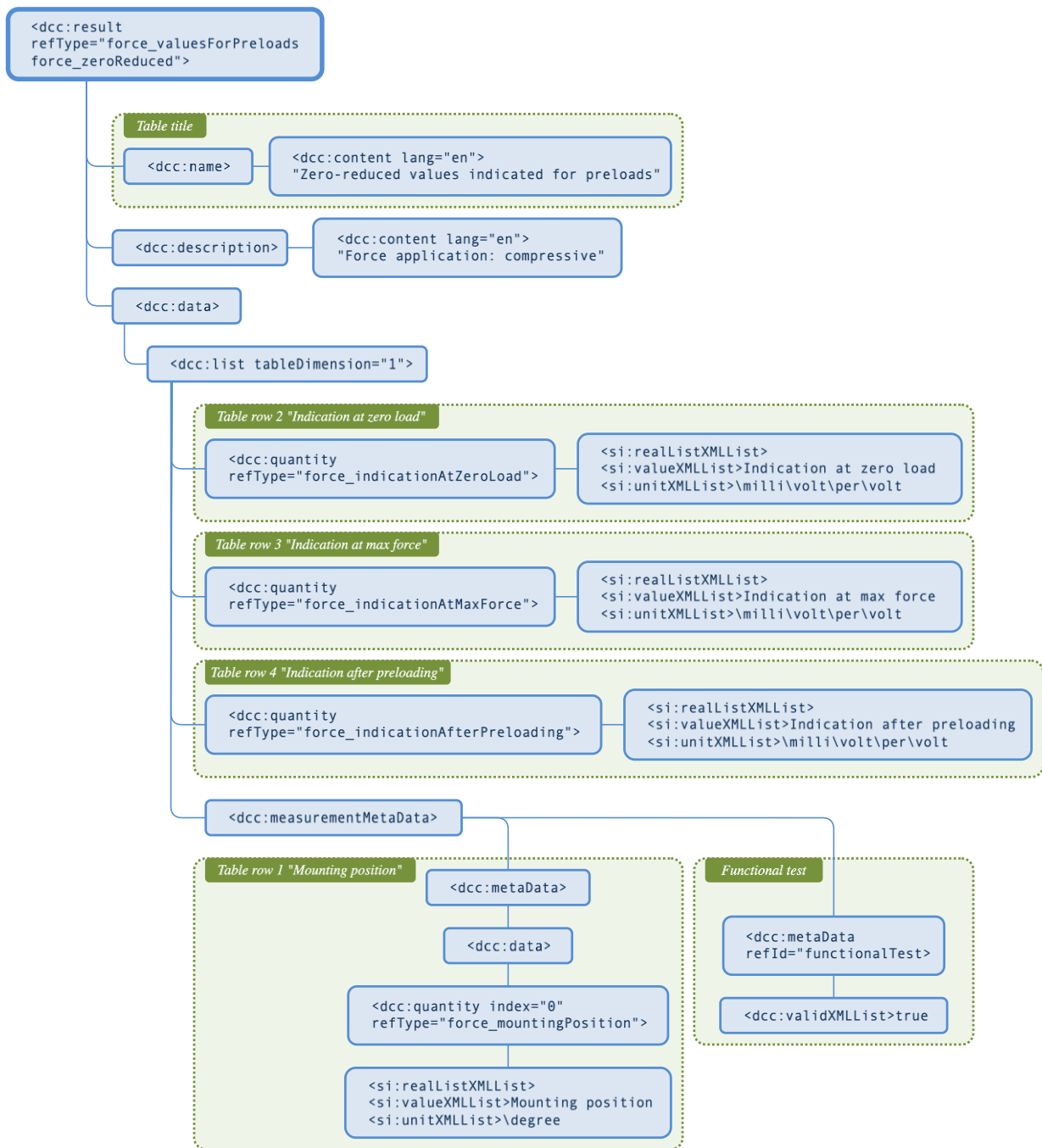



Figure 12: Example of the schematic structure dcc:result for the table in Figure 11.

A code example is given in Figure 13.


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```

1 <dcc:result refType="force_valuesForPreloads force_zeroReduced">
2   <dcc:name>[...]</dcc:name>
3   <dcc:description>[...]</dcc:description>
4   <dcc:data>
5     <dcc:list>
6       <dcc:quantity refType="force_indicationAtZeroLoad">
7         <dcc:name>[Indication at zero load]</dcc:name>
8         <si:realListXMLList>
9           <si:valueXMLList>0.000000 0.000000 0.000000</si:valueXMLList>
10          <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
11        </si:realListXMLList>
12      </dcc:quantity>
13      <dcc:quantity refType="force_indicationAtMaxForce">
14        <dcc:name>[Indication at max force]</dcc:name>
15        <si:realListXMLList>
16          <si:valueXMLList>2.000100 2.000000 2.000000</si:valueXMLList>
17          <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
18        </si:realListXMLList>
19      </dcc:quantity>
20      <dcc:quantity refType="force_indicationAfterPreloading">
21        <dcc:name>[Indication after preloading]</dcc:name>
22        <si:realListXMLList>
23          <si:valueXMLList>0.000011 0.000033 0.000055</si:valueXMLList>
24          <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
25        </si:realListXMLList>
26      </dcc:quantity>
27      <dcc:measurementMetaData>
28        <dcc:metaData>
29          <dcc:data>
30            <dcc:quantity refType="force_mountingPosition">
31              <dcc:name>[Mounting position]</dcc:name>
32              <si:realListXMLList>
33                <si:valueXMLList>0 120 240</si:valueXMLList>
34                <si:unitXMLList>\degree</si:unitXMLList>
35              </si:realListXMLList>
36            </dcc:quantity>
37          </dcc:data>
38        </dcc:metaData>
39      </dcc:measurementMetaData>
40    </dcc:list>
41  </dcc:data>
42 </dcc:result>

```

Figure 13: Result (code has been shortened for clarity; the full version is available in Appendix A: Example of an extended digital calibration certificate for force calibration, lines 1017-1083)

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5.1.2 Example for combining tables

Due to the requirements of human readability of the paper and screen display formats, conventional certificates often contain separate tables on separate pages. In a DCC, they can be combined into one single table for each loading direction.

In analogue force calibration certificates, the values of the introduced calibration quantity, i.e. the calibration force steps that represent the reference values, are repeated in several tables, which show the measured data, calculated results, and classifications. In such a case, these tables can be restructured and combined into one single table. The first column contains a list of reference values, which should include all force step values from all tables to be combined. The redundant data of force steps, i.e. the first column of each table, are eliminated. Then, some columns of a table are extended with “empty cells” to match the first column of force steps. Finally, there are totally 21 columns in one table.

	Table: Zero-reduced values indicated for all series		Table: Mean values, parameters and measurement uncertainties for incremental single forces		Table: classifications		Table: fitted results and measurement uncertainties	
<i>F</i> Kraft Force in kN	<i>X</i> ₁ Messreihe 1 Meas. series 1 0° in mV/V	<i>X</i> _{6'} Messreihe 6' Meas. series 6' 240° ab/down in mV/V	\bar{X}_{wr} arithmet. Mittelwert Arithm. mean 1-2 in mV/V	$W_{\bar{x}_r}$ erw. rel. Mess- unsicherheit Exp. rel. meas. uncertainty AM in %	Fall A / Case A ...	Fall D / Case D	<i>X</i> _a Balanced mean (BM) in mV/V ...	W_{xv} Rel. meas. uncertainty incr/decr in %
0	0,000000	0,000188	0,000000	-			0,000000	-
100	0,199962	0,200201	0,199967	0,034	00	0,5	0,199979	0,113
200	0,399929	0,400243	0,399939	0,034	00	00	0,399962	0,077
300	0,599901	0,600276	0,599916	0,034	00	00	0,599951	0,063
400	0,799878	0,800300	0,799898	0,034	00	00	0,799945	0,054
500	0,999862	1,000312	0,999888	0,034	00	00	0,999946	0,047
600	1,199854	1,200314	1,199884	0,034			1,199954	0,043
800	1,599859	1,600283	1,599899	0,034			1,599993	0,037
1000	1,999900		1,999950	0,034			2,000067	0,034
0	0,000122							

Table 3: Example of a table formed by merging four single tables.

The whole table is provided only in one element dcc:result with two child elements dcc:name and dcc:data. All the content of the table is provided in the dcc:list element of the dcc:data element. The schematic structure for the combining tables is shown in Figure 14.

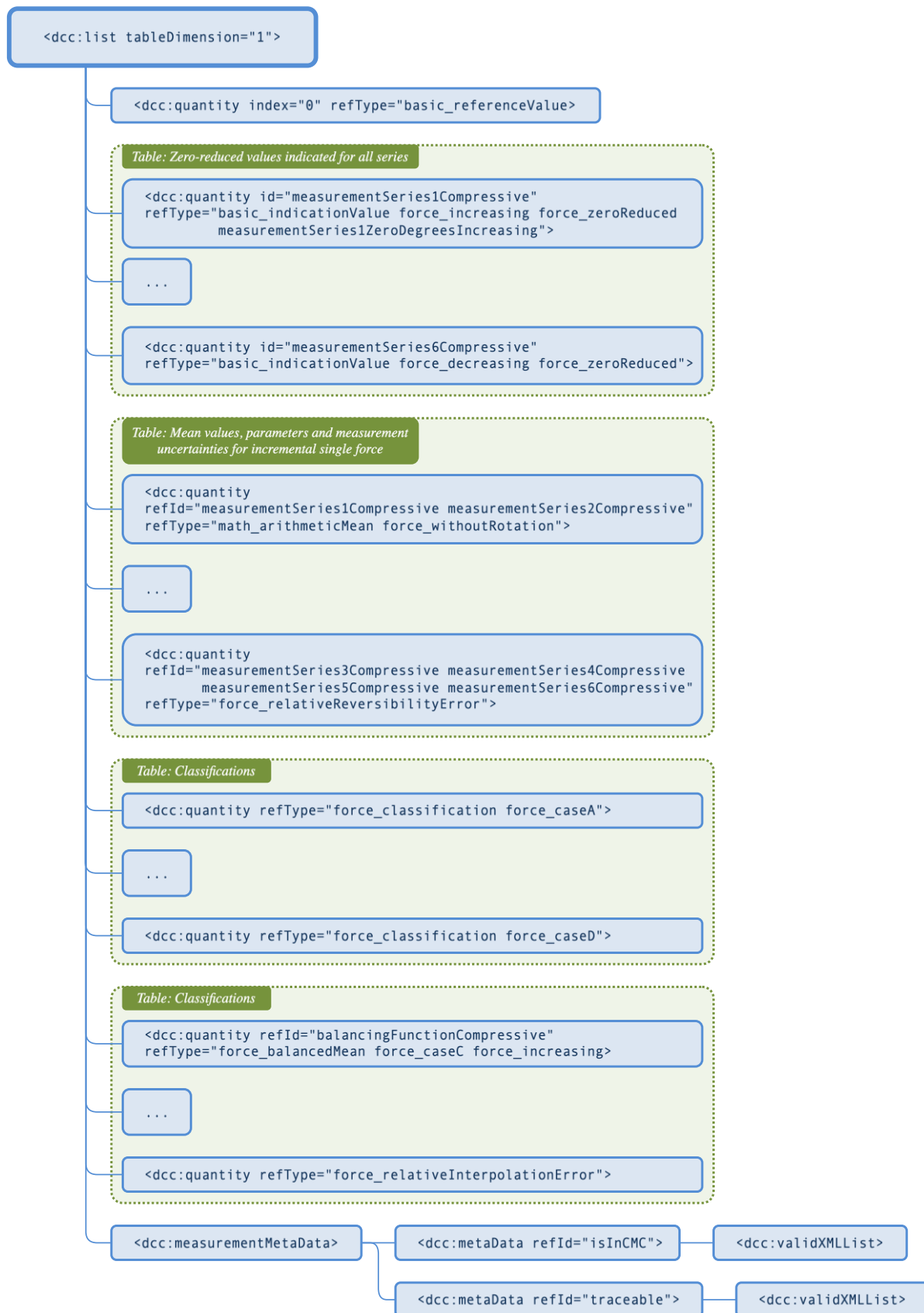



Figure 14: Example of the schematic structure dcc:list for combining tables.

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Generally, one column is provided in one element `dcc:quantity` with attributes of one or more `refType(s)`, and some of them are with `id` or `refId`. For example, the first column is force steps, and is given the `refType = "basic_referenceValue"`. When numerical values are used in a column, the element `si:reallistXMLList` is used, in which the element `si:valueXMLList` gives all the numerical values, while the element `si:unitXMLList` gives the unit. For classifications, the element `dcc:charsXMLList` is used to give the listing from case A to case D. If the column represents the relative uncertainties associated with one quantity, two columns of the quantity and its relative uncertainty can be combined, and the numerical values of relative uncertainties are given in the `dcc:relativeUncertainty` element. The details can be found in Chapter 5.3.

As shown in Table 3, there are “empty cells” after combining tables. For handling “empty cells” in force DCCs, the details can be found in Chapter 5.1.3 and Chapter 5.1.4.

The XML code for the schematic structure seen in Figure 14 is given in Appendix A: Example of an extended digital calibration certificate for force calibration, lines 1341-1687.

5.1.3 Example for a table with empty cells

In some tables in analogue force calibration certificates, there are “empty” cells in the following cases:

- values that were not measured;
- values in the table with calculated results, e.g. relative values at zero (division by zero is not defined) or hysteresis at the end of the measuring range (only one value was measured and there is no second value to calculate the hysteresis);
- merging different tables into one table, which leads to additional “empty” cells in the merged table;
- undefined if a class cannot be determined.

When dealing with numerical values, the representation “NaN” is used for not determined values. If a class cannot be determined, “undefined” is suggested to be used. Details for classification tables can be found in Section 5.1.4.

Figure 15 shows an example of a table containing “empty” cells, indicating values that were not measured. A corresponding code example is provided in Figure 16, where such cells are represented as NaN.

Note: Support for “NaN” entries in `<si:value>` or `<si:valueXMLList>` elements is available for the D-SI schema version 2.2.0. Therefore, the D-SI schema version 2.2.0 (and higher) and DCC schema version 3.3.0 (and higher) are required.

Tabelle 4: Nullkorrigierte Anzeigewerte der Messreihen
Table 4: Zero-reduced values indicated for all series

Kraftrichtung: Druckkraft
 Force application: compressive


<i>F</i>	<i>X₁</i>	<i>X₂</i>	<i>X₃</i>	<i>X₄'</i>	<i>X₅</i>	<i>X₆'</i>
Kraft Force	Messreihe 1 Meas. series 1	Messreihe 2 Meas. series 2	Messreihe 3 Meas. series 3	Messreihe 4' Meas. series 4'	Messreihe 5 Meas. series 5	Messreihe 6' Meas. series 6'
in kN	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V	in mV/V
0	0,000000	0,000000	0,000000	0,000166	0,000000	0,000188
100	0,199962	0,199972	0,199982	0,200146	0,199992	0,200201
200	0,399929	0,399949	0,399969	0,400183	0,399989	0,400243
300	0,599901	0,599931	0,599961	0,600211	0,599991	0,600276
400	0,799878	0,799918	0,799958	0,800230	0,799998	0,800300
500	0,999862	0,999913	0,999963	1,000238	1,000013	1,000312
600	1,199854	1,199914	1,199974	1,200234	1,200034	1,200314
800	1,599859	1,599939	1,600019	1,600193	1,600099	1,600283
1000	1,999900	2,000000	2,000100		2,000200	
0	0,000122	0,000133				

Figure 15: Extract from a human-readable PTB certificate for the table with measured data for compressive force.

```

1 <dcc:list>
2   [...]
3   <dcc:quantity id="measurementSeries3Compressive"
4     refType="basic_indicationValue force_increasing force_zeroReduced">
5     <dcc:name>
6       <dcc:content lang="de">Messreihe 3</dcc:content>
7       <dcc:content lang="en">Measurement series 3</dcc:content>
8     </dcc:name>
9     <si:realListXMLList>
10      <si:valueXMLList>0.000000 0.199982 0.399969 0.599961 0.799958 0.999963
11      1.199974 1.600019 2.000100 NaN</si:valueXMLList>
12      <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
13    </si:realListXMLList>
14    <dcc:measurementMetaData>[...]</dcc:measurementMetaData>
15  </dcc:quantity>
16  <dcc:quantity id="measurementSeries4Compressive"
17    refType="basic_indicationValue force_decreasing force_zeroReduced">
18    <dcc:name>
19      <dcc:content lang="de">Messreihe 4'</dcc:content>
20      <dcc:content lang="en">Measurement series 4'</dcc:content>
21    </dcc:name>
22    <si:realListXMLList>
23      <si:valueXMLList>0.000166 0.200146 0.400183 0.600211 0.800230 1.000238
24      1.200234 1.600193 NaN NaN</si:valueXMLList>
25      <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
26    </si:realListXMLList>
27    <dcc:measurementMetaData>[...]</dcc:measurementMetaData>
28  </dcc:quantity>
29  [...]
30 </dcc:list>
  
```

Figure 16: XML example for a table containing empty cells represented as NaN (code has been shortened for clarity; the full version is available in Appendix A: Example of an extended digital calibration certificate for force calibration, lines 1341-1683)

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5.1.4 Example for classification tables


If a class cannot be determined, “undefined” is suggested to be used. For example, when the reference force is 0 kN, the class is not determined, and “undefined” is used at the position of the class for the force 0 kN in the dcc:charsXMLList. Moreover, if the requirements for obtaining a classification are not met, “noClass” is suggested to be used.

Figure 17 gives an example of a classification table in a human-readable PTB certificate. This table has to be reconstructed and combined with other tables (see Table 3). In Figure 17, the upper limits of the force range are consistent, and thus only lower limits are used to merge with the first column (force steps) in Table 3. This combination leads to “empty” cells, and the use of “undefined”.

Kraftbereich / Force range		Geräteklasse / Instrument class			
Von / From	Bis / To	Fall A / Case A	Fall B / Case B	Fall C / Case C	Fall D / Case D
100 kN	1000 kN	00	0,5	00	0,5
200 kN	1000 kN	00	00	00	00
300 kN	1000 kN	00	00	00	00
400 kN	1000 kN	00	00	00	00
500 kN	1000 kN	00	00	00	00

Figure 17: Extract from a human-readable PTB certificate for the table of classifications.

The XML example in Figure 18 shows the representation of “empty” cells in classification tables and illustrates how the table in Figure 17 is structured within the merged table in the DCC structure.

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```

1 <dcc:list>
2   <!-- dcc.xsd v3.4.0 and later: use the index attribute to indicate that the following
   quantity represents an index column of the table:
3   <dcc:quantity index="0" refType="basic_referenceValue" -->
4   <dcc:quantity refType="basic_referenceValue">
5     <dcc:name>
6       <dcc:content lang="de">Kraft</dcc:content>
7       <dcc:content lang="en">Force</dcc:content>
8     </dcc:name>
9     <si:realListXMLList>
10      <si:valueXMLList>0 100 200 300 400 500 600 800 1000 0</si:valueXMLList>
11      <si:unitXMLList>\kilo\newton</si:unitXMLList>
12    </si:realListXMLList>
13  </dcc:quantity>
14  [...]
15  <dcc:quantity refType="force_classification force_caseA">
16    <dcc:name>
17      <dcc:content lang="de">Fall A</dcc:content>
18      <dcc:content lang="en">Case A</dcc:content>
19    </dcc:name>
20    <dcc:charsXMLList>undefined 00 00 00 00 00 00 00 00 undefined</dcc:charsXMLList>
21  </dcc:quantity>
22  <dcc:quantity refType="force_classification force_caseB">
23    <dcc:name>
24      <dcc:content lang="de">Fall B</dcc:content>
25      <dcc:content lang="en">Case B</dcc:content>
26    </dcc:name>
27    <dcc:charsXMLList>undefined 0,5 00 00 00 00 00 00 00 undefined</dcc:charsXMLList>
28  </dcc:quantity>
29  <dcc:quantity refType="force_classification force_caseC">[...]</dcc:quantity>
30  <dcc:quantity refType="force_classification force_caseD">[...]</dcc:quantity>
31 </dcc:list>


```

Figure 18: XML example of the classification section of the result table (code has been shortened for clarity; the quantities showing the classifications are available in Appendix A:

Example of an extended digital calibration certificate for force calibration, lines 1584-1611, the quantity showing the reference values in lines 1346-1355)

5.2 Good practice: calibration function

The calculation functions including fitting functions and optional envelope functions for measurement uncertainties are part of the force calibration certificate and reported in separate dcc:result elements with a list of refTypes, respectively. Each calibration function is represented as an equation using the element dcc:formula with the child element dcc:mathml. The coefficients of all the variables are given in a separate dcc:list element with refType = "force_functionParameters", within the same dcc:result. The numerical value of each coefficient is given in a dcc:quantity element with refType = "force_coefficient".

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5.2.1 Example for fitting function

Figure 19 presents fitting functions of the balanced mean values extracted from a human-readable PTB certificate. The first function is fitting function for increasing forces, while the second one is for decreasing forces.

<p>Ausgleichsfunktionen / Fitting functions $X = X(F)$</p> <p>Die in der Tabelle oben aufgeführten ausgeglichenen Mittelwerte X_a sind mit folgender Funktion berechnet: <i>The balanced mean X_a values stated in the table above have been calculated with the following function:</i></p> $X_a = [+ 0,001999767 \cdot F / \text{kN} + 1,99 \cdot 10^{-10} \cdot (F / \text{kN})^2 + 1 \cdot 10^{-13} \cdot (F / \text{kN})^3] \text{ mV/V}$ <p>Unter Berücksichtigung der Umkehrspanne v ergibt sich folgende Funktion für abnehmende Kraftbeträge: <i>Considering the reversibility v the following function results for decremental forces:</i></p> $X_r = [+ 0,002000139 \cdot F / \text{kN} + 1,91 \cdot 10^{-10} \cdot (F / \text{kN})^2 - 4,33 \cdot 10^{-13} \cdot (F / \text{kN})^3 + 1,67 \cdot 10^{-4}] \text{ mV/V}$
--

Figure 19: Extract from a human-readable PTB certificate for the fitting function of the balanced mean.


Both fitting functions follow the same mathematical form but with different coefficients, i.e.

$$X = a \cdot F + b \cdot F^2 + c \cdot F^3 + d$$

where X is the balanced mean in units of the indication value (here mV/V), F is force (e.g. in kN, and a , b , c , and d are linear, quadratic, cubic, and constant coefficients.

The equation is given in the dcc:formula element with a refType = "force_function" and contains a dcc:mathml child element that implements the MathML Content Markup. Each coefficient (a , b , c , d) is associated with its corresponding quantity value through id/refId references. The set of numerical values of coefficients referring to the formula are given in a separate dcc:list element, and each coefficient's specific value is provided in individual dcc:quantity elements. Additionally, to address the coefficients individually, each is assigned the refType "force_coefficient" along with one of the specific types: "force_linear", "force_quadratic", "force_cubic", "force_constant", or "force_reciprocal". Figure 20: Example of the schematic structure of the dcc:result for fitting functions. Figure 20 shows a schematic representation of the formula and its coefficients.

The corresponding XML code can be found in Appendix A: Example of an extended digital calibration certificate for force calibration, lines 1802-1884. In the minimal example (see Appendix B: Example of a simple digital calibration certificate for force calibration, lines 851-889), only a linear polynomial is used as the fitting function.

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Note: It should be noted that the relative measurement uncertainty is expressed in \percent (%). The numerical value of the relative measurement uncertainty calculated by the envelope function is expressed in the unit \one and must be converted to \percent when presented in the results.

5.3 Good practice: Relative measurement uncertainty in a DCC

Table 4 shows an example of a quantity \bar{X}_r and its relative measurement uncertainty $W_{\bar{X}_r}$.

Table: Mean values, parameters and measurement uncertainties for incremental single forces			
<i>F</i>	...	\bar{X}_r	$W_{\bar{X}_r}$
Kraft Force in kN		arithmet. Mittelwert (AM) <i>Arithm. mean</i> 1-3-5 (AM) in mV/V	erw. rel. Mess-unsicherheit <i>Exp. rel. meas.</i> uncertainty AM in %
0		0,000000	-
100		0,199979	0,034
200		0,399962	0,034
300		0,599951	0,034
400		0,799945	0,034
500		0,999946	0,034
600		1,199954	0,034
800		1,599992	0,034
1000		2,000067	0,034
0			

Table 4: Example of a table with values and their relative measurement uncertainties.

Both lists are contained within a single dcc:quantity element. The values of \bar{X}_r are provided in the child element si:valueXMLList of si:realListXMLList, while the relative measurement uncertainties are stored in dcc:relativeUncertaintyXmlList of dcc:relativeUncertainty. Since dcc:relativeUncertaintyXmlList has type si:realListXMLListType, its structure must comply with the D-SI schema. Within this structure, si:valueXMLList contains the actual uncertainty values, and si:unitXMLList is set to "\percent". The element si:measurementUncertaintyUnivariate and its child si:expandedMUXMLList provide additional information about the measurement uncertainty, such as the coverage factor, coverage probability and distribution. The element si:valueExpandedMUXMLList is set to NaN because the uncertainty values are already specified in the higher-level si:valueXMLList. The schematic structure is shown in Figure 22: Example of the schematic structure of a dcc:quantity with a relative measurement uncertainty.

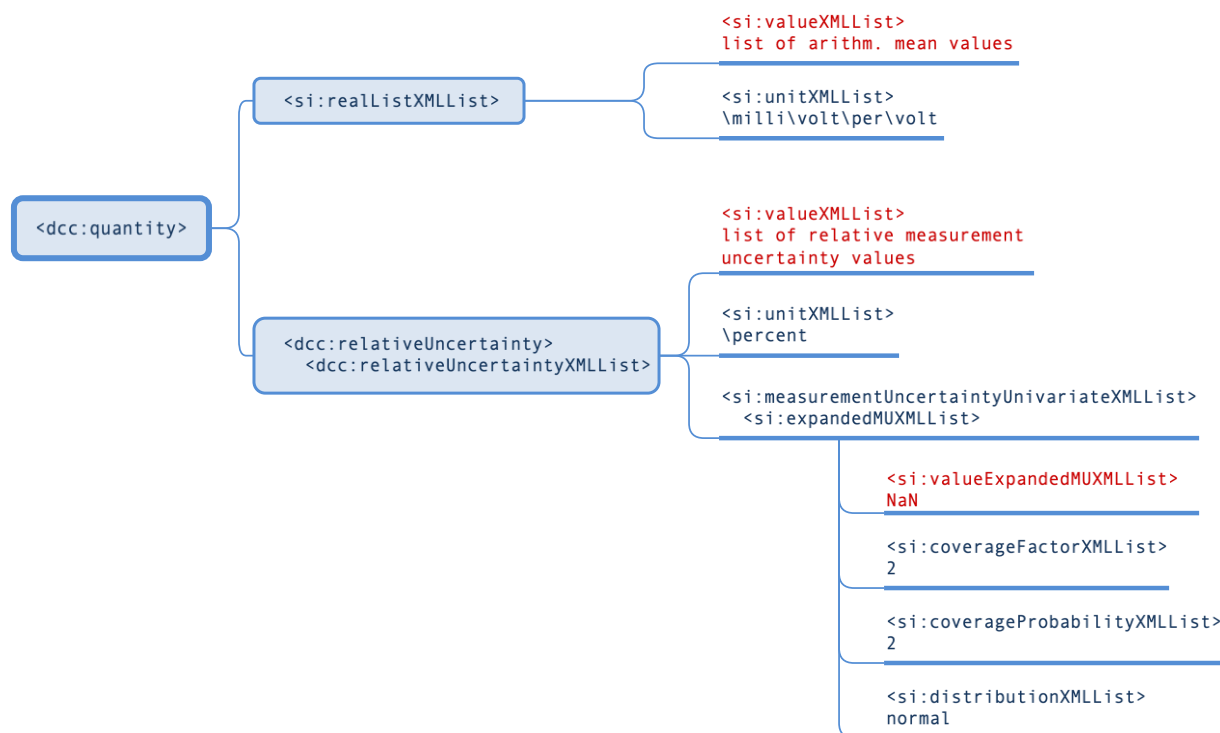



Figure 22: Example of the schematic structure of a dcc:quantity with a relative measurement uncertainty.

```

1 <dcc:quantity refId="measurementSeries1Tensile measurementSeries3Tensile
2 measurementSeries5Tensile" refType="math_arithmeticMean force_withRotation">
3   <dcc:name>
4     <dcc:content lang="de">Arithmetischer Mittelwert (AM)</dcc:content>
5     <dcc:content lang="en">Arithmetic Mean</dcc:content>
6   </dcc:name>
7   <dcc:description>
8     <dcc:content lang="de">Messreihen 1 + 3 + 5</dcc:content>
9     <dcc:content lang="en">Measurement series 1 + 3 + 5</dcc:content>
10  </dcc:description>
11  <si:realListXMLList>
12    <si:valueXMLList>0.000000 -0.199979 -0.399962 -0.599951 -0.799945 -0.999946
13    -1.199954 -1.599992 -2.000067 NaN</si:valueXMLList>
14    <si:unitXMLList>\milli\volt\per\volt</si:unitXMLList>
15  </si:realListXMLList>
16  <dcc:relativeUncertainty>
17    <dcc:relativeUncertaintyXMLList>
18      <si:valueXMLList>NaN 0.034 0.034 0.034 0.034 0.034 0.034 0.034 0.034
19      NaN</si:valueXMLList>
20      <si:unitXMLList>\percent</si:unitXMLList>
21      <si:measurementUncertaintyUnivariateXMLList>
22        <si:expandedMUXMLList>
23          <si:valueExpandedMUXMLList>NaN</si:valueExpandedMUXMLList>
24          <si:coverageFactorXMLList>2</si:coverageFactorXMLList>
25          <si:coverageProbabilityXMLList>0.95</si:coverageProbabilityXMLList>
26          <si:distributionXMLList>normal</si:distributionXMLList>
27        </si:expandedMUXMLList>
28      </si:measurementUncertaintyUnivariateXMLList>
29    </dcc:relativeUncertaintyXMLList>
30  </dcc:relativeUncertainty>
31 </dcc:quantity>

```

Figure 23: XML code of arithmetic mean values and its uncertainties (see also Appendix A: Example of an extended digital calibration certificate for force calibration, lines 2737-2764)

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6 List of refType identifiers for force calibration

The refType attributes are used to improve machine interpretability of the DCC. The DKD has developed a system where harmonised refTypes are stored in a machine-readable and machine-interpretable format. All refType definitions, along with their scope and guidelines for their use, can be accessed in the Metrology refType database (<https://digilab.ptb.de/dkd/refType/vocab/>). The refTypes are categorized into different scopes based on their applications, with so-called “Broader Terms” defining their range.

In force calibration, refTypes from three Broader Terms are used: [basic](#), [math](#) and [force](#). The term “*basic*” applies to all fields of metrology. The term “*math*” applies to mathematical fields and “*force*” is specific to force metrology. The refTypes used for “*basic*”, “*math*” and “*force*” in force calibration are detailed in the following sections.

6.1 Basic identifiers

Identifier	Description
ambient	Specifies the influence condition that includes all ambient conditions
calibratedInterval	Statement about the calibrated range
calibrationMethod	Link to the description of the calibration method used
certificateNumber	Calibration (certificate) ID issued by the laboratory
humidityRelative	Ambient relative air humidity
identificationNumber	Unique identifier of the calibration object element
indicationValue	Quantity value indicated by a measuring instrument
isFunctionaTest	Statement about functional tests in the calibration certificate
isInCMC	Note that existing CMCs cover all or some of the results
marking	Marking on the calibration item
measurementStandard	Realization of the definition of a given quantity, with stated quantity value and associated measurement uncertainty, used as a reference
metrologicallyTraceableToSI	Statement, if and how measurement results are metrologically traceable to the SI
nominalValue	Rounded or approximate value of a characterizing quantity of a measuring instrument or measuring system that provides guidance for its appropriate use
orderNumber	Number used to identify the order or placed order by a customer

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recalibrationDate	Information about a recalibration date
referenceValue	Value used as a basis for comparison with values of the same kind
resultScope	Statement that the results only refer to the tested/calibrated/sampled items
serialNumber	Number used to identify an individual occurrence of an item of production
temperature	Ambient temperature

Table 5: Identifiers for prefix basic used in the DCC for force.


6.2 Math identifiers

Identifier	Description
arithmeticMean	Arithmetic mean of a set of values
maximum	Highest value in a set of values
minimum	Smallest value in a set of values


Table 6: Identifiers for prefix math used in the DCC for force.

6.3 Force identifiers


Identifier	Description
afterMeasurementSeries	Describes values that relate to a measurement that was performed following a series of measurements
afterPreloadings	Describes values that relate to a measurement that was performed following a preloading
balancedMean	Indicates balanced mean values
calculatedForce	Indicates calculated force values
caseA	Describes Case A according to ISO 376:2011
caseB	Describes Case B according to ISO 376:2011

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caseC	Describes Case C according to ISO 376:2011
caseD	Describes Case D according to ISO 376:2011
classification	Describes the classification of a force transducer
coefficient	Indicates the values of coefficient for force function
compressive	Indicates that values refer to a compressive force load
creepDwellTime	Describes the duration of the application of force prior to removal
creepTestAfterPreloading	Describes the creep test after force removal
creepTestAtMaximumLoad	Describes the creep test at maximum calibration force
creepTime	Indicates creep time
decreasing	Denotes values that refer to measurement series with decreasing load
envelopeFunctionMeasurementUncertaintyBalancedMean	Specifies the envelope function for measurement uncertainties of the arithmetic mean W_{xa}
extensionCableLength	Refers to the length of an extension cable via which an analogue signal is transmitted
fittingFunction	Denotes fitting function
function	Denotes functions
functionParameters	Denotes parameters that refer to function
increasing	Denotes values that refer to measurement series with increasing load
indicationAfterPreloading	Denotes values that refer to indication after preloading
indicationAtMaximumLoad	Denotes values that refer to indication at maximum force
indicationAtZeroLoad	Denotes values that refer to indication at zero load

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inverseInterpolationPolynom	Denotes a formula to be the inverse interpolation polynomial
itemAmplifier	Amplifier from the customer for calibration
itemCableLength	Refers to the length of the cable which is permanently connected to the calibration item and via which analogue signal transmission takes place
itemConnectorNumber	Number of connectors of the calibrated item
itemTransducer	Force transducer being calibrated
measurementSeries1ZeroDegreesIncreasing	Specifies first measurement series performed at a mounting position of 0 degrees with increasing load levels
measurementSeries2ZeroDegreesIncreasing	Specifies second measurement series performed at a mounting position of 0 degrees with increasing load levels
minimumDwellTime	Describes used method for minimum dwell time
mountingPosition	Denotes values that refer to mounting position
referenceList	Indicates that the elements in the following structure are references
relativeCreepError	Denotes values that refer to relative creep error
relativeInterpolationError	Denotes values that refer to relative interpolation error
relativeRepeatabilityError	Denotes values that refer to relative repeatability error without rotation
relativeReproducibilityError	Denotes values that refer to relative reproducibility error with rotation
relativeReversibilityError	Denotes values that refer to relative reversibility error
relativeZeroError	Denotes values that refer to relative zero error
results	Describes measurement results
tensile	Indicates that values refer to a tensile force load


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valuesCreepTest	Indicates that values refer to creep test
valuesForPreloads	Indicates that values refer to preloads
withoutRotation	Without rotation
withRotation	With rotation
zeroReduced	Indicates that values refer to zero-reduced
zeroSignal	Indicates that values refer to zero signal

Table 7: Identifiers for prefix force used in the DCC for force.


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8 Change history

Revision	Date	Changes
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Appendix A: Example of an extended digital calibration certificate for force calibration with both compressive and tensile force measurements

The DCC examples are attached to this PDF and can usually be accessed via clicking on the paperclip symbol.

Additionally, they can be found via the following DOI:

Example Appendix A: <https://doi.org/10.7795/550.20260528A>

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Appendix B: Example of a simple digital calibration certificate for force calibration with only compressive force measurements

The DCC examples are attached to this PDF and can usually be accessed via clicking on the paperclip symbol.

Additionally, they can be found via the following DOI:

Example Appendix B: <https://doi.org/10.7795/550.20260528>



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