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Measurement Data and Information of Non-Automatic Weighing Instruments as Structured Data

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Abstract **– The successful digitization of documents in conformity assessment, e.g. for calibration and test, requires both the compliance with different requirements and the use of a unified machine-readable data structure. A well-known example is the data structure for the Digital Calibration Certificate (DCC). Its use is proposed by the German Calibration Service (DKD) in its Report DKD-E 7-3 for the digitization of calibration certificates for non-automatic weighing instruments (NAWIs). An analysis has been carried out to check whether the proposal can be applied to OIML R 76 test reports. By comparing the measurement data and information in both types of documents, similarities and differences in the content description were identified. The following publication gives an overview of this analysis and its results and provides suggestions for the description of the test reports using the DCC.**

I. INTRODUCTION

The digitization of documents used in conformity assessments of non-automatic weighing instruments (NAWIs), such as calibration and test, poses several challenges: On the one hand, all relevant requirements from different standards and other normative sources have to be considered. On the other hand, a unified machine-readable data structure needs to be applied, that can cover documents for a wide range of products. A good example to this issue is the already established machine-readable data structure for the Digital Calibration Certificate (DCC) [1]. The DCC is intended to replace the paper-based calibration certificates issued until now in accordance with ISO/IEC 17025 [2]. The German Calibration Service (DKD) has published an Expert Report DKD-E 7-3 [3], which, as a result of extensive discussions, includes a detailed guideline for the content description of the NAWI calibration certificates based on the requirements of EURAMET/CG-18/v.02 [4], the Guide on the Calibration of NAWIs.

Since the types of conformity assessment laid down in ISO/IEC 17025 [2] also cover testing, digitizing the corresponding test reports for NAWIs seems to be useful too. NAWIs are tested extensively to support type evaluation of NAWIs, i.e. conformity assessment of the instrument type within legal metrology. The respective requirements, tests and templates for test reports are standardized in the International Recommendations OIML R 76 [5], [6].

Due to the fact that the content of NAWI test reports and NAWI calibration certificates is largely similar, it makes sense to check whether the DCC data structure proposed in DKD-E 7-3 [3] could also be applied to the test reports. For this, a usability analysis was carried out to identify the similarities and the differences between the content of both document types. The detailed description of this analysis and the discussion of its results are therefore the subject of this publication.

The publication is structured as follows: After a brief introduction to the subject, a short overview of overall requirements for the description of the content within a calibration certificate and test reports is given in Chapter II. Chapter III summarizes the findings and gives an outlook of possible future activities.

II. MEASUREMENT DATA AND INFORMATION OF NON-AUTOMATIC WEIGHING INSTRUMENTS

The overall requirements for reporting the results of a calibration and a test are set out in ISO/IEC 17025 [2]. It states that the results shall be provided unambiguously, usually as a report or certificate, and include all data and information necessary to interpret the results correctly [2]. In addition, the standard provides a list of mandatory information, that each calibration and test report must contain. According to them, both types of documents must, among other things, include information on the object of conformity assessment, the measurement methods applied, the influence conditions, and the measurement results which are obtained and used for further interpretation. All of these content elements have been considered for a comparative analysis and represented in detail in separate sub-chapters. For better differentiation the following notation is applied: the DCC elements are in bold, and the quantities are in lower case italics.

A. Object of conformity assessment

ISO/IEC 17025 [2] and EURAMET/CG-18/v.02 [4] require a calibration certificate to provide a detailed description of the object of conformity assessment. Based on this, the DCC structure has been proposed [2], as shown in Fig. 1.

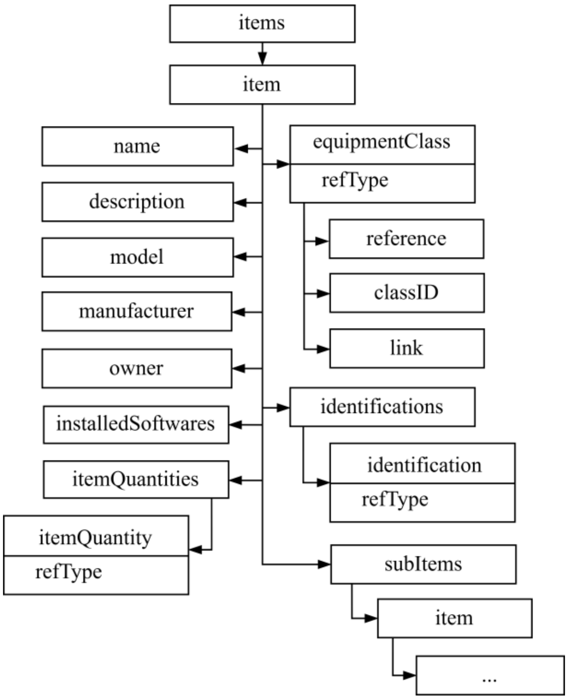

*Fig. 1. DCC structure of **dcc:items** [1].*

An individual calibrated NAWI is described by the element **dcc:item**. Its sub-elements allow to provide a set of further descriptive information. Using the element **dcc:identification**, one or more identification type can be added. Each identification is referenced by a **refType** attribute [3]. The **refTypes** are predefined and can be selected from the centralized "Metrology refType Database" [7]. Here, several types of **refType** are differentiated by their prefixes: The prefix **basic_** relates to the universal methods suitable to different application domains, quantities and instruments [7]. The prefix **NAWI_** refers to the methods used only for the calibration of NAWIs [7]. The prefix **math_** relates to universal mathematical **refTypes**, which are usually used in combination with other **refTypes** to specify them [7]. To identify a NAWI, the **refType basic_serialNumber** [7] ("serial number") is applied, as this is the typical identification type used in calibration certificates [7].

The element **dcc:equipmentClass** and its sub-element **dcc:classID** are used to specify a category of the NAWI. As there is no main specified classification of the NAWIs within the scope of calibration, this element was used to describe the categorization of NAWIs based on one of the metrological characteristics, such as "single range instrument" ("NAWI-SR"), "multiple range instrument" ("NAWI-MR") or "multi-interval instrument" ("NAWI-MI"). The **dcc:reference** and **dcc:link** elements are used in combination with these predefined categories [3].

In cases where the calibrated NAWI is represented as a "complex device" incorporating different "devices" and "parts", they can be presented using **dcc:subItems**. Each of them can then be separately described in detail by the sub-element **dcc:item**. In addition, this sub-element is used to specify several (partial) weighing ranges in case of a multiple range or multi-interval NAWI [3]. The following **refTypes** have been created to refer the item to the ranges: **NAWI_range1**, **NAWI_range2**, **NAWI_range3**, and **NAWI_range4** [7].

All metrological nominal and reference characteristics (**dcc:itemQuantities**) can be separately described by **dcc:itemQuantity** in combination with a **refType.** (Here, the element **dcc:itemQuantity** is one of the variants of the element **dcc:quantity**, which can also be used within other elements such as **dcc:influenceConditions**, **dcc:results**, or **dcc:usedMethods** [3], as shown in Fig. 2.

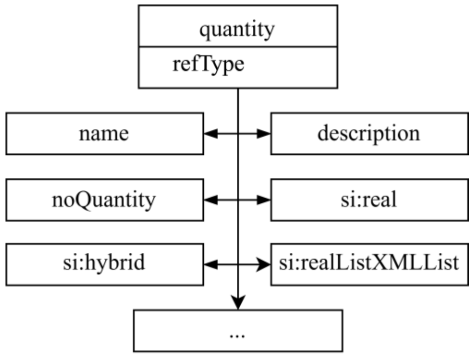

*Fig. 2. DCC structure of **dcc:quantity** [1].*

The following characteristic are already covered by the **refTypes**:

- *actual scale resolution* (*d*) (**NAWI_resolutionOfDisplayingDevice**) [7],
- *verification scale interval* (*e*) (**NAWI_verificationScaleInterval**) [7],
- *nominal value* **(basic_nominalValue)** [7].

For the description of range characteristics, the two different **refTypes** are usually combined to express quantities such as *maximum weighing capacity* (*Max*) (**math_maximum basic_nominalValue** [7]) and *minimum weighing capacity* (*Min*) (**math_minimum basic_nominalValue** [7]) [3].

The requirements for describing a NAWI in the framework of tests according to OIML R 76-2 [6] are similar to those for calibration in several aspects. For example, an unambiguous identification is also mandatory. As the NAWI is tested for a subsequent type evaluation, its "type designation" must be specified [6]. This information can be covered by **dcc:identification** [1] and its sub-elements, but the corresponding **refType** should be created.

In terms of classification, there is no predefined uniform one. For tests, NAWIs can be classified according to their accuracy class ("special" (I), "high" (II), "medium" (III), and "ordinary" (IIII)), as the accuracy is directly related to further main characteristics such as *verification scale interval* (*e*), *number of verification scale intervals* (*n*), and the *minimum capacity* (*Min*), which are important to describe the NAWIs in a required level of detail [5].

There is also no unified classification for the incorporated "devices" and "parts" of the NAWIs. Instead, different test methods require different classification, each focusing on a specific characteristic. For example, the test report on "weighing performance", "eccentricity" or "repeatability" must include the cate of "tracking device" and/or "setting device", if available. For the "eccentricity test using a rolling load", the "load receptor" has to be specified [6]. This can be described by **dcc:equipmentClass** within **dcc:subItem**.

The main characteristics of NAWI(s), such as *Min*, *Max*, *d*, *e*, and *resolution during the test* [6] can be described by **dcc:itemQuantities**, since these are also partially relevant to a calibration and the required **refTypes** are available [3]. The **refTypes** are still missing for such main characteristics as the *number of verification scale intervals* (*n*) as well as for specific characteristics that are not relevant for calibration and are only important for certain test methods. These are, for example:

- *nominal voltage* (U_{nom}),
- *maximum voltage* (U_{max}),
- *minimum voltage* (U_{min}), and
- *frequency* (*f*)

necessary for the test method "electrical disturbances" [6].

Among the method-specific characteristics, there are also those that carry only qualitative information. As part of an "eccentricity test", for example, it is important to document whether the NAWI is mobile. For a "discrimination test", the characterization in terms of the type of indication is required, as this determine which variant of the "discrimination test" is to be applied [6]. These characteristics can be either described by **refTypes**, which have also to be created, or by the element **dcc:noQuantity**, as shown in Fig. 2.

B. Methods

According to the common requirements of ISO/IEC 17025 for the reporting of results, the identification of the method used is considered as mandatory for each calibration certificate and test report [2]. To cover this requirement, the element **dcc:usedMethods** with its sub-element **dcc:usedMethod** in combination with a **refType** and a further detailed description [3] has been proposed in the DCC [8], as shown in Fig. 3.

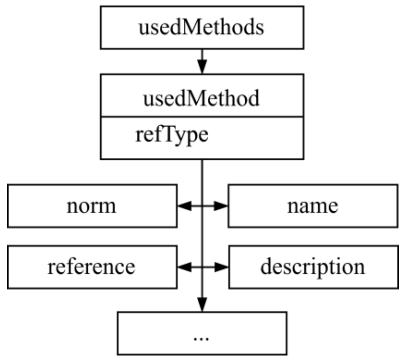

*Fig. 3. DCC structure of **dcc:usedMethods** [1].*

In the context of calibration, this requirement is specified for NAWIs more precisely in EURAMET/CG-18/v.02 [4]. Based on this, DKD-E 7-3 [3] defined **refTypes** for the "calibration method" (**NAWI_calibrationMethod**) and for the "measurement uncertainty" (**basic_methodMesasurementUncertainty**) [7].

In contrast to a calibration, a test of NAWI(s) generally includes a larger range of test methods, as these are used for the subsequent type evaluation. A general overview and the detailed description of the test methods is given in OIML R 76-1 [5]. OIML R 76-2 [6] provides a standardized format for the respective test reports. However, all these methods cannot currently be digitized by **dcc:usedMethod**, as the corresponding **refTypes** are missing. Two solutions are possible: (i) to use the general approach as in DKD-E 7-3 [3] and define a new **refType** (**NAWI_testMethod**) or (ii) to define a new **refType** for each test method, e.g. **NAWI_eccentricityTestMethod** or **NAWI_weighingPerformanceTestMethod**. In both cases the DCC is flexible enough to provide further human-readable description.

C. Conditions

According to ISO/IEC 17025 and EURAMET/CG-18/v.02, the conditions must be a mandatory part of each calibration certificate, because they affect the result of the calibration [2], [4]. This requirement has been met in the DCC by use of **dcc:influenceConditions** [8], as shown in Fig. 4.

The following main "influence conditions" have been created so far as **refTypes**: **basic_humidityRelative**, **basic_adjustment**, **mass_airDensity**, **mass_airPressure**, and **basic_temperature** [7].

"Influence conditions" in the DCC are not further specified in categories, such as "operational", "environmental" or "disturbances", but can be expressed in different ways within the element **dcc:data**, as in Fig. 4, among other forms, as text (**dcc:text**) or quantity (**dcc:quantity**), according to the principle described in Sub-chapter A, presented in Fig. 2. So, a *temperature* (**basic_temperature**) [7] can be described by **si:real** with a single value, unit, and (if applicable) measurement uncertainty. It is also possible to document a *temperature range*. For this, the **refType basic_temperature** [7] is used in combination with the **refTypes math_maximum** or **math_minimum** [7], each described by a **si:real**. In addition, there are also conditions that do not require a numerical value but freely formulated explanations or expressions from a predefined list. For example, the "adjustment status" (**basic_adjustment)** [7] is described by **dcc:status** in combination with one or more explanatory notes (**dcc:text**) [3]. For "status", several values are predefined in DCC ("beforeAdjustment", "afterAdjustment", "beforeRepair", and "afterRepair"), as they are required by ISO/IEC 17025 [2].

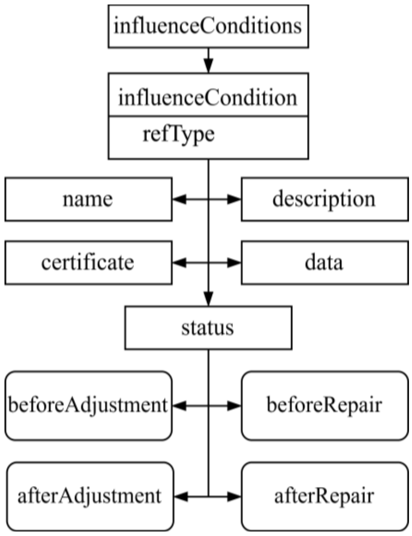

*Fig. 4. DCC structure of **dcc:influenceConditions** [1].*

In the framework of an OIML R 76 test, there are several conditions that must be considered in all test methods required for a type evaluation, as well as those that are method-specific. For instance, an "environmental condition" such as *temperature* is mandatory for each test method. The optional "environmental conditions" *relative humidity* and *barometric pressure* (*Bar. Pres.*) are only documented for specific types of test methods or for testing NAWIs with a specific accuracy class [5]. Each of these conditions can be expressed by one to three individual values that relate to the start, the end of the measurement and/or to the maximum value recorded during the measurement [6].

The DCC structure proposed for the calibration is also partially applicable to a test. Thus, the three "environmental conditions" expressed by a single maximum value, can be fully covered by both the **refTypes** and **si:real**. However, it is not possible to relate these conditions to the start and the end of the measurement, as no **refTypes** are provided. These should be added for the use in test reports. In addition, there is no possibility to express several "operational conditions" which provide the information on how the "devices" and "parts" incorporated in the NAWI operate during the measurement. For example, for some test methods, it is required to specify, whether the "automatic zero-setting device" and "automatic zero-tracking device" are "not-existent", "not in operation", "out of working", or "in operation" [6]. As these expressions are not relevant to calibration and therefore not part of the DCC data structure, they should be given in a harmonized form, similar to the "adjustment status".

D. Measurement results

The description of the measurement results within a calibration according to requirements of [2] and [4] is realized by **dcc:results** [3], as shown in Fig. 5:

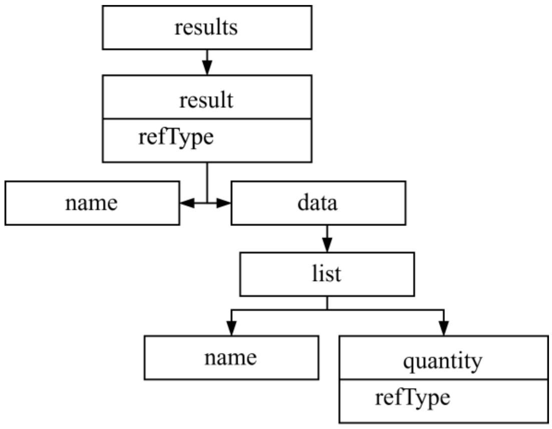

*Fig. 5. DCC structure for **dcc:results** [1].*

Here, an individual measurement can be specified using the sub-element **dcc:result** in combination with one of the following predefined **refTypes**:

- **NAWI_repeatabilityMeasurement** ("repeatability measurement") [7],
- **NAWI_eccentricityMeasurement** ("eccentricity measurement") [7],
- **NAWI_errorOfIndication** ("error of indication") [7], and
- **NAWI_auxiliaryMeasurement (**"auxiliary measurement"**)** [7].

Within **dcc:data**, each quantity (**dcc:quantity**) is represented by a **refType** [3]. The typical **refTypes** used in calibration are:

- **basic_nominalValue** (*nominal value*) [7]
- **basic_referenceValue** (*reference value*) [7],
- **basic_measuredValue** (*measured value*) [7], and
- **basic_measurementError math_maximum** (*maximum deviation*) [7].

The description of the quantities depends on their type and follows the pattern specified in the Digital System of

Units (D-SI) [8]. For example, the *nominal value* (**basic_nominalValue**) [7] of a test load as part of a “repeatability test” is usually documented as a single numerical value with the corresponding unit. In a calibration certificate, it is described using **si:real** [8] as in Table 1:

Table 1. D-SI-based description of a nominal value [3].

Human Readable Equivalent	Sub-elements of si:real	Value Example
value	**si:value**	2
unit	**si:unit**	\kilogram

The same pattern can also be applied to a *reference value* (**mass_referencedValue**) [7].

The *measured values* (**basic_measuredValue**) [7] obtained in one measurement sequence of the “eccentricity test” shall be related to the position of the test load on the load receptor [5]. For this, the following D-SI pattern has been applied, as given in Table 2:

Table 2. D-SI-based description of measured values [3].

Human Readable Equivalent	Sub-elements of si:realListXMLList	Value Example
load position	**si:labelXMLList**	Position1 Position2 Position3 …
measured values	**si:valueXMLList**	0.1004 0.1005 …
SI unit	**si:unitXMLList**	\kilogram

The description of the measurement results in the framework of the OIML R 76-2 test reports [6] have some similarities to the calibration certificate. For example, measurement types such as “repeatability measurement”, “eccentricity measurement”, and “error of indication” can be covered by the respective **refTypes** used for a calibration. However, OIML R 76-2 also includes a large number of other measurement types for which no **refTypes** have yet been provided, as they are not relevant for calibration, such as “discrimination and sensitivity”, “tare”, “warm-up time”, “voltage variation”, and “electrical disturbances” [6].

Most of the main quantities used in a test can be covered by the existing **refTypes** and D-SI quantities. So, the **basic_nominalValue** can be applied to describe the *nominal value* of different types of loads, such as:

- “test load”,
- “additional load” (ΔL), which is only required for NAWIs without higher resolution,
- “zero-load” (L_0) as load at or near zero indication, and
- “tare-load” needed, among others, for the test method “stability of equilibrium” [6].

The **refType basic_measuredValue** can be used for an *indicated weight value* (I) [6], which is always an individual value. In cases where several values are obtained depending on the position of the test load, such as in an “eccentricity test”, the D-SI quantity pattern **si:realListXMLList** can be reused here. The **refType basic_measurementError** is applicable to an *error of indication* (E) [6], while *mpe* is part of the statement of conformity and serves as a **basic_toleranceLimitUpper** and **basic_toleranceLimitLower** [7]. This is similar to the *tolerance* in [4] but was not considered in [3].

Some test-specific quantities do not have **refTypes** because they are not applicable within a calibration, such as the *corrected error of indication* (E_c) as the difference between the *error of indication* and the *error calculated at or near zero indication* ($E - E_0$). Additionally, the **refType** for E_0 (**zeroReduced** [7]) actually exists only in relation to the force-related quantity and could be adopted for NAWIs within the framework of calibration or tests. Some measurements, such as those carried out within “repeatability test”, requires the difference between the *maximum* and *minimum error of indication* ($E_{max} – E_{min}$) in order to make the result statement about the success or failure if the test. Since the “repeatability test” within a calibration does not require such a difference but a *standard deviation* of the measured value, a **refType** for ($E_{max} – E_{min}$) shall be created. Furthermore, the **refType basic_referenceValue** from the calibration is not applicable, as tests based on OIML R 76-2 are only carried out with the *nominal values* of the loads [6].

III. CONCLUSIONS

The comparison showed that the DCC data structure for a NAWI calibration certificate can largely be applied to the test reports according to OIML R 76 [5], [6]. Most of the information/data that occur in the test reports can be captured by the DCC data structure, e.g. the object of conformity assessment, the method, the conditions, and the results.

In general, it is not possible to describe test-specific information that does not appear in a calibration certificate and is therefore not reproducible in machine-readable form using DCC. In many cases, this is caused by missing **refTypes**. With regard to the description of the object of conformity, these are, for example, the identification as "type designation" as well as some specific metrological and functional characteristics that can be treated as “influence conditions”. As most of these conditions form the basis of specific test methods as part of a type evaluation, they do not occur in this form in a calibration. This also concerns the **refTypes** for the test methods as such.

Another important aspect is the difference in how the classification of the NAWIs is treated. For a calibration, the categorization was fixed in terms of measurement ranges and measurement intervals [3], as these are the focus of each calibration. The categorization for a test is more complex. However, each classification used within different tests can be described by the DCC due to its generalized structure.

Despite the existing differences between the two types of documents presented here, it is extremely important to adhere to existing structures and procedures during digitization to maintain consistency in such a wide area as conformity assessment. In addition, many other areas related to conformity assessment, such as manufacturing, standardization or market surveillance, may also benefit from the harmonization, especially those, where the data and information from both calibration certificates and test reports can be reused, as e.g. Asset Administration Shell (AAS) or Digital Product Passport (DPP).

IV. ACKNOWLEDGMENTS

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