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S.R. CWA 16200:2010

A Guide to the Development and Use of Standards Compliant Data Formats for Engineering Materials Test Data

S.R. CWA 16200:2010

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CEN WORKSHOP AGREEMENT

CWA 16200

September 2010

ICS 35.040

English version

A Guide to the Development and Use of Standards Compliant Data Formats for Engineering Materials Test Data

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

The formal process followed by the Workshop in the development of this Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN Management Centre can be held accountable for the technical content of this CEN Workshop Agreement or possible conflicts with standards or legislation.

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Foreword

The production of this CWA (CEN Workshop Agreement), *Economics and Logistics of Standards-Compliant Schemas for Interoperability of Engineering Materials Data,* was formally accepted at the Workshop's kick-off meeting on 12th May 2009, held at CEN, Brussels.

The document was developed through the collaboration of a number of contributing partners in the CEN WS ELSSI-EMD, including universities, digital curation centres, industry, consultants, software houses. The CEN Workshop was active from May 2009 until June 2010.

A period of public comment was held during March-April 2010. The final text of the CWA was formally endorsed at the Workshop final meeting, 27th May 2010, and following an electronic round of comments in June 2010. The name of companies/organizations, which endorse the CWA, is listed hereunder.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

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The CEN WS ELSSI Project Team (PT) expresses its thanks to Dr Chris Bullough for his active participation in the work and his expert guidance.

Finally, the contributions from the registered participants, experts in the domains of engineering materials, data curation, and standardization, to the work of CEN WE ELSSI are gratefully acknowledged.

NOTE While a decision on CEN hosting the data formats that CEN WS ELSSI-EMD delivers is pending, the links to the resources at HTTP URIs beginning http://www.cen.eu/cen/cwa/elssi-emd/ will be unavailable. Until such time as the data formats are published as HTTP URIs, the CWA includes an electronic copy (ZIP file) of the ontology, the schema, and the examples.

Companies supporting the current CWA

Registered participants:

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Comments or suggestions from the users of the CEN Workshop Agreement are welcome and should be addressed to the CEN-CENELEC Management Centre.

0. Introduction

0.1 Overview

The engineering community invests significantly in generating materials test data of a high inherent value. Very often, the data sets are richly structured and amenable to reuse. The materials community has however, largely failed to address the issue of data capture and preservation. Although technologies for the automated capture and preservation of test data exist, on the rare occasions that data are conserved, they are invariably inaccessible to the wider materials community. This inevitably acts as an obstacle to the research process, and hinders business activities in the engineering sector. In recognition of these issues, CEN (the European Committee for Standardization) sponsored the 12-month ELSSI-EMD Workshop to develop schemas and ontologies derived from procedural materials testing standards. With the emergence of a Semantic Web of data, the project aimed to emulate other branches of the sciences that are developing and leveraging Web technologies to their advantage, and that of associated business sectors. Beyond developing schemas and ontologies for a chosen test type that complement existing specifications, the Workshop investigated their role in promoting the capture and conservation of experimental data in the materials sector, the opportunities that may arise for new and improved business, and the viability of appending the schemas and ontologies to their corresponding materials testing standards. This CWA reports the work performed and the findings of the ELSSI-EMD Workshop.

0.2 Requirements for Engineering Materials Data

Documentary Standards are an essential tool for underpinning virtually all aspects of society. In the engineering sector, material testing standards play a vital role in ensuring that the design of structures, monitoring of safety critical components, and the certification of materials for product release are all based on an agreed and validated method for determining material properties. So far, paper-based standards have been used to control the testing procedure, and paper certificates or reports are commonly used for reporting and storing such data. Various stakeholders using the documentary Standards directly, or the data so obtained, identify the need for greater interoperability of the data, not least in consistency of testing method, storage of tests results, and usage of those results in a wide engineering context.

It is contended that there are significant benefits that may be accrued from developing documentary testing and calibration Standards used for the determination of materials properties into formats that allow direct interoperability with computers and computer-controlled facilities. This would allow such Standards to be used to set-up mechanical testing machines and allow the measured output to be transferred directly to material property databases or data processing tools, or enable the material properties to be directly uploaded to product release certificates.

To understand the full benefits that would accrue from improved interoperability, it is important to consider both the mechanics of use of the Documentary standards, and the subsequent usage of the data by key stakeholders. One of the most ubiquitous materials tests is the tensile test, typically applied using the documentary standard EN ISO 6892-1:2009. Often it is applied to qualify a particular product against a material specification. A material test certificate produced in that way can have several uses, as illustrated by a simplified ship-building example in Figure 1 ***- The use of a material test certificate in ship building and operation***

Here it is used not only to provide confidence that the ship plate has been produced to the required specification, but it may also be used to demonstrate the quality processes employed during ship building. In each of those transactions information (that is, data) is taken from the store of the sender, transmitted and re-stored by the recipient.

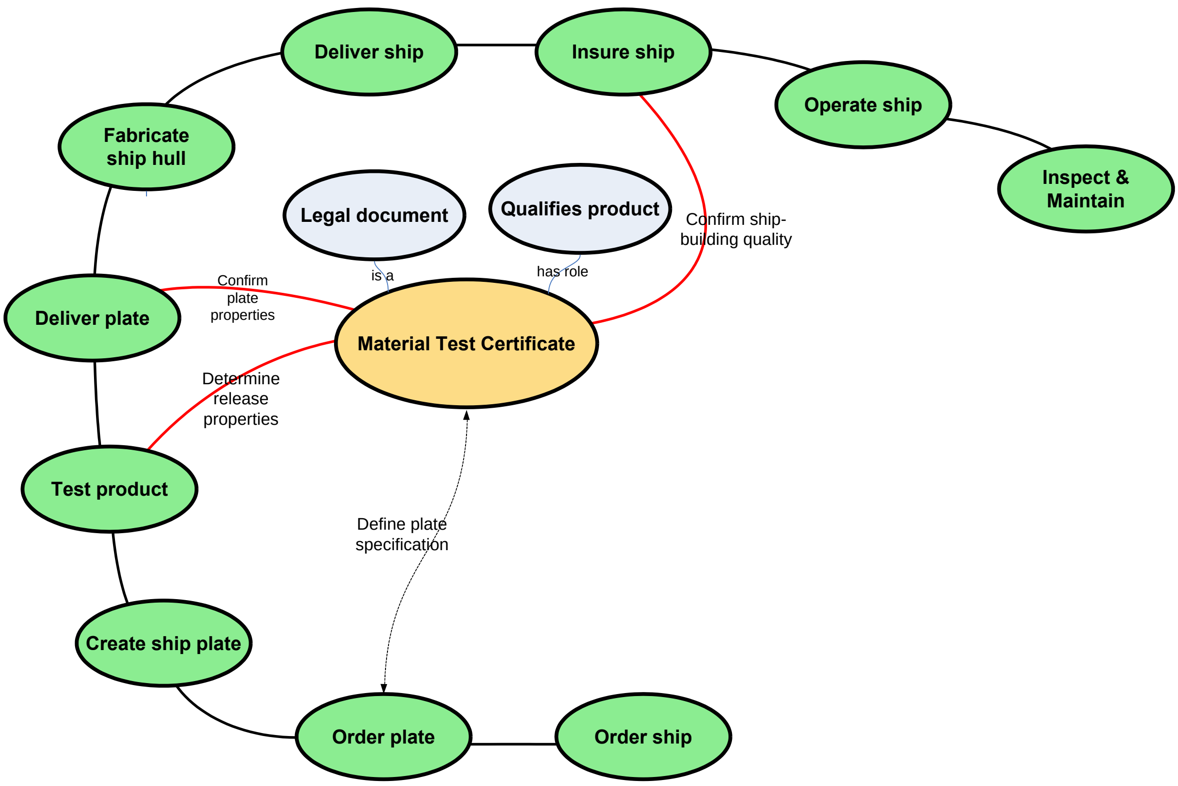

Figure 1 - The use of a material test certificate in ship building and operation

In general, there are three groups of stakeholders using data obtained from a mechanical test on a material

- Within the supply chain - to demonstrate product quality assurance
- During R&D and Design data evaluation – to develop and characterise materials
- Structural Analysis / Life Cycle Analysis – use of assessed materials data calculate component life.

This is illustrated in Figure 2 - ***Stakeholders and their use of engineering materials data***

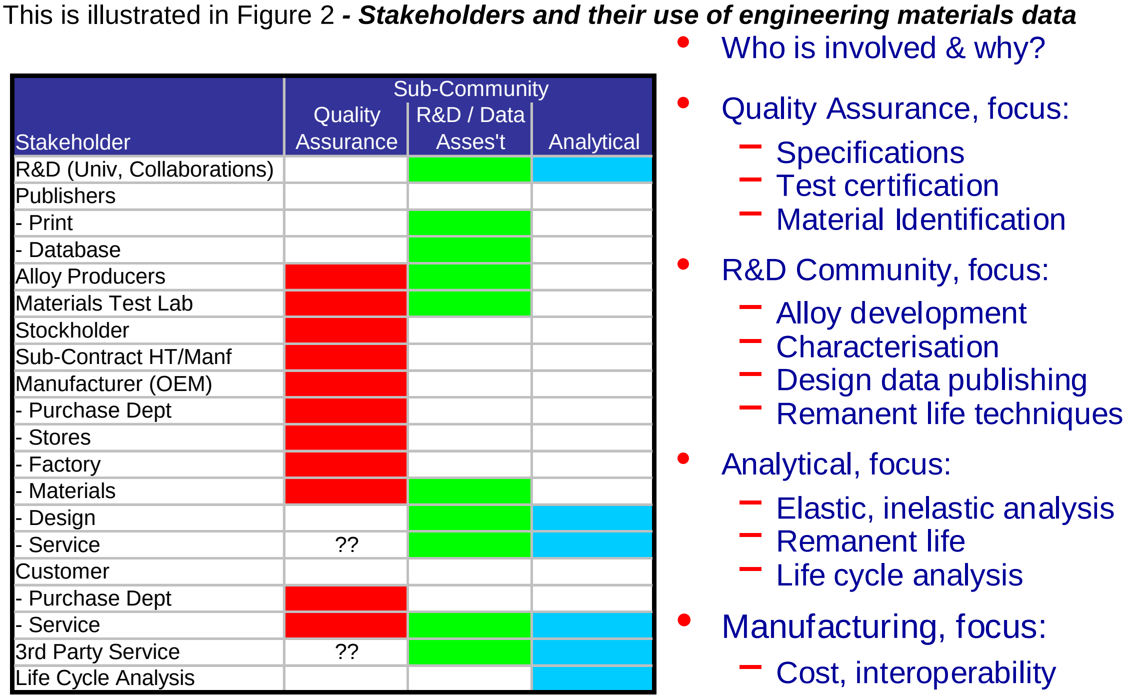

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Figure 2 - Stakeholders and their use of engineering materials data

The same documentary procedural standard for the mechanical test is used by each group of stakeholders but they require the data for different reasons, often in different formats and to differing levels of detail, abstraction and complexity.

One potential barrier to the interoperability of materials data is that the vocabulary and processes involved with computer technology are unfamiliar to those in the materials testing domain. Terms such as 'schema' and 'ontology' are used representing the process outlined in the documentary standard in a computer compatible format either in a schematic form (schema) or in a computer mark-up language (ontology). Thus whilst present users of the procedural standards will recognise the benefits that will accrue, it is important to recognise that technologies outside of their normal experience must be explained clearly, and without recourse to jargon.

0.3 CEN Support and General Approach

Under the auspices of a CEN (European Committee for Standardization) Workshop, funding has been forthcoming from the European Commission to evaluate the benefits that may be accrued from developing documentary testing Standards used for the determination of materials properties into formats that allow direct interoperability with computers and computer-controlled facilities. The CEN Workshop is entitled 'Economics and Logistics of Standards-Compliant Schemas for Interoperability of Engineering Materials Data' (ELSSI-EMD), and this CWA (CEN Workshop Agreement) reports its findings and recommendations.

The work reported in this document is motivated by the opportunity to deliver improved data management in the engineering materials sector. Although the facilities used to generate and process test data have evolved to be predominantly computer-controlled, there has not been an accompanying evolution of standard data formats. Consequently the processes for generating, processing, and storing information are not at all well integrated, and instead of a digital infrastructure, the materials community is simply left with a collection of largely stand-alone, isolated systems. Although aggregating data from different sources is possible, it is far from straightforward simply because of differences in data formats. Standard data formats resolve this issue and allow an opportunity to be seized that has so far eluded the materials community, namely the realization of a seamless infrastructure of computer-controlled facilities in anticipation of improved business processes and more effective research.

In recent years, advances in information technology and increasing pressure for more effective business and research practices has made the requirement for effective data management more a necessity than an option. CEN WS ELSSI-EMD delivers a new and perhaps radical approach, but one that offers prospects for a solution that has long evaded the engineering materials community. By developing computer-readable versions of existing technical standards for mechanical testing, ELSSI-EMD aims to deliver data formats that mitigate against obsolescence, that are maintainable, and that find widespread adoption. All these criteria are met exactly because the technical standards to which the data formats comply are themselves already maintained and accepted by the engineering materials community.

This document is a guide to using and developing computer-readable data formats that comply with technical standards for mechanical testing. It focuses specifically on the EN ISO 6892-1:2009 ambient temperature tensile testing standard. The scope of the work is defined entirely by this written testing standard, so that not only the results of performing the test are computer-readable, but also all the metadata that are defined in the written standard, including conditions, specimen and machine configurations, and constraints, all of which are required to put the results of applying the standards into context.

The expectation is that technical standards in the engineering sciences can be translated to computer readable reference implementations in the same way that specifications in the ICT find realization as reference implementations. From another perspective, the work can simply be seen as delivering a computer-readable equivalent to a natural language translation of the technical standard.

As with any translation, the primary objective is to remain true to the original meaning, and this is the governing factor when implementing a computer-readable version. Beyond this requirement, there are other considerations driven by contemporary IT paradigms, namely object-orientation and reuse. From the perspective of object-orientation, the implications for developing a format that is compliant with a technical standard for mechanical testing are that common entities need to be identified and form a base data model that can then be specialized for information that is characteristic to an individual test. For tests on engineering materials, properties data tend to be unique to individual test types, such as fracture toughness for fracture mechanics tests, yield and proof strengths for tensile tests, and time to rupture for creep, while ancillary information, such as production route and specimen type are common.

In terms of reuse, there is a requirement to align the work to existing data models and modelling standards. Those relevant to the work reported in this document include ISO 10303 Parts 41, 45, and 235, MatML, JRC MatDB, and NMC MatDB.

While the work mirrors the development of natural language editions of the technical standard, the implications of delivering computer readable versions of technical standards are far more profound, especially with respect to the impact on business models in both the industrial and standardization sectors. This CWA anticipates the possible impacts, and offers guidance on how to proceed to promote the adoption of standards-compliant data formats.

0.4 Motivations for Improved Data Management

0.4.1 Business Sector

From finance to health care, the electronic transfer of information, commonly termed electronic data interchange (EDI), has had a significant impact on business practice (http://www.aberdeen.com/c/report/sector_insights/5097-SI-supplier-enablement-enterprise.pdf). In EDI, the computer-to-computer exchange of business data relies on information being organized according to a standard format recognized both parties, allowing computer transactions that require no human intervention. All information contained in an EDI transaction typically the same as that of a conventionally printed document. Some of the recognized benefits of EDI include reduced cycle time, increased productivity, reduced costs, improved accuracy, improved business relationships, and minimized paper use and storage.

Standards-compliant data formats offer an opportunity to realize the benefits of EDI in the engineering sector. Besides facilitating improved productivity, a move away from paper-based transactions and archiving can reasonably be expected to counter accidental data loss, which can be a serious issue considering the high inherent worth of test data. It can also be expected that standards-compliant data formats will lead to new business opportunities, improved auditing, and greater traceability. As demands on the industrial sector for greater accountability become ever more stringent, these are important considerations. Examples include the long-term preservation of conformance certificates and increased data quality control, as manifested in the ISO 8000 family of standards. The first ISO 8000 standard was published in 2008 as a Technical Specification (TS) entitled Data quality -- Part 110: Master data: Exchange of characteristic data: Syntax, semantic encoding, and conformance to data specification. ISO/TS 8000-110:2008 specifies general, syntax, semantic encoding and data specification requirements for master data messages between organizations and systems. The focus is on requirements that can be checked by computer. Further details available from http://www.iso.org/iso/catalogue_detail.htm?csnumber=50800. Other Technical Specifications published in 2009 include part 100 (introduction), part 120 (provenance), part 130 (accuracy) and part 140 (completeness). If ISO 8000 follows a trend similar to ISO 9000 in terms of industry adoption, then it can reasonably be expected that in the coming years, data management will become a primary concern for organizations in the industrial sector.

0.4.2 Research Sector

Although the motivations are fundamentally different to those of business, the research sector now recognizes the fundamental role that access to research data in a viable research infrastructure. Under the auspices of Knowledge Exchange partnership (http://www.knowledge-exchange.info), agencies from the UK (www.jisc.ac.uk and www.dcc.ac.uk), Germany (www.dfg.de), and Denmark (www.deff.dk), and The Netherlands (www.surf.nl) are leading their efforts on the conservation and reuse of data. In the UK, BBSRC has a stated data sharing policy that makes effective data management a prerequisite for obtaining funding [11]. EPSRC has adopted a similar, if less stringent policy. Details of these and other data management policies are available from the DCC at http://www.dcc.ac.uk/resources/policy-and-legal/data-management-plans.

At the European level, the European Commission invests significantly in research that generates materials data of an high inherent worth, little of which remains available to the broader engineering community. With the introduction of an Open Access Pilot initiative for selected FP7 projects [14], it is clear that the European Commission is also favouring the improved management of research output.

In the context of improved data management, the research sector also acknowledges the fundamental role of standards to codify the boring, so that the exciting can happen on top of them [26,29]. Again the natural and life sciences are developing a robust foundation, leveraging standards and technologies (http://www.biosharing.org/ and http://esw.w3.org/topic/HCLSIG).

A recent DCC SCARP Synthesis Report [17] provides a critical review of the disciplinary differences in research data sharing and data management. While the natural and life sciences have embraced and benefited from efforts to conserve and share data, the engineering disciplines have a very poor record [10]. This inevitably hinders research in engineering sciences. Although it is something of an anomaly that the engineering sciences have such a poor record in research data management, when its students are highly IT literate and generate significant volumes of data, with projects such as MDC (http://www.materialsdatacentre.com) and EP2DC (http://wiki.eprints.org/w/EP2DCOverview), there are indications, the engineering sciences are beginning to demonstrate an appreciation of the importance of effective data management.

0.4.3 Standardization Sector

The European Commission White paper on ICT Standardization [13] supports the adoption of the more agile standardization development process required in the ICT sector. In anticipation of the demands for standard data formats, CEN WS ELSSI-EMD is pioneering the introduction of processes that will facilitate the conventional Standards bodies contributing their expertise to the needs of the ICT and related sectors.

0.5 The Role of Ontologies and Schemas

There are a number of aspects whereby it would be beneficial if testing standards were to have compatible interoperability with the computer systems that control the test machine and the output from the testing machine software used to determine the material properties. In addition, it would be possible to transform the data directly into product release certificates and other types of reports. In the case of EN ISO 6892-1:2009 and other mechanical testing standards, the potential benefits include:

- **Improved interoperability**—data formats compliant with testing standards will allow the seamless transfer of test data between computer-controlled facilities, such as test machines and materials databases.
- **Improved data conservation**—data formats compliant with testing standards will allow a complete records to be conserved, an important consideration in light the ever more stringent auditing and traceability demands placed on the manufacturing sector.
- **New and improved business processes**—data formats compliant with testing standards allow for greater ease of use and manipulation of data, such as transformation into electronic material product release certificates.
- **Opportunities for new and improved research**—ever increasing volumes of high quality test data will facilitate data mining and pattern discovery, and allow model validation and development.
- **Greater rigour in the development of testing standards**—the breadth of knowledge of materials engineers in combination the precise definitions demanded by ICT specialists combines to deliver a combination of competencies that is particularly well suited to the process of developing robust mechanical testing standards.

1. Scope

The present document gives guidance on the development of computer-readable data formats that comply with technical standards for mechanical testing. This guidance extends to the interpretation of the written testing procedure and extraction of the relevant information. For this, many considerations will need to be taken into account, including the structure implicit to the written document itself and the applicability of existing specifications, such as ISO 10303-45, ISO 10303-235, MatML, JRC MatDB, and NMC MatDB.

The present document focuses on the development of data formats for a specific technical standard, namely EN ISO 6892-1:2009 Metallic materials — Tensile testing — Part 1: Method of test at ambient temperature, but is intended to deliver guidance on the general case translating any mechanical Testing Standards and associated Calibration Standards to a computer-readable format.

NOTE 1 In the scope of the present document, computer-readable format is intended to mean a format that makes possible computer processing of the information generated in accordance with the technical standard.

The scope of the work is concerned with a subset of the supply chain engineering data integration problem, namely the integration of test data, including derived properties data, but does not extend to design data.

NOTE 2 The present document does not fully address the integration of material test data with other parts of the supply chain. Instead, its focus has been on the development of a robust approach to material test data with broad industry support, which is based on existing standard for material testing and on existing standards for industrial data. The integration of material test data with the broader supply chain is of relevance to many different Application Protocols within ISO 10303, and it is intended that this integration will be addressed by future work.

The purpose of the present document is to establish the viability of developing standards-compliant formats, both from the perspective of technical feasibility and from the perspective adoption in the business and standardization sectors.

The target audience comprises organizations in the research, business, and standardization sectors with a vested interest in engineering materials.

The added value of the work includes encouraging the transition from document-based processes to electronic processes for generating, conserving, and processing engineering materials data.

To establish a case for the adoption of standards-compliant data formats by the business sector, this document includes the findings of a business analysis of the transition from document-based test certificates (also known as certificates of conformance or mill test reports) to electronic test certificates.

To encourage the adoption of standards-compliant formats, this document takes into consideration the implications for the standards authorities of converting technical standards to computer readable formats from the perspectives of revenue generation and copyright, and offers guidance on publishing options.