DEUTSCHE
GESELLSCHAFT FÜR
ZERSTÖRUNGSFREIE
PRÜFUNG e.V.

DGZfP Technical Committee NDE 4.0
Subcommittee on interfaces, documentation , data formats

Specification ZfP 4.0 – 01E

DICONDE in industrial inspection

August 2023

WHAT IS THE DGZfP?

The DGZfP is a technical-scientific association that pursues the goal of exploring, applying and disseminating non-destructive testing methods. The society has around 1,600 members, including not only large industrial companies, SMEs that use non-destructive testing (NDT), research institutions, universities and public authorities, but also individuals involved in NDT.

The DGZfP organises communication and the exchange of experience between research and development institutes and NDT users, equipment manufacturers and service providers. The society also provides information about the latest developments in NDT technology and application.

The society has established technical committees for the solution of specific technical problems. Regional working groups facilitate the practice-oriented exchange of experience and free-of-charge technical training.

The DGZfP regularly organises conferences and seminars. The main event is an annual conference, attracting more than 500 participants. The DGZfP is a member of EFNDT and ICNDT, the European and worldwide associations of NDT societies.

The society is also involved in the qualification and certification of NDT personnel. Activities include courses and qualification tests according to DIN EN ISO 9712, in all product sectors, in ten NDT techniques and three qualification levels, as well as officially recognised training in radiation protection according to the technical qualification guidelines for technology.

An independent DGZfP Personnel Certification Body (DPZ) was established following the publication of the European standard DIN EN 473 in 1993, replaced by DIN EN ISO 9712 in 2013.

The DPZ is an independent certification authority in accordance with the European Directive 2014/68/EU (Pressure Equipment Directive "PED") and recognised by the Central Office of the Federal States for Safety Engineering (ZLS). The DPZ is also accredited as a certification body for NDT personnel in the non-regulated area by the Deutsche Akkreditierungsstelle GmbH (DAkkS). Furthermore, global recognition of DGZfP certificates is guaranteed by treaties with many countries in Europe and further afield, and by being a party to the Multilateral Recognition Agreement of EFNDT.

The content of DGZfP Guidelines and Specifications, drafted by experts, reflects the state of the art; the application of this content is recommended..

Visit us:

Publisher:

DGZfP
DEUTSCHE
GESELLSCHAFT FÜR
ZERSTÖRUNGSFREIE
PRÜFUNG e.V.

www.dgzfp.de
Max-Planck-Str. 6, 12489 Berlin
Tel.: +49 30 67807-0 | E-Mail: mail@dgzfp.de

ISBN 978-3-947971-32-9

OTHER DGZfP GUIDELINES AND SPECIFICATIONS:
(Status: 07/2023)

A 01 Richtlinie über die Qualifizierung von Prüfwerkern der Zerstörungsfreien Prüfung

A 05 Richtlinie für Ausbildungsstätten – Mindestanforderungen an Ausstattung und Organisation

AT Kom. Kompendium Schallemissionsprüfung – Grundlagen, Verfahren und praktische Anwendung

B 02 Zerstörungsfreien Betondeckungsmessung und Bewehrungsortung an Stahl- und Spannbetonbauteilen

B 03 E Electrochemical Half-Cell Potential Measurements for the Detection of Reinforcement Corrosion

B 04 Ultraschallverfahren zur zerstörungsfreien Prüfung im Bauwesen

B 05 Merkblatt über das aktive Thermographieverfahren zur Zerstörungsfreien Prüfung im Bauwesen

B 06 Merkblatt über die Sichtprüfung und Endoskopie als optische Verfahren zur Zerstörungsfreien Prüfung im Bauwesen

B 08 E Specification Seismic Methods for Site Characterization

B 09 Dauerüberwachung von Ingenieurbauwerken

B 10 Merkblatt über das Radarverfahren zur Zerstörungsfreien Prüfung im Bauwesen

B 11 Merkblatt über die Anwendung des Impakt-Echo-Verfahrens zur Zerstörungsfreien Prüfung von Betonbauteilen

B 12 E Corrosion monitoring in reinforced and prestressed concrete structures

B 14 Quantifizierung von Chlorid in Beton mit der laserinduzierten Plasmaspektroskopie (LIBS)

Bruchortung Positionspapier – Magnetische Verfahren zur Spannstahl bruchortung

B-LF 01 Leitfaden zur Erstellung von Prüfanweisungen für die Zerstörungsfreie Prüfung im Bauwesen (ZfP Bau)

D 01 E Measuring Optical Densities in Radiographs

D 02 E Darkroom Processing of Industial X-ray Films

D 03 E Weld Measurement in Non-Destructive Testing and Film Identification in Radiographic Testing

D 04 E Determining Testing Zone Dimensions in Radiographic Testing of Castings

D 05 Vergleichs-Durchstrahlungsbilder für Gussstücke aus Gusseisen mit Lamellen- und Kugelgraphit

D 06 E Requirements and general conditions for the use of X-ray Computed Tomographie according to DIN EN

DP 01 E Guideline on the Selection of a suitable Trace Gas for Leak Testing according to DIN EN 13185

DP 02 Richtlinie zur Umrechnung der mit Prüfgasen gemessenen Leckageraten in andere Medien (Gase, Flüssigkeiten)

DP 03 Merkblatt zur Charakterisierung von Prüfgas-Nachweissystemen für Dichtheitsprüfungen

DP 04 Arten von Gasprüflecks und ihre Verwendung bei Dichtheitsprüfverfahren

DP 05 Messunsicherheit und Messmittelfähigkeit bei der Dichtheitsprüfung

EM 06 E Inspection Areas for Fluorescent Testing with Magnetic Particle and Penetrant Testing - Equipment and Protection Measures during Operation with UV Radiation

HB PA Handbuch für die Materialprüfung mit Ultraschall Phased Array

ISB 02 Zustand der Eisenbahnfahrzeuge – Verfahren zur Bestätigung der Kompetenz einer ZfP-Prüfstelle nach DIN 27201-7 durch eine dritte Seite

ISB 03 Zustand der Eisenbahnfahrzeuge – Validierung und Überwachung von mechanisierten bzw. automatisierten Prüfanlagen in ZfP-Prüfstellen

MC 01 Richtlinie für Kriterien zur Auswahl von Härteprüfverfahren mit mobilen Geräten

MR 01 Metrologische Rückführbarkeit von Hilfsgeräten für die Eindring- und Magnetpulverprüfung

MTHz 01 Mikrowellenprüfung: Grundlagen und Anwendungen

NDT 01 Guideline Nondestructive Testing According to ASME Boiler and Pressure vessel Code

OV 01 E Optical Methods - Selection and initial inspection of optical visual testing equipment, examination of optical visual testing equipment by the user

SE 02 E Verification of sensors and their coupling in laboratories

SHM 01 E Structural Testing with Guided Waves

US 06 Akustische Resonanzverfahren zur Zerstörungsfreien Prüfung

US 07 E Guideline for the Determination of Scanning Grid for the Automated Ultrasonic Testing of Large Forgings

US 08 E Characterization and verification of air-coupled ultrasonic probes

Information at: www.dgzfp.de

CONTENT

1 Introduction

DICONDE (Digital Imaging and Communication in Non-Destructive Evaluation) is an open international standard for storing and exchanging industrial test data and process-related information. The DICONDE standard defines both the semantics for structured storage of data and the network-based communication between two endpoints. This allows many test processes to be mapped digitally and securely, while at the same time meeting normative requirements such as traceability to the tester and test object and reproducibility of test results.

The standard ensures that the data is still readable even after years and decades. In addition to the actual test data, all the metadata required for the test procedure and the test conditions, which are necessary for the reproducibility of the test results, are stored. Test reports can also be stored together with the test data.

DICONDE was derived from the medical DICOM standard (Digital Imaging and Communication in Medi-cine) by ASTM Inter-national, formerly the American Society for Testing and Material. DICOM was origi-nally developed by the National Electrical Manufacturers Association (NEMA) for medical radiology, but has since evolved to cover all data generated during medical examinations and planning. Both DICOM and DICONDE have a wide range of applications and are continuously updated and adapted to new use cases. All the DICOM features described below are identically present in DICONDE.

The ASTM standards on DICONDE are currently defined for test methods such as RT, RT-D, RT-CT, UT, ET and extend data types of the base standard DICOM only where necessary or indicated. For the stor-age of inspection results from the field of visual inspections (VT, PT, MT), the object types defined in the DICOM base standard are used. In addition to many image data types, this standard also defines signal, video and 3D data (volumes, surfaces).

Just like DICOM, the DICONDE standard is constantly evolving, e. g. in order to be able to store raw and metadata from UT and ET in a vendor-independent way or to extend the basis defined in DICOM for thermographic or microscopic test procedures to industrial applications.

Another important feature inherited by DICONDE from the DICOM standard is its explicit suitability as a long-term storage format. Long-term compatibility of the data, which is also required for systems that are part of critical infrastructure, can be fulfilled by DICONDE. In some areas DICONDE is already estab-lished as an international standard.

Alongside OPC UA, DICONDE represents a key technology for the implementation of digital NDT pro-cesses in Industry 4.0. DICONDE data can provide important partial information for a digital twin, as described in the chapter on use cases.

In 2020, the DGZfP subcommittee on interfaces recommended the use of the DICONDE standard /ZFP-Zeitung/.

1.1 Data design and structure

The object assignment in the DICONDE standard is hierarchically structured in four logical levels:
In accordance with the data hierarchy in the processes of inspection technology shown in Figure 1, the DICONDE data model is referred to as the Real World Information Model. A defined mechanism of glob-ally unique identifiers ensures that data objects, once created, are not overwritten in an archive ("Picture Archiving and Communication System", PACS).

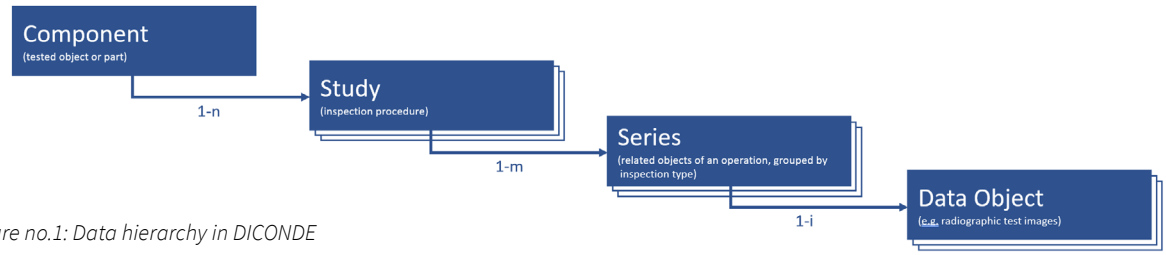

Figure no.1: Data hierarchy in DICONDE

1.2 Implementation

The worldwide distribution and use of the basic DICOM standard has the great advantage that there are a large number of tools for creating DICONDE objects and a large number of (in some cases freely avail-able) programs for viewing them. Programming interfaces are available for many operating systems, programming languages and hardware platforms. ASTM recommends the tool "DVTk" for the valida-tion of data objects /DVTK/.

1.3 Documentation

Products that implement the DICONDE standard ensure their interoperability by means of suitable documents (Conformance Statements). These list all supported test procedures and services in the network.

2 Use cases

The DICONDE standard is mainly used for the following use cases:

2.1 Storage of test data of different test methods

With the help of DICONDE, a wide variety of test data formats can be coded in a standardized way. Based on the basic document E2339, ASTM defines special formats, see also Appendix 1:

- RT (CR: E2738 DR: E2699)
- RT-CT (E2767)
- ET (E2934)
- UT (E2663)

The further development of DICONDE is supervised by the ASTM E07.11 Committee /link/. However, due to the derivation from the DICOM standard, all object types defined in DICOM are also permitted for use in DICONDE. Thus, a structured storage of data from visual inspection (VT), magnetic particle inspection (MT), dye penetrant inspection (PT), thermography (TT) and other inspection methods is possible, even if no special definition exists in DICONDE yet.

2.2 Order communication with test systems

The DICONDE standard defines a protocol for communicating order data (DICOM Modality Worklist) from planning systems (ERP, MES, etc.) directly to inspection systems or their control software. A typical entry in such a worklist contains essential data about the inspection object and the inspec-tion process. In concrete terms, this includes information such as

- a unique identification number
- a description of the test object
- an order number
- a description of the test
- the place of installation
- the planned type of test

and other parameters that are important in the context of the operation. Like the DICOM Storage protocol described in the previous section, the DICOM Modality Worklist is a network-based data transmission. The individual inspection systems retrieve the inspection jobs from a providing system. The use of the worklist is intended for both manual and automated test procedures.

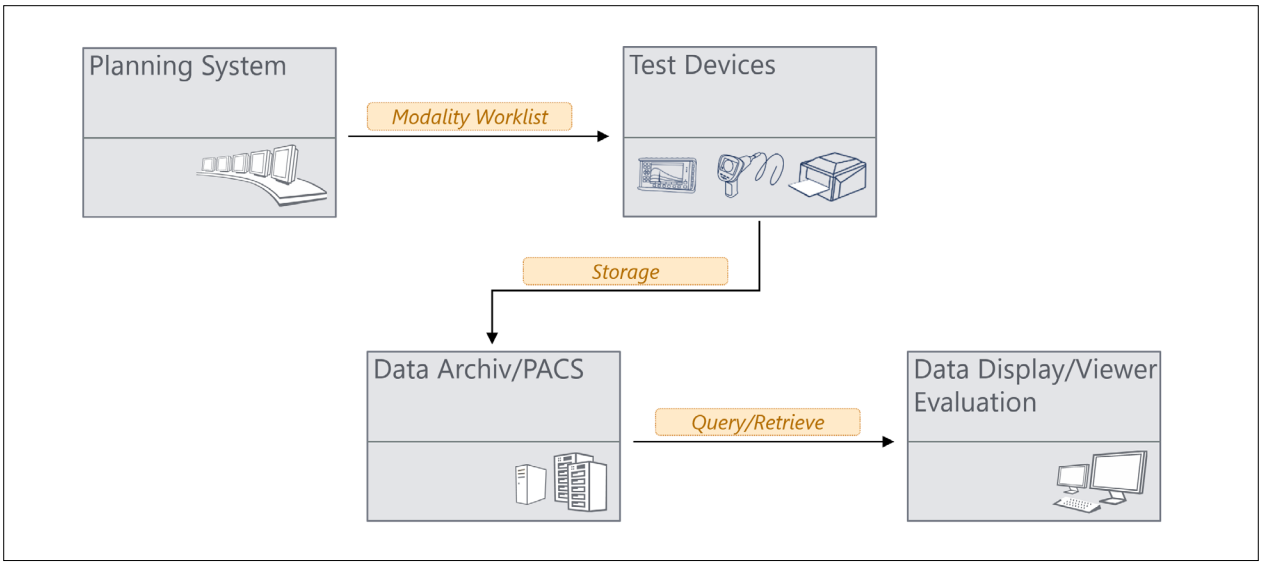

Figure no.2: DICONDE communication in the test process

2.3 Storage of results

In addition to the test data (image, signal, video data, etc.), the DICONDE standard also defines op-tions for storing the associated results. In the simplest case, a test report is stored as a PDF in a DICOM object. However, DICONDE also recognizes machine-readable formats (structured reports).

The system that generates the test report, for example, does not have to be the same as the source of the test data. Results can be clearly assigned to the test data at a later time.
In addition, the ASTM defines a further possibility to write the result of a test into the metadata of the test object itself (e. g pass/fail).
Furthermore, the standard defines a structured storage of annotations that are generated by the in-spector or an inspection system during the evaluation. These annotations are stored in separate DICOM Presentation State objects and refer to the corresponding objects with check data. This en-sures that the latter always remain unchanged and that, for example, parts of an RT image are not irrevocably superimposed by drawn-in markings.
The basic idea of the DICONDE standard is that test data, annotations and results are stored in one study (=one test process) and form one unit.

2.4 Structured Big Data Format for ADR and AI Processes

If annotations (e. g. as DICOM Presentation States) are stored in the same archive, this, in combina-tion with the metadata of the inspection data objects, provides an ideal basis for teaching software systems to post-process data using artificial intelligence ("annotated data"). For this purpose, the data can also be made available for evaluation anonymously, e. g. without manufacturer and com-ponent designation.
Ideally, results from trained, AI-supported systems or systems with Automated or Assisted Defect Recognition (ADR) are assigned to the DICONDE archive as DICOM Structured Reports. This allows AI results to be viewed in any DICONDE-compatible display software and archived together with the inspection data.

2.5 Central archiving (PACS)

Depending on the requirements and components, test results and underlying test data must be ar-chived. Based on DICOM, which has been used as a long-term archive format for more than 25 years and guarantees backward compatibility by design, DICONDE is also designed for the revision-safe storage of data over a long period of time /VOI/. Central indexing and storage of all test data and results in one system and their rapid retrieval are ensured. Data stored in DICONDE is always unique and unchangeable.

The use of DICONDE in conjunction with a PACS enables a

- consolidated,
- structured,
- non-proprietary and
- centralized

storage of test data.

In addition, DICONDE offers the possibility to store data in a defined structure on external data carri-ers. In addition to a cost reduction in archiving, there are many other advantages, see the following section.

3 Advantages

3.1 Reproducibility and traceability

Many standards and regulations in the field of materials testing, quality assurance and production (e.g. ISO 17020, ISO 17025, IATF 16949) require verifiable traceability of test results to the test object, test order, tester, test system and the test procedure itself. The reproducibility of results is also re-quired.

The technically correct implementation of the digitization of analog test processes is challenging. With existing software, existing network infrastructures and established data formats (e. g. JPG, TIFF, STL), the normative requirements often cannot be sufficiently fulfilled.

The DICONDE standard supports the structured storage of all relevant information and thus enables the required reproducibility and traceability.

3.2 Improvement of the quality assurance of testing processes in NDT

The application of the DICONDE standard increases the quality of testing processes in industrial in-spection in many ways.

3.2.1 Secure data transmission

The transfer of data by means of removable storage media is still widespread today. Only through modern communication technologies can test results be transmitted completely, quickly and suffi-ciently encrypted. The use of storage media also allows sufficient security with regard to data encryption, but at the same time the transfer of results and data in this way is tedious and involves the risk of data being lost during transport. To avoid this danger, DICONDE contains a network-based data transmission with encryption, which ensures that data is communicated and stored un-changed.

3.2.2 Cross-system data consistency

DICONDE enables data consistency in all systems involved in the digital inspection process by stor-ing corresponding metadata on the inspection object, inspection order, inspection system and inspector.
The goal is to avoid errors caused by manual data entry. For this reason, future implementations should use the digital interface services of the DICONDE standard (Modality Worklist, Storage) throughout.

3.2.3 Merging and history of test data and results

Due to the hierarchical model (see Figure 1), DICONDE makes it easy to merge data from several pro-cesses when a part or component has been tested with different test types. This allows an in-process linking of data sources and a consolidated visualization in a suitable software.

Especially in the field of maintenance, DICONDE fulfills the requirement to view a history of test data and results of the same component over time. The standard thus makes an important contribution to the tracking of material degradation processes as well as to predictive maintenance and risk-based inspection planning.

3.2.4 Consistent presentation of test data

The DICOM standard defines basic rules for the presentation of data during evaluation. This ensures that inspection results are displayed identically regardless of the evaluation software and hardware used (e.g., brightness, contrast, gray value dynamics, cropping of images). These rules are defined for all types of objects and facilitate the reproducibility of inspection results.

3.2.5 Vendor-independent interoperability

The comprehensive and unambiguous definitions of the data and meta-structures of the DICONDE standard guarantee that products from different manufacturers can communicate with each other without any problems. ASTM regularly offers events for this purpose, during which interoperability is tested and documented.
DICONDE makes test systems, evaluation software and archiving software independently inter-changeable, avoiding proprietary ecosystems. In this way, the standard contributes to investment security and cost reduction in NDE 4.0.

Appendix 1: Existing DICONDE standards

ASTM International has developed the following series of international standards which regulate the basic structure and appli-cation of DICONDE in non-destructive testing. The following generally applica-ble standards can be distinguished:

ASTM E2339 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE), ASTM International, 2021

ASTM E3147 Standard Practice for Evaluating DICONDE Interoperability of Nondestructive Testing and Inspection Systems, ASTM International, 2018

ASTM E3169 Standard Guide for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE), ASTM International, 2018

ASTM E3267 Standard Guide for Building Information Models and Archiving Digital Imaging and Communication in Nondestructive Evaluation (DICONDE), ASTM International, 2021

Separate DICONDE standards exist for selected non-destructive methods:

ASTM E2663 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Ultrasonic (US) Test Methods, ASTM International, 2018

ASTM E2699 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Digital Radiographic (DR) Test Methods, ASTM International, 2020

ASTM E2738 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Computed Radiography (CR) Test Methods, ASTM International, 2018

ASTM E2767 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for X-ray Computed Tomography (CT) Test Methods, ASTM International, 2021

ASTM E2934 Standard Practice for Digital Imaging and Communication in Nondestructive Evaluation (DICONDE) for Eddy Current (EC) Test Methods, ASTM International, 2022

Appendix 2: Links with additional information

All links verified on 04.10.2022:

DCLUNIE	Informationen und Dokumentationen zum aktuellen Stand des DICOM Standards: https://www.dclunie.com
INNOLITICS	Online Browser für DICOM Tags und Semantik: https://dicom.innolitics.com/ciods
WIKIDICOM	https://de.wikipedia.org/wiki/Digital_Imaging_and_Communications_in_Medicine
WIKIPACS	https://de.wikipedia.org/wiki/Picture_Archiving_and_Communication_System
WIKIDICONDE	https://de.wikipedia.org/wiki/DICONDE
DVTK	Freies Toolkit zur Validierung von DICOM Daten: https://www.dvtk.org
VOI	Merksätze des VOI zur revisionssicheren elektronischen Aufbewahrung (05/2019): https://www.voi.de/downloads/top-10-downloads
TMF	TMF Rechtsgutachten zur elektronischen Archivierung in der Medizin: https://www.tmf-ev.de/DesktopModules/Bring2mind/DMX/Download.aspx?Method=attachment&Command=Core_Download&EntryId=1425&PortalId=0
ASTM E07.11	ASTM Subcommittee E07.11 on Digital Imaging and Communication in Non-destructive Evaluation (DICONDE): https://www.astm.org/get-involved/technical-committees/committee-e07/subcommittee-e07/jurisdiction-e0711
VIEWER	Alphabetisch: File Viewer Plus https://fileviewerplus.com MicroDicom https://www.microdicom.com Weasis https://nroduit.github.io
AG DICONDE	Arbeitsgruppe DICONDE im Unterausschuss Schnittstellen im Fachausschuss ZFP 4.0 der DGZfP https://www.dgzfp.de/Fachausschuesse/ZfP-40/UA-Schnittstellen-Dokumentation/AG-DICONDE

Appendix 3: Bibliography

DICOM

Digital Imaging and Communications in Medicine (DICOM) Standard, National Electrical Manufacturers Association (NEMA), Rosslyn, VA, USA (available free at http://www.dicomstandard.org/current)

Revet

Bas Revet, DICOM Cook Book, Philips Medical Systems Nederland B. V., 1996, 1997, 2012 (available free at http://incenter.medical.philips.com/doclib/enc/8916819/DICOM_CookBook.pdf%3Ffunc%3Ddoc.Fetch%26no-deid%3D8916819)

DIN EN ISO 12052

DIN EN ISO 12052 (2017-12): Medizinische Informatik – Digitale Bildverarbeitung und Kommunikation in der Medizin (DICOM) inkl. Workflow und Datenmanagement

PIANYKH

Pianykh, O.: Digital Imaging and Communications in Medicine (DICOM): A Practical Introduction and Survival Guide, 2012, Springer

ZfP-Zeitung

J. Vrana: Erste Empfehlungen für Datenformate und Schnittstellen, ZfP-Zeitung 170, 11-12 (2020), DGZfP

Appendix 4: Directory of authors/companies

Dr. Nick Brierley	diondo GmbH
Ralf Casperson	Bundesanstalt für Materialforschung und -prüfung (BAM)
Daniela Engert	GMH Prüftechnik GmbH
Stephan Heilmann	Fraunhofer IKTS
Dr. Frank Herold	VisiConsult X-ray Systems & Solutions GmbH
Dr. Dirk Hofmann	Fraunhofer IKTS
Heiko Küchler	Evident Europe GmbH
Frank Leinenbach	Fraunhofer IZFP
Sebastian Lorenz	Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe
Jens Martin	DIMATE GmbH
Jörg Rehbein	Wehrwissenschaftliches Institut für Werk- und Betriebsstoffe
Bernd Sprau	Fraunhofer IZFP
Dr. Alexander Suppes	Baker Hughes Digital Solutions GmbH
Dr. Johannes Vrana	Vrana GmbH
Dr. Eric Wild	DB Systemtechnik GmbH

Appendix 5: Image credits

Figure no. 1	AG DICONDE, Jens Martin
Figure no. 2	AG DICONDE, Jens Martin

Glossary

ADR	Automated Defect Recognition
DICOM	Digital Imaging and Communication in Medicine
DICONDE	Digital Imaging and Communication in Non-Destructive Examination
ERP	Enterprise Resource Planning
ET	Eddy Current Testing (Wirbelstromprüfung)
MES	Manufacturing Execution System
MT	Magnet Particle Testing (Magnetpulverprüfung)
NEMA	National Electrical Manufacturers Association
OPC UA	Open Platform Communications Unified Architecture
PACS	Picture Archiving and Communication System
PT	Penetration Testing (Farbeindringprüfung)
RBI	Risk-Based Inspection
RT	Radiography Testing (Durchstrahlungsprüfung)
RT-D	Digital Radiography Testing (Digitale Durchstrahlungsprüfung)
RT-CT	Computed Tomography based Radiographic Testing (Computertomografie)
TT	Thermography Testing (Thermografie)
UT	Ultrasonic Testing (Ultraschallprüfung)
VT	Visual Testing (Sichtprüfung)