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Non-destructive testing — Pulsed eddy current testing of ferromagnetic metallic components

Essais non destructifs — Contrôle par courants de Foucault pulsés de composants métalliques ferromagnétiques

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Foreword

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This document was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 4, *Eddy current methods*.

Non-destructive testing — Pulsed eddy current testing of ferromagnetic metallic components

1 Scope

This document specifies the pulsed eddy current (PEC) testing technique used to perform thickness measurement on ferromagnetic metallic components with or without the presence of coating, insulation and weather sheeting.

This document applies to the testing of in-service components made of carbon steel and low-alloy steel in the temperature of –100 °C to 500 °C (temperature measured at metal surface). The range of wall thickness of components is from 3 mm to 65 mm and the range of thickness of coatings is from 0 mm to 200 mm. The tested components also include piping of diameter not less than 50 mm.

The technique described in this document is sensitive to the geometry of the component and applying the technique to components outside of its scope will result in unpredictable inaccuracy. This document does not apply to the testing of crack defects and local metal loss caused by pitting.

This document does not establish evaluation criteria. The evaluation criteria shall be specified by the contractual agreement between parties.

2 Normative references

The following documents are referred to in text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15548-3, *Non-destructive testing — Equipment for eddy current examination — Part 3: System characteristics and verification*

ISO 16809, *Non-destructive testing — Ultrasonic thickness measurement*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 12718 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
coating
material which covers the surface of a tested component in the forms of adhesive, adsorbed layer, bundle, twine or inlay, etc. such as paint, plastic, asphalt, rock-wool, foam, metal mesh, cement, carbon (glass) fibre, marine organism, etc.

Note 1 to entry: For the purpose of this document, the word coating is used to describe any protective or insulative layer on the component to be tested.

3.2
cover
sheet metal protective layer on the outside of the coating

3.3
excitation pulse duration
time needed for the energy to travel through the actual thickness of the component

Note 1 to entry: It needs to be long enough to penetrate the full thickness

3.4
decay rate
rate of change in electromagnetic field measured by the receiver sensor after the transmitter has been switched off

Note 1 to entry: For example, the bending point of one of the typical measurement methods (see Figure 1).

3.5
bending point
point where the received signal decay rate changes from linear to exponential

3.6
characteristic time
time measured between the end of the excitation pulse and the bending point

Note 1 to entry: Its value is proportional to the magnetic permeability, electrical conductivity and the thickness squared.

3.7
pulse repetition frequency
prf
number of pulses generated per second, expressed in Hertz (Hz)

4 General principles

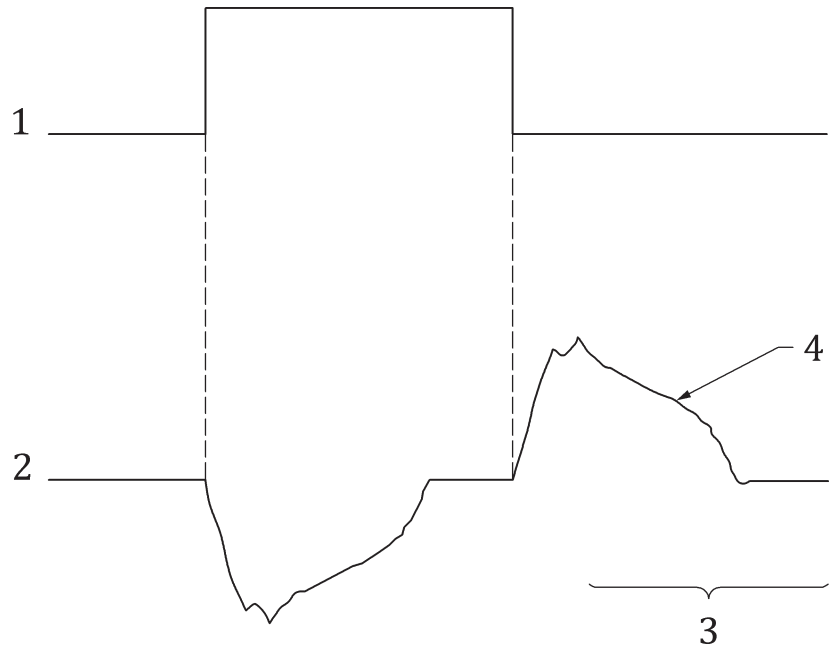
4.1 Principles of PEC testing

According to ISO 12718, pulsed eddy currents are eddy currents generated by a pulsed electromagnetic field.

Similar to sinusoidal eddy currents, induced pulsed eddy currents are modified by any local variation in the material properties.

The pulse is characterized by its duration (T), which enables to generate induced currents with a very high intensity.

The time interval between two measurements is linked to the material thickness.



Key

1 excitation signal waveform
2 detection signal waveform
3 decay curve
4 bending point

Figure 1 — Pulsed eddy current signal

The transmission signal from the probe shows a very broad spectrum of frequencies.

The received signal also has a frequency (or time) spectrum, the analysis of which provides information coming from different depths in the material.

The instrument is specific to the technique, as it must be capable of generating pulses.

Probes are of the separate transmit-receive type.

The measurement technique varies from one instrument to another, depending on the manufacturer.

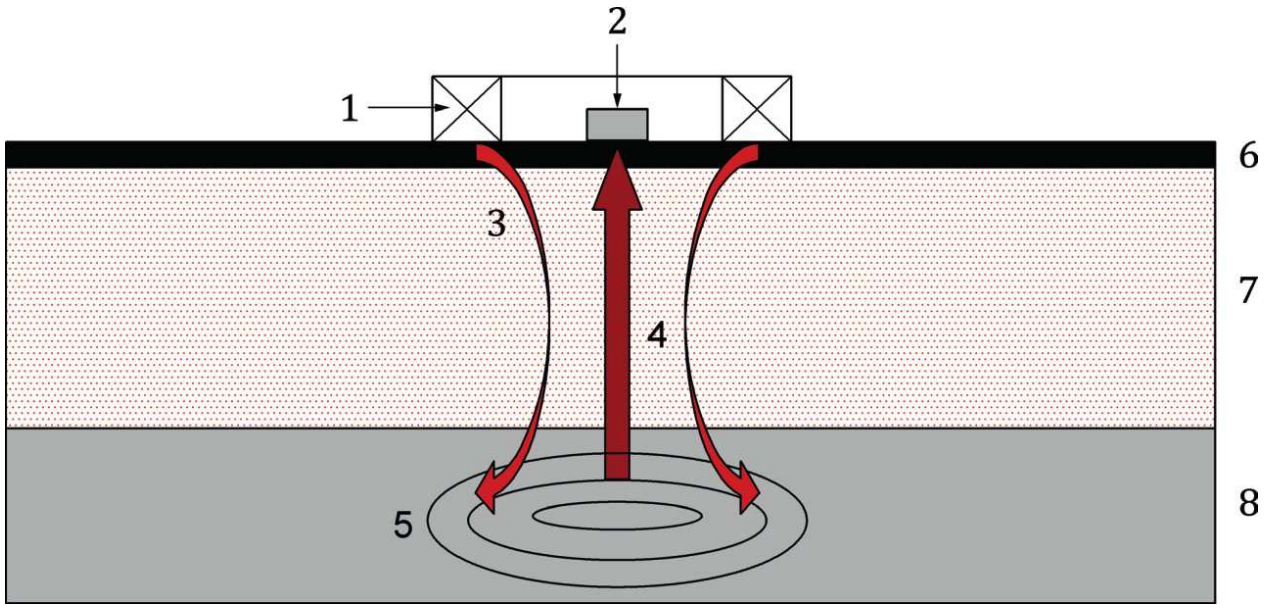
For example, the measurement techniques could be:

— use of characteristic time at the bending point;

— measurement of the time required for a specific decay;

— measurement of the decay curve slope, etc.

See Figure 2.



Key

1 sender coil
2 receiver devices
3 primary magnetic field
4 secondary magnetic field
5 eddy currents
6 cover/sheeting
7 insulation
8 tested component

NOTE Cladding and insulation form the coating.

Figure 2 — Basic principle of pulsed eddy current testing technique

4.2 Characteristics of PEC testing

4.2.1 Advantages

The following characteristics of the method represent the main advantages of PEC testing technique:

— the method does not require removing the insulation on the product tested;

— the test can be performed while the plant is in operation;

— no coupling medium, such as water, is needed.

4.2.2 Limitations

The component geometry shall be known to enable the instrument to be set up properly e.g. excitation pulse length and pulse repetition frequency.

There is a number of influencing factors that need to be controlled or taken into account when deploying the technique.

4.3 Influence factors

4.3.1 Coating

The nature of the coating can have an influence on the accuracy and sensitivity of the technique. Coating/insulation parameters such as electrical conductivity, magnetic permeability, and thickness should be taken into account.

For a coating with ferromagnetic material, extra magnetization may be needed to saturate it for more accurate testing results. It is also important to reduce the vibration, often occurring with such cover, to improve the reliability of the test. Indeed, signals corrupted by too high vibration shall not be recorded.

4.3.2 Tested component

The tested component may have an influence on the accuracy and sensitivity of the technique, parameters such as

— material properties of tested component,

— variation in material properties (from pipe to pipe for example), and

— variation in thickness

should be taken into account.

Vibration of the tested component during testing can also lead to the inaccuracy of testing results.

4.3.3 Temperature

The temperature variation inside a component can influence the electromagnetic characteristics of the tested component, and can therefore influence the testing results accuracy.

Temperature variation shall not exceed 20 °C.

4.3.4 Probe

The probe shall be selected to suit the component geometry.

Other factors influence the accuracy of the technique, including:

— probe active area;

— probe motion or probe speed (for dynamic scan);

— probe position with respect to the component;

— pulse length.

4.3.5 Reference zone

The reference zone is the zone on which the calibration is performed.

The differences between test zones and reference zone in physical characteristics such as magnetic permeability and conductivity can influence the testing results. If the differences are too significant, the reference zone shall be reselected.

4.3.6 Other factors

Care shall be taken to avoid the presence, modification or movement of conductive or magnetic pieces in the zone of influence of the probe, otherwise test results may be affected.

5 Qualification of personnel

It is assumed that eddy current testing is performed by qualified and capable personnel. In order to ensure that this is the case, it is recommended that the personnel be certified in accordance with ISO 9712 or equivalent.

6 Equipment

6.1 Testing system

The test employs a PEC instrument, a probe and interconnecting cables. This combination, together with some mechanical equipment holding the probe, forms the testing system.

All essential parts of the system shall be defined in a written procedure agreed at the time of enquiry or order (see 10.2).

6.2 PEC instrument

The PEC instrument shall meet the following requirements:

a) the repetition frequency and the pulse duration of the excitation signal shall be adjustable and the pulse rise time shall be significantly smaller than the decay time;

b) the data acquisition card resolution and sampling frequency shall match the required accuracy of the test, and the number of points collected shall be sufficient to enable the assessment of the target defect;

c) the system shall have an adjustable sensing duration to ensure that the acquired waveform is long enough to obtain the information necessary for the wall thickness measurement;

d) the display shall be suitable for the measurement method employed, e.g. log/log display for bending point;

e) the instrument shall enable the user to store the raw data of an inspection.

6.3 Probe

The following probe characteristics shall be made available to the user:

— active area dimensions;

— pulse frequency range;

— acceptable lift-off range.

Cables can be extended to connect the probe and instrument under the condition that the sensitivity and the accuracy of the test results are not changed.

6.4 Sensitivity adjustment

When the instrument requires an adjustment of the sensitivity response, a specific block with at least two known wall thicknesses (known original and the smallest thickness reduction of interest) shall be used.

6.5 Test pieces

6.5.1 Reference blocks

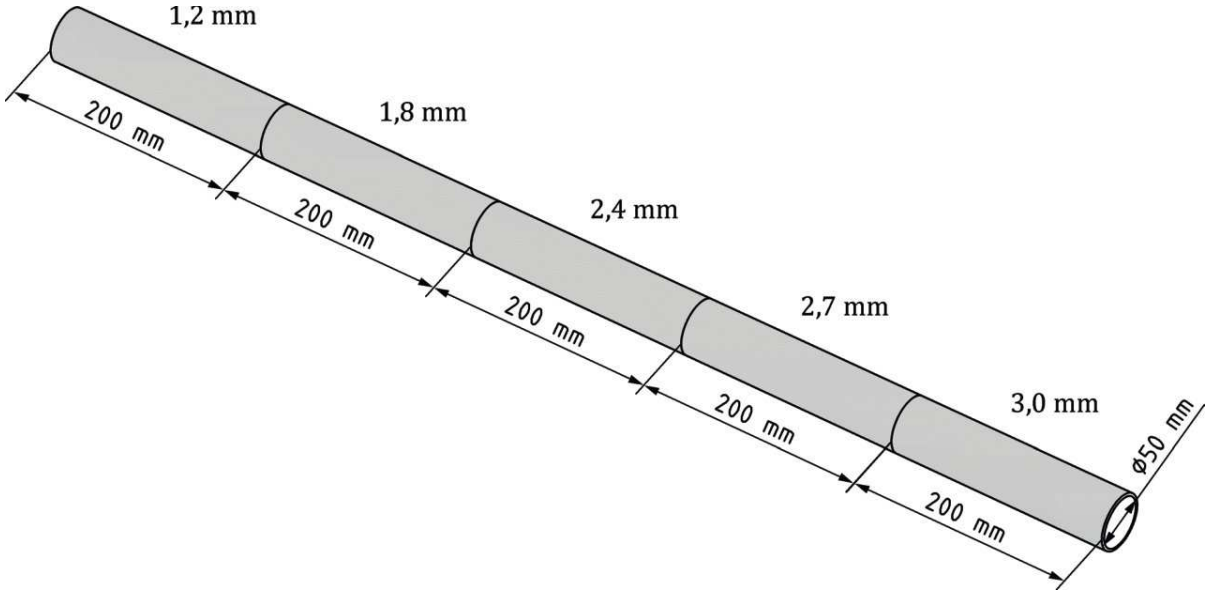
The reference blocks shall enable the user to test the system error, the reliability of instruments and probe performance. The dimensions and the geometry of the reference blocks shall be adapted to the component being tested and the probe (edge effect shall be avoided).

The reference blocks ensure that the instrument is working properly. They should therefore have an appropriate size to fit this purpose.

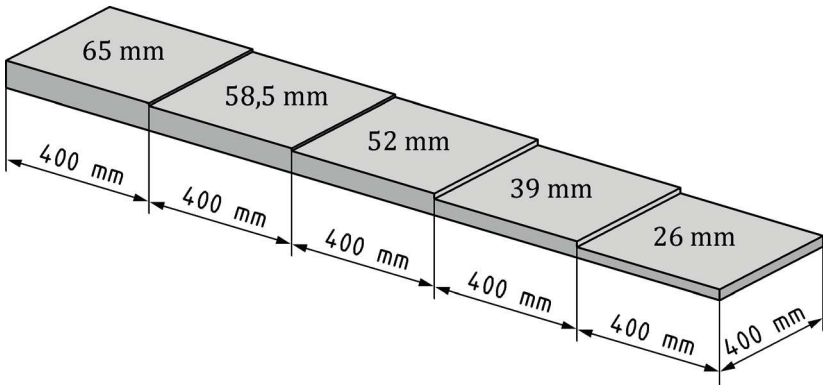
The nominal thickness of the reference block shall be identical to the nominal thickness of the component and shall feature steps representative of the wall thickness losses expected.

Figure 3 a) shows an example of reference block for 50 mm diameter tube.

Figure 3 b) shows an example of reference block for 300 mm diameter probe for a 65 mm wall thickness.



a) Step wedge pipe test piece



b) Step wedge plate test piece No. 1

Figure 3 — Reference blocks

If no reference blocks are available, then the instrument shall enable the user to renormalize the wall thickness on a specific acquired point and reapply this normalization to all the data collected during the inspection,

If the reference block cannot be at the same temperature as the component under test, then a transfer correction curve should be built using reference blocks at various temperatures.

6.5.2 Spacers

To simulate coatings representative of the component, spacers of known thickness can be used. Integral multiple thickness of 5 mm is recommended.

6.5.3 Metal sheet cover

To simulate the cover layer, stainless steel, aluminium, galvanized sheets representative of the component can be used.

6.6 Maintenance and verification of equipment

The performance of the testing system shall be verified at specified intervals in conformity with ISO 15548-3.

7 On-site testing

7.1 Preparation of documentation

7.1.1 Document prerequisites

The following documents are required as a minimum:

a) Manufacturing documents of the component to be tested: product certification, quality qualification document, as built drawing, etc.;

b) Operation recording documents of the component made available by the contractor: operating conditions and parameters, working medium, loading fluctuations, abnormal situation in operation, etc.;

c) Inspection documents: previous testing and inspection report;

d) Other documents showing repairs or modifications, etc.

To reduce inspection time, PEC testing zones can be modified to match the corrosion patterns expected.

7.1.2 Site investigation

Prior to testing, it is necessary to carry out a site investigation to find all factors, such as hanger, internal or external accessories, outer thermal insulation, etc. The interference of these factors shall be avoided during on-site testing.

7.1.3 Preparation of testing procedure and record sheets

The testing procedure and record sheets shall be prepared in accordance with the general testing procedure (see 10.2), product and site conditions. The instrument, applicable probes, testing place and surface conditions of the component are determined. In the meantime, all the test zones or points shall be numbered and indicated in the schematic diagram of the component. Test points shall be selected in order to avoid measurements being affected by geometrical features.

7.2 Preparation of the component to be tested

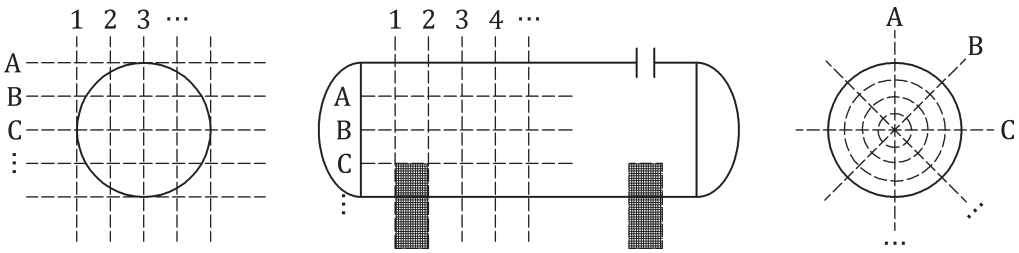
7.2.1 Surface preparation

The absence of large areas of loose corrosion layer, welding scar and other metal connection structure on the surface to be tested shall be verified. Noticeable vibration may influence the inspection results. Signals corrupted by too high vibration shall not be recorded.

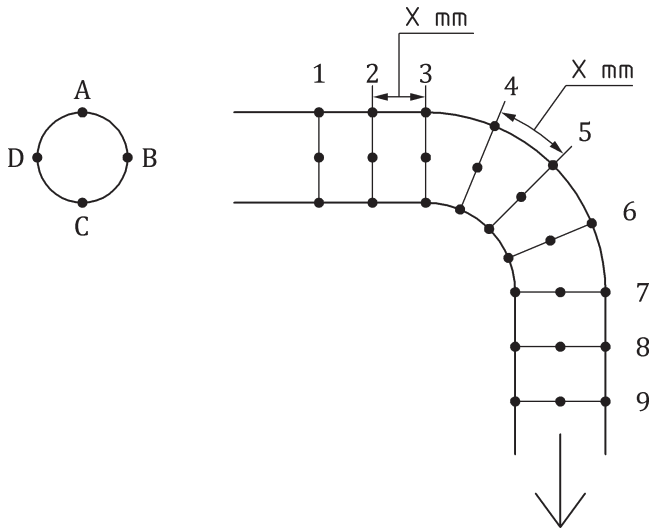
Coatings should have a uniform thickness. For components with a metal cover, testing on damaged cover shall be avoided. Noticeable variations of coating thickness or structure from that which is previously documented shall be reported as it influences the measurements.

7.2.2 Identification

The zone to be tested on the component shall be identified. Figure 4 shows examples for a pressure vessel and a pipe.



a) Pressure vessel



b) Pipe

Figure 4 — Example of numbering testing zones

7.3 Selection of the references

7.3.1 Principles

a) A zone with a known or measured wall thickness can be selected as reference. The thickness shall be measured according to ISO 16809.

b) Choose the zone which has an obvious bending point in its corresponding signal as the reference.

c) Existing data can be used as reference if they were obtained from a component of the same nature and with the same testing conditions.

7.3.2 Reselection of references

When there is a change of physical properties between test zone and reference zone, the reference zone shall be reselected. The following items are identified as essential variables:

a) material;

b) original thickness;

c) curvature;

d) type and structure of coatings (thickness variation, metal mesh, etc.);

e) significant temperature variation.

7.3.3 Record of references

The information on the reference zone such as its location, the selection principle and wall thickness shall be recorded in detail.

7.4 Performing test

The test shall be performed under the condition that the excitation magnetic field is perpendicular to the surface of the tested component.

Precautions shall be taken to ensure that probe stability during inspection avoids any tilting or vibration effects. In the case of dynamic tests, additional care shall be taken regarding probe travel speed.

Repeatability tests shall be carried out at least prior to and after the inspection in order to ensure that the measurement error is within the tolerance specified by the contracting parties. In the event the error is outside of this, corrective actions shall be taken as per contractual agreement.

7.5 Safety

The instrument and its accessories shall meet the applicable safety regulations, for example, electrical hazard, surface temperature, explosion, etc.

8 Interpretation and evaluation of test results

On completion of the test, the results shall be documented. The schematic diagram of the remaining wall thickness of tested component may be drawn if necessary.

9 Verification of test results

In locations where diminution is greater than the acceptance criteria specified in the contractual agreement, coating shall be removed and verification of the thickness shall be performed as follows:

a) determine if the corrosion is internal or external by visual inspection or other appropriate techniques;

b) measure the depth of external corrosion using a depth gauge.

NOTE 1 Other NDT methods such as ultrasound, radiography, etc. can be used for verification.

NOTE 2 Destructive methods may be used if agreed.

10 Documentation

10.1 General

The documentation consists of written testing procedure, testing record and testing report.

10.2 General written testing procedure

The organization performing the PEC testing shall prepare the general written testing procedure according to this document. The general requirements for the application and use of the PEC method for a product are described in application documents such as:

— product standards;

— specifications;

— codes of practice;

— contractual documents.

The testing procedure is derived from these documents and describes all the essential parameters, as well as the precautions to be observed. The following information shall be included:

— purpose of the test;

— description of the product to be tested;

— application documents;

— details of qualification and certification of personnel;

— area to be tested;

— scanning plan;

— details of surface preparation;

— environmental conditions;

— details of reference blocks;

— arrangement of the testing system;

— verification intervals for the instrument and the probes;

— requirements for signal evaluation;

— description of the test and the sequence of the steps in the test;

— information to be included in the test report.

Prior to the definition of the testing procedure, some or all of the following information will be necessary:

— purpose of the test;

— details of the product to be tested;

— physical location of the area where the test is to be conducted;

— requirements for surface preparation;

— degree of surface deformation due to the test process that can be tolerated without reducing the fitness for purpose of the product to be tested;

— degree of coverage of the product to be tested;

— sensitivity of the test;

— method used to verify the sensitivity;

— acceptance criteria, if specified;

— requirements relative to the test report;

— details of qualification of personnel.

10.3 Testing record

The testing records shall include the contents shown in 10.4 at least. The testing record and PEC data shall be kept according to contract agreements.

10.4 Testing report

The test report shall contain sufficient information to enable the test to be repeated at a future date.

At least the following shall be included:

— identification of the manufacturer of the component;

— identification of each object tested;

— reference to the application documents and the testing procedure;

— technical sheet (or equivalent) giving the details of the procedure in cases where the testing procedure allows a variation in the method of test, the equipment or the equipment set-up;

— identification of the testing system, in particular all details necessary for the complete identification of the type of instrument and type of probe used;

— instrument settings used;

— identification of the reference test pieces used;

— results of the test;

— any deviation from the test procedure;

— organization responsible for carrying out the test;

— name and qualification of the person who carried out the test;

— signature of the person who carried out the test or the name and signature of another authorized person;

— date and place of the test.

The format of the examination report shall be agreed at the time of enquiry and order.

Bibliography

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